An ecological economics of eco-efficiency

- theory, interpretations and applications

A thesis presented in partial
fulfilment of the requirements for the degree of
Doctor of Philosophy in ecological economics

At Massey University, Palmerston North

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This is to certify that the research carried out for my Doctoral thesis entitled "An ecological economics of eco-efficiency – theory, concepts and applications" in the School of People, Environment and Planning, Massey University, Palmerston North, New Zealand is my own work and that the thesis material has not been used in part or in whole for any other qualification.

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Abstract

Eco-efficiency emerged onto the world stage as the business input into the 1992 Rio Earth Summit. The concept has served to bring the business community into the sustainability debate and enabled businesses to demonstrate significant environmental improvement. The concept is also beginning to play a key role in national sustainable development policy. However, the recent interest in eco-efficiency has highlighted several unresolved and sometimes contentious issues which are addressed in this thesis.

The overall aim of this thesis is to contribute to the understanding of the eco-efficiency concept and its analytical application by situating the research within an ecological economic framework.

This thesis begins by arguing that conventional 'eco-industrial épistémé' interpretations of eco-efficiency are developed within the narrow confines of a world view that is committed to business-as-usual. This assumes controllability of production processes, sees technology as a fix for environmental problems and assumes independence of economic and environmental production processes. This thesis then proposes to broaden the notion of eco-efficiency by applying an ecological economic theoretical framework. This thesis recommends a nested-hierarchy framework of three tiers for interpreting eco-efficiency. The thesis uses ecological economic theory to argue that eco-efficiency must be embedded within physical scale (first tier) and social considerations (second tier). The third (eco-efficiency) tier is interdisciplinary and pluralistic. It encourages a view that perspectives of eco-efficiency are context dependent. It also promotes tolerance and acceptance that all perspectives of eco-efficiency provide important insights into eco-efficiency.

Previously, little attention has been devoted to measuring and analysing eco-efficiency for national policy purposes. This thesis develops and applies three promising analytical techniques to aspects of New Zealand's eco-efficiency; Divisia decomposition analysis (for isolating structural and technical components of change), inverse-Leontief based multiplier analysis (for measuring indirect effects) and principal components analysis (for reducing the number of indicators to a manageable level). All three empirical chapters identify the road transport sector as having relatively low and decreasing energy and CO_2 efficiencies. This is of concern as the sector has proven to be one of the most difficult to influence from an environmental perspective. Several other sectors warrant attention by virtue of their low eco-efficiency measures; 'other mining', 'other farming', dairy farming, meat products and dairy products. Urgent attention is required to improve the environmental behaviour of these sectors.

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My love and gratitude must also go to my partner Veronica Lysaght and my daughter Ella Jollands. They have provided constant support over the past three years. I am grateful that they have stood by my side through the (often difficult and frustrating) PhD process and reminded me that an ice cream is just a walk away.

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A special thanks to Sue Edwards and the staff of the Resource and Environmental Planning Programme at Massey University. They have all been very generous in their support of my research and teaching endeavours.

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List of abbreviations used in this thesis

BAU	Business as usual
BOD	Biological oxygen demand
CO_2	Carbon dioxide
DRP	Dissolved reactive Phosphorous
EECA	Energy Efficiency and Conservation Authority
EIE	Eco-industrial épistémé
EKC	Environmental Kuznets Curve
EPIP	Environmental Performance Indicators Programme
GDP	Gross Domestic Product
ID	Index decomposition
ILM	Inverse Leontief matrix
IO	Input-output
IOD	Input-output decomposition
IPCC	Intergovernmental Panel on Climate Change
ISEE	International Society for Ecological Economics
ISEW	Index of sustainable Economic Welfare
kJ	Kilo Joule
MB	Marginal benefit
MC	Marginal cost
MEC	Marginal external cost
MK	Manufactured capital
MPP	Maximum power principle
MRPT	Marginal rate of product transformation
MRS	Marginal rate of substitution
MRTS	Marginal rate of technical substitution
MSB	Marginal social benefit
MSC	Marginal social cost
N_2O	Nitrous oxide
NH_4	Ammonia
NHS	British National Health Service
NK	Natural capital
NZBCSD	New Zealand Business Council for Sustainable Development
NZSIC	New Zealand Standard Industrial Classification
OECD	Organisation for Economic Co-operation and Development
OPEC	Organisation of Petroleum Exporting Countries
PCA	Principal components analysis
PPF	Production possibility frontier
QEM	Quality equivalent method
sej	Solar emjoule
TKN	Total Kjeldahl Nitrogen
UN	United Nations
WBCSD	World Business Council for Sustainable Development
WCED	World Council on Environment and Development
WTP	Willingness to pay
ΔG	Gibbs free energy change

1 Introduction

1.1 Origins of the eco-efficiency concept

As humanity enters the 21st century, a number of global environmental crises have emerged in ways that have made their impact impossible to ignore. Chapter 4 of Agenda 21 (United Nations Conference on Environment and Development, 1992) points to one of the causes of these global crises. As a blueprint for a 'sustainable' future developed by world leaders in 1992, it states the major cause of the continued deterioration of the global environment is the unsustainable pattern of consumption and production, particularly in the industrialised countries.

One potential strategy to mitigate the problems of unsustainable production and consumption patterns is increasing efficiency. Indeed, Agenda 21 exhorts the nations of the world to examine the demand for natural resources generated by unsustainable consumption and production, and seek ways of using resources that minimise depletion and pollution. Agenda 21 goes on to state:

> "*achieving the goals of environmental quality and sustainable development will require efficiency in production and changes in consumption patterns in order to emphasise optimisation of resource use and minimisation of wastes*" (United Nations Conference on Environment and Development, 1992, paragraph 4.15).

This sentiment is echoed in the more recent World Summit on Sustainable Development's Plan of Implementation.

> "*[Action is needed to] encourage and promote the development of a 10-year framework of programmes in support of regional and national initiatives to accelerate the shift towards sustainable consumption and production to promote social and economic development within the carrying capacity of ecosystems by addressing and, where appropriate, delinking economic growth and environmental degradation through improving efficiency and sustainability in the use of resources and production processes, and reducing resource degradation, pollution and waste.*" (United Nations, 2002, paragraph 14).

It is out of this focus on efficiency that the concept of 'eco-efficiency' has emerged. The term eco-efficiency was coined in Schmidheiny's (1992) *Changing Course* - a document produced for the Business Council for Sustainable Development as input into the Rio Earth Summit of 1992. Consequently, eco-efficiency has been described as the "business contribution to sustainable development" (Organisation for Economic Co-operation and Development, 1998, p. 15).

Since 1992, many in the corporate world have adopted the eco-efficiency concept. In doing so, Gebhart (1998) claims the eco-efficiency concept has brought business into the sustainable development debate. Within that debate, eco-efficiency has:

- served as a bridging concept allowing policy-makers from business and government to connect different conditions for sustainability such as integrating ecological and economic concerns and the timing of short-run business management with the long-run view of sustainable development (Organisation for Economic Co-operation and Development, 1997);
- prompted many businesses to emphasise the need for a precautionary approach to achieve sustainable development (Schmidheiny, 1992, p. 3);
- helped to emphasise the need to recognise physical ecological limits and the effect these have on the production process;
- challenged business to move away from the simplistic 'jobs-versus-environment' mindset to consider wider sustainability issues.

The notion of eco-efficiency is also beginning to take hold in wider circles than just business. Scientific, government and international organisations as well as business communities "see eco-efficiency as an essential answer to the global ecological challenge" (Hinterberger & Stiller, 1998, p. 275). For some, eco-efficiency is "the most effective method of promoting sustainable development in business" (Hilson, 1999, p. 191). The Organisation for Economic Co-operation and Development (OECD) has also recently adopted the eco-efficiency concept – the culmination of work that began in 1995 where eco-efficiency was identified as one of the most useful concepts for measuring progress towards sustainable development (OECD, 1998, p. 3).

Eco-efficiency has also established a presence in New Zealand. The New Zealand Business Council for Sustainable Development (NZBCSD) was set up in May 1999 with an aim of, inter alia, promoting eco-efficiency (NZBCSD, 2002). In addition, eco-efficiency has received attention in the popular media as prominent business people and commentators promote the eco-efficiency cause (see for example, Graeme, 1999; Williams, 1999).

Despite the widespread adoption of the eco-efficiency concept, several important and sometimes contentious issues remain unresolved. For example, there is little "unanimity when it comes to the detailed definition of eco-efficiency" (Hinterberger & Stiller, 1998, p. 275). Why then are organisations flocking to the eco-efficiency banner – and what does the eco-efficiency concept really mean? A review of past studies helps to shed some light on these two questions.

1.2 Previous studies into eco-efficiency

Previous studies of eco-efficiency can be grouped into two categories: those that address the concept and philosophy of eco-efficiency, and those that present the results of technical studies of eco-efficiency.

1.2.1 The concept and philosophy of eco-efficiency

Two groups have emerged within the literature on the concept and philosophy of eco-efficiency – those that promote the merits of eco-efficiency, and those that are critical of eco-efficiency.

The position of the eco-efficiency 'protagonists' is characterised by the work of numerous authors, including Barber (1999), Brady et. al. (1999), Cramer (1997), Desimone and Popoff (2000), Gilkinson (1999), Glauser and Muller (1997), Hilson (1999), Jayne (1999), Metti (1999), the OECD (1998), Riebel (1999), Schmidheiny (1992) and the World Business Council for Sustainable Development (WBCSD) (2000). These authors promote the view that it is the business community that will deliver 'green' economies: "the most significant net contribution to a greener world will be made by industry... not every company is there yet, but most are trying" (Edgar Woolard, past chairman of DuPont cited in Barber, 1999, p. 1). This is echoed by Gilkinson (1999, p. 104) who states "the fact is that only business has the resources, technology and innovation to build a sustainable future."

One way businesses will deliver this 'sustainable future', these authors argue, is through increasing eco-efficiency. That is, by "weaving eco-efficiency into the very fabric of how businesses... think and act" (DeSimone et al., 2000, p. viii).

Eco-efficiency is promoted as a business management philosophy that links "environmental excellence to business excellence" (DeSimone et al., 2000, p. 11). And improving eco-efficiency is often motivated by company competitivenes: "the environment and sustainable development are seen as opportunities – sources of competitive advantage. Progressive companies have understood this and they are grabbing the opportunity" (Barber, 1999, p. 1). In the eyes of the eco-efficiency protagonist, eco-efficiency is an unalloyed good that is relevant to all businesses and in all contexts.

Not all authors are as sanguine about the merits of eco-efficiency, although compared to the protagonists, there is relatively little literature critical of eco-efficiency. Hukkinen (2001) criticises eco-efficiency from cognitive and institutional perspectives. He suggests that "eco-efficiency [erroneously] assumes that an individual's concern for the environment can be decoupled from his or her material dependency on ecosystems services" (Hukkinen, 2001, p. 311).

Chatterjee and Finger (1994) criticise eco-efficiency from a socio-cultural perspective and maintain that businesses that promote eco-efficiency in the South are guilty of ethnocentricism. Welford (1997) supports this claim and provides a further critique of eco-efficiency as emerging from what he refers to as an 'eco-modernism' framework. In contrast, Hawken et al. (1999) evaluate eco-efficiency from what they call a natural capitalism perspective. They state:

> *Eco-efficiency, an increasingly popular concept used by business to describe incremental improvements in materials use and environmental impact, is only one small part of a richer and more complex web of ideas and solutions. Without a fundamental rethinking of the structure and reward system of commerce, narrowly focused eco-efficiency could be a disaster for the environment by overwhelming resource savings with even larger growth in the production of the wrong products, produced by the wrong processes, from the wrong materials, in the wrong place, at the wrong scale and delivered using the wrong business models* (Hawken et al., 1999, p. x)

McDonough and Braungart (2000) echo this concern. They suggest eco-efficiency is a useful business concept, but "it does not reach deep enough" (McDonough & Braungart, 2000, p. 85). That is, it relies on making "the old, destructive system less so."

Several issues stand out from this brief discussion of eco-efficiency-related literature. One issue that is notable by its absence is a critical analysis of the meaning of eco-efficiency. As was noted above, there is a lack of agreement about what eco-efficiency actually means. Many authors have attempted to define eco-efficiency. For example, Williams (1999, p. 37) defines eco-efficiency as "endeavouring to get more from less for longer." Metti (1999, p. 83) states "eco-efficiency is simply creating more value with fewer materials and less waste." In a similar vein, DeSimone et al. (2000, p. xix) comment that eco-efficiency is used to "describe activities that create economic value while continuously reducing ecological impact and the use of resources." Glauser and Muller (1997, p. 201) suggest eco-efficiency is "the optimal use of material, energy, human resources, and capital to supply innovative products to the market." A relatively detailed definition of eco-efficiency comes from the WBCSD:

> *"Eco-efficiency is reached by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing environmental impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity"* (DeSimone et al., 2000, p. 47).

Despite the plethora of interpretations, Hinterberger and Stiller (1998, p. 275) note that they all have an obvious theme in common. "All concepts call for a more efficient use of natural resources." Beyond that, there is little agreement.

A related issue is the limited critique of world views that underpin contemporary perspectives of eco-efficiency. Any analysis of eco-efficiency necessarily requires an examination of world views. This is because interpretations of eco-efficiency are necessarily inflected by assumptions and beliefs about the way the world operates, particularly the nature of economic activity and its interaction with the environment.

The lack of a critical understanding of the meaning, scope and world views underlying eco-efficiency is concerning for at least two reasons. With a poor understanding of the interpretation and epistemology of eco-efficiency, there is a danger that eco-efficiency may be applied to situations where the concept is inappropriate (as Chatterjee and Finger (1994) argue).

Further, there is a danger that strategies and policies designed to promote eco-efficiency may be misdirected or inappropriately specified. There is an urgent need for a critical analysis of the meaning of eco-efficiency, as well as the world views that underpin contemporary perspectives of eco-efficiency.

Another issue to stand out is the lack of attention paid by ecological economics literature to eco-efficiency. For example, other than Hukkinen (2001) (mentioned above), only two other articles in the journal Ecological Economics discuss eco-efficiency (Huesemann, 2001; Jalas, 2002). Huesemann (2001) addresses eco-efficiency peripherally in his discussion of the technological and thermodynamic limits to solving pollution problems. Jalas (2002) attempts to extend the notion of eco-efficiency to include a time-use perspective on the materials intensity of consumption.

The lack of attention given to eco-efficiency by ecological economists is surprising given the important role of efficiency in ecological economic theory (Ayres & Nair, 1984; Callens & Tyteca, 1999; Daly, 1996; Harris & Kennedy, 1999). Furthermore, eco-efficiency reflects the central focus of ecological economics; the relationship of the economic system to its biophysical environment (Buenstorf, 2000). Stemming from this focus, ecological economics has developed a specialised research agenda that draws on ecological, economic and thermodynamic theory. These three disciplines provide a useful theoretical foundation for an analysis of environment-economy interactions. Given that eco-efficiency is concerned with economy-environment interactions, it would appear that an enquiry into eco-efficiency provides fertile ground for ecological economic research.

1.2.2 Technical studies of eco-efficiency

The literature documents many technical studies of the eco-efficiency of individual companies or specific sectors. Perhaps the most prominent of these studies is *Factor Four – Doubling Wealth, Halving Resource Use* (Weizsäcker, Lovins, & Lovins, 1997). These authors advocate using "resources *at least four times as efficiently as we do now*" (Weizsäcker et al., 1997, p. xxi, italics in original) in order to 'cure' the 'disease of wastefulness' associated with current production and consumption processes. These authors give many examples where resource efficiency can be, or has been, substantially improved. Examples of these technical innovations include hypercars (that are 2 to 2.5 times as energy efficient as normal vehicles) (Weizsäcker et al., 1997, p. 8), passive solar buildings (Weizsäcker et al., 1997, p. 13), energy efficient electric appliances (Weizsäcker et al., 1997, p. 41) and water and material efficiency measures in industrial plant (Weizsäcker et al., 1997, p. 68). Together, these technological advances contribute to what the authors refer to as the '(resource) efficiency revolution' (Weizsäcker et al., 1997, p. xviii).

Other examples of technical studies of eco-efficiency abound, and include:

- Glauser and Muller (1997) who outline a range of eco-efficiency improvements in the pharmaceuticals company Roche in the areas of solid waste reduction, waste-heat recovery and water savings;
- Metti (1999) who describes achievements by Cadbury Schweppes with respect to eco-efficiency of waste water, water and energy use, protection of groundwater, solid waste and packaging and air emissions;
- Cramer (1997) who documents the eco-efficiency achievements of Philips' Sound and Vision/Consumer Electronics Division in its development of a 'green television' concept;
- Gilkinson's (1999) summary of a number of eco-efficiency achievements such as Monsanto's reduction in toxic-air emissions per unit by 90 percent over five years and GB Cement's reduction in water use by 80 percent over several years;
- McDonough and Braungart (2000) who cite 3M's savings of more than $750 million through pollution prevention;
- Hilson (1999) who looks at the eco-efficiency of the non-ferrous metal mining sector in Canada;
- Riebel's (1999) description of progress with eco-efficiency in the pulp and paper sector of Canada;
- The OECD's (1998) attempt to compare aspects of eco-efficiency across several countries using an ad hoc set of example indicators.

In addition, many other analyses could be considered studies of eco-efficiency, although they are not considered as such. For example, in New Zealand, the Energy Efficiency and Conservation Authority (EECA) has published several studies on energy efficiency in New Zealand (Energy Efficiency and Conservation Authority, 2000). Similarly, Landcare Research has a 'Measure to Manage' program for "measuring resource use efficiency and waste production as a basis for ongoing management, cost-saving and reduced environmental impact" (Landcare Research, 2002).

Three important observations can be made about these studies documenting technical improvements in eco-efficiency. First, with the exception of a few studies such as the work by the OECD and the energy efficiency studies by EECA in New Zealand, most studies focus on the eco-efficiency of specific companies or sectors. Few studies look at eco-efficiency at a national level. Second, no studies provide an overall assessment of a country's eco-efficiency across multiple aspects of the environment.

This lack of a national-level focus is of concern for national eco-efficiency policy development. This is particularly a concern in New Zealand where eco-efficiency is potentially an important part of the New Zealand government's pursuit of sustainable development. For example, one aspect of the work on sustainable development is the government's objective to "use resources in a sustainable manner" (Clark, 1999). Eco-efficiency has a key role to play in the government's strategy.

However, the lack of information on eco-efficiency in New Zealand limits policy makers' ability to develop well-targeted policy. Consequently, the OECD (1998) states that work in a number of areas could support the development of policies to improve eco-efficiency. First among these is the provision of information on eco-efficiency for national policy purposes. A logical home for such information-provision work in New Zealand would be the Ministry for the Environment's Environmental Performance Indicators Programme (EPIP). The EPIP is still under development, and until recently has focused on indicators of the state of the environment. Information on the pressures on the environment from consumption and production patterns are limited. The lack of information on trends in New Zealand's eco-efficiency is a clear gap in the EPIP arsenal. There is an urgent need to undertake studies focused on eco-efficiency for use in policy formulation and evaluation in New Zealand.

A third observation that can be made about the 'technical studies' literature is that there is relatively little attention given to the development of analytical methods for explicitly measuring and analysing eco-efficiency. This lack of methodological development poses a significant limitation for policy makers. In the New Zealand context, the methodological gap means that it is currently difficult to assess:

- the key factors influencing changes in eco-efficiency;
- which sector(s) are the most eco-efficient in a system-wide sense;
- whether New Zealand is getting more or less eco-efficient overall.

A range of methods are available and have been applied to measuring various 'efficiency' concepts. These methods include the use of efficiency indicators (see for example Azar, Holmberg, & Lindgren, 1996; Callens & Tyteca, 1999; Färe, Grosskopf, & Tyteca, 1996; Keeler & McLemore, 1996; Organisation for Economic Co-operation and Development, 1998), optimal control modelling (Bach, 1999; Pan, 1994), economic-ecological models (Amir, 1994; Giannias & Lekakis, 1997; Regev, Gutierrez, Schreiber, & Zilberman, 1998), simulation modelling (Cornwell & Costanza, 1994), decomposition analysis (Färe et al., 1996; Stern, 2002), computable general equilibrium models (Felder & Schleiniger, 2002; Ricker, 1997), input-output analysis (Hannon, 1998; Hannon, 2001; Nakamura, 1999; Schrder, 1995), complex adaptive system models (Matutinovic, 2002) and multi-attribute decision-making (Prato, 1999). Many of these could potentially be applied to eco-efficiency.

Three of these techniques in particular show promise for use in eco-efficiency analysis and could usefully be applied to analysing eco-efficiency in New Zealand; decomposition analysis, ecological multiplier analysis and aggregate indices.

Decomposition is a powerful tool that provides the analyst with the ability to identify the key factors that effect (eco-efficiency) indices. Decomposition analysis has been widely applied to studies of energy efficiency (see for example Ang, 1994; Ang & Choi, 1997; Ang & Zhang, 2000; Cleveland, Kaufmann, & Stern, 2000; Jollands, Lermit, & Patterson, 2003; Schipper, Meyers, & Howarth, 1993). However, its application beyond energy efficiency is limited. Also, there are still several important methodological issues that require attention including the need to account for the issue of resource 'quality.'

Ecological multipliers are useful because they can be used to measure the system-wide eco-efficiency of production processes or sectors. Ecological multipliers have previously been used to analyse eco-efficiency in three regions of New Zealand (McDonald & Patterson, 1999). However, no attempt has been made to calculate ecological multipliers for New Zealand as a whole. Also, there is a conceptual tension in the specification of some of McDonald and Patterson's 'eco-efficiency indicators.' Some of their indicators are specified as the ratio of economic ('useful') output to waste output. Strictly speaking, this is not consistent with the common definition of efficiency as the ratio of useful output to *inputs*.

Aggregate indices are potentially useful for communicating complex information succinctly to decision-makers. However, there has been no development of eco-efficiency indicators for policy purposes in New Zealand. Even internationally, the development of eco-efficiency indicators has not extended beyond ad hoc indicator lists. Consequently, the OECD (1998) commented that many indicator-related issues remain unresolved. In particular, no research has been conducted into methods of calculating aggregate eco-efficiency indices.

These three techniques all have the potential to provide insights into important aspects of eco-efficiency in New Zealand. They can also be applied using available data. However, each of these tools face methodological issues that need resolving before they can be usefully applied to eco-efficiency. There is an urgent need for the further development of these methods for analysing eco-efficiency to assist in the policy formulation in New Zealand.

In summary, from the two bodies of literature it appears that the eco-efficiency concept is an important focus of research for four compelling reasons. There is an urgent need:

- for an analysis of the meaning of eco-efficiency as well as world views that underpin contemporary perspectives of eco-efficiency;
- to tap the potential that ecological economics provides for illuminating the eco-efficiency concept;
- to undertake studies of eco-efficiency for use in policy formulation and evaluation in New Zealand;
- for the development of methods for analysing eco-efficiency in New Zealand.

These four research imperatives provide the rationale for this research.

1.3 Research aims and objectives

The overall research aim of this thesis is to contribute to the understanding of the eco-efficiency concept and its analytical application, by situating the research within an ecological economics framework. The intention is to broaden and enrich the eco-efficiency concept (and its analysis), beyond the current restrictive interpretations that tend to dominate the literature.

The specific research objectives for this thesis are:

1. to evaluate the limitations of the dominant business-oriented perspective of eco-efficiency;
2. to develop a broad theoretical appreciation of the eco-efficiency concept based on ecological economic theory. This ecological economics perspective will draw on its foundational disciplines of thermodynamics, economics and ecology. It will also acknowledge the importance of scale, context-dependent problem solving, policy pragmatism and other such issues;
3. within the context of an ecological economics perspective of eco-efficiency, to develop and refine a selection of methods for analysing eco-efficiency trends and performance;
4. to apply these methods to the analysis of New Zealand-based case studies and to draw out their policy implications and messages for the practice of eco-efficiency.

1.4 Research method

This thesis is presented as an attempt to provide insights into the concept of eco-efficiency and eco-efficiency trends in New Zealand. In order to achieve this, the thesis will apply a research method that is derived from ecological economic theory.

Three characteristics of ecological economics are relevant to the research method of this thesis; a pluralistic approach, interdisciplinarity and a systems approach. Pluralism is a system that recognises more than one ultimate principle (Sykes, 1982). "Pluralism affirms neither that truth is one, nor that it is many" (Panikkar cited in Raine, 2001, p. 32). Truth can neither be one for all world views, nor many within any one particular world view (Raine, 2001). Thus, pluralism requires an acknowledgement that there are multiple perspectives of reality.

A pluralistic approach should not be used as an excuse to avoid making difficult decisions. Rather, it is an acknowledgement that many perspectives of 'reality' exist, regardless of the relative importance of the different perspectives. A pluralistic approach is about open-mindedness and acknowledging the interrelatedness and complementarity of different multiple perspectives.

In the context of this research, the pluralistic approach is manifested in two ways. First, it is manifested through an acceptance that there are potentially many valid perspectives of eco-efficiency. Second, it leads to a view that a range of analytical methods are necessary to illuminate the many and varied aspects of eco-efficiency.

The use of ecological economic theory implies a synthesising approach that draws together several areas of learning to provide insights relevant to the research objectives. Ecological economics is therefore, necessarily 'inter-disciplinary'[1]. Interdisciplinarity is concerned with the transfer of knowledge and methods between disciplines. It involves efforts to develop a common language or set of concepts across several disciplines. Because of the interdisciplinary approach in this research, the reader will not find an exhaustive examination of theories from one discipline, as one might expect in a mono-disciplinary thesis. Rather, this thesis reviews relevant literature from across several disciplines – specifically the foundational disciplines of thermodynamics, economics and ecology – in its analysis of eco-efficiency.

In a general sense, a systems approach is "a way of thinking about the set of interconnected parts that makes up the whole in such a way as to bring out of the properties of the whole rather than those of the parts" (Peet, 1992, p. 25). A systems approach involves the study of systems and among other aspects, encourages systemic analysis (Flood & Carson, 1988). Systemic analysis is concerned with holistic thinking. In systemic thinking "something to be explained is viewed as part of a larger system and is explained in terms of that role in that larger system" (Ackoff, 1974, p. 14). Systemic thinking influences this research in that it encourages a view of eco-efficiency within the broader biophysical and socio-political whole.

Together, these three aspects of research method guide this thesis in its attempt to address the four research objectives outlined above.

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[1] The issue of whether ecological economics is necessarily interdisciplinary or transdisciplinary is addressed in Chapter 2.

1.5 Thesis outline

In general terms, the thesis is divided into two parts. *Part I* deals with research objectives one and two and lays the theoretical foundations for the chapters that follow. Chapter 2 sets the theoretical framework for the rest of the thesis. It provides a detailed argument as to why ecological economics is an appropriate theoretical foundation for eco-efficiency analysis.

Chapters 3 and 4 critique several approaches to interpreting eco-efficiency: the business-management literature from where the eco-efficiency concept emerged, thermodynamic, economic and ecological theory. The critique aims to identify the common characteristics and the strengths and limitations of these different approaches to interpreting eco-efficiency. Such a theoretical critique has hitherto been neglected in eco-efficiency and ecological economic literature. Following the analysis of alternative eco-efficiency interpretations, Chapter 5 discusses the role of efficiency in general terms in ecological economics. It then proceeds to propose an ecological economic approach to interpreting eco-efficiency. The proposed ecological economic approach attempts to address the relationship between eco-efficiency and scale issues as well as other socio-political goals.

Part II turns the attention of the thesis to research objectives three and four – the development and application of methods to measure eco-efficiency for national policy purposes. Chapter 6 develops and applies a decomposition method for quantifying the effect that key factors have on changes in eco-efficiency indices. Chapter 7 develops an approach to quantifying system-wide eco-efficiency in New Zealand. The method is applied to the New Zealand context in order to estimate a matrix of eco-efficiency multipliers.

Chapter 8 addresses the issue of how to develop reliable aggregate eco-efficiency indices. A multivariate statistics technique is used to produce a set of aggregate eco-efficiency indices for New Zealand. The aim is to assist in assessing whether New Zealand overall is getting more or less eco-efficient. Chapter 9 concludes the thesis and draws together the many strands covered throughout the research.

2 Ecological economic foundations for investigating eco-efficiency

This chapter investigates the relevance of ecological economic theory as a basis for analysing eco-efficiency. The chapter will explore the epistemological roots of ecological economics and the relevant themes in ecological economic theory that are pertinent to eco-efficiency: integration of ecological and economic theory, a biophysical focus, systems thinking, sustainable development and pluralism and transdisciplinarity.

2.1 Ecological economics - epistemological roots[1]

Ecological economics can trace its origins to the Physiocrats of the 1700s (van den Bergh, 1996, p. 12). Unlike the mercantilists before them, the Physiocrats saw a world based on 'natural order.' To the Physiocrat, the 'laws of nature' governed human society. In modern parlance, the Physiocrats took a 'biophysical approach' to the economy.

The Physiocrats also emphasised the interrelationships within the economy. For example, Francois Quesnay (1694-1774), a leading Physiocrat, developed his well-known *Tableau Economique*. As the precursor to the modern input-output table[2], the *Tableau Economique* traces the interrelationships between economic sectors and the consequent multiplier effects[3]. Input-output tables, and the resulting focus on interrelationships and structure, are now widely employed by ecological economists (Duchin, 1996, p. 290).

Ecological economics could also be said to be descended from Thomas Malthus's (1766 - 1834) proposal that the Earth sets physical limits to population growth and human well being. Hardin (1991), for example, pursues the Malthusian tradition and emphasises the role of carrying capacity in ecological economics. The concern for scale and physical limits might lead some to label ecological economics as neo-Malthusianism (Peet, 1992).

More recently, ecological economics has evolved out of the ecological and thermodynamic critiques of economics (Burley & Foster, 1994; Martinez-Alier, 1991) which began over 100 years ago. These critiques tend to adopt Bates's (1964, p. 95) position that ecology and economics are intertwined, and that the separation of the two disciplines is "an accident of the

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[1] Note that this section focuses on the origins of ecological economics in the West. For readers interested in the origins of ecological economics in China, see the article by Shi (2002).
[2] Described in more detail in Chapter 7.
[3] In general terms, in economics, a multiplier measures the effect of changes in the level of expenditure on total income (Richardson, 1972, p. 31).

history of scholarship, rather than a reflection of any profound cleavage of subject matter." Since the late 19th century, economics has relied heavily upon metaphors and analogies derived from the physical sciences; particularly thermodynamics. However, until the early 1970s only a few theorists seriously applied actual thermodynamic principles to economics. These theorists include Stanley Jevons[4], Frederick Soddy[5], Paul Samuelson[6] and Georgescu-Roegen. Georgescu-Roegen (1971) drew attention to the general neglect of thermodynamic thinking in economics. According to Sahu and Nayak (1994, p. 14) "Georgescu-Roegen's magnum opus ... represents the new dialectical synthesis of the genetic materials of ecology and economics through the entropic problem of humanity." Other significant critiques of neoclassical economics' inadequate treatment of environmental issues came from Kapp (1950)[7], Daly (1980)[8], and the Club of Rome (Meadows, Meadows, Randers, & Behrens, 1972), whose report *Limits to Growth* criticised uncontrolled economic growth.

Ecological economics can also be said to derive from what Pepper (1984) refers to as 'romantic' roots[9]. These 'romantic' roots are linked to two powerful and related pre-19th century ideas on the relationship between living and non-living things on Earth. The first idea is that of the 'Great Chain of Being.' This cosmology suggests "living things are interlinked, via regularly-grade affinities, in an hierarchical order" (Pepper, 1984, p. 69). Eliminating one link would fully dissolve the 'cosmical order,' and, ceasing to be full, the world would be incoherent. Evidence of the 'Great Chain of Being' idea can be found in ecological theory. For example, the food chain and trophic levels contain remnants of this 'Great Chain' idea. Ecological economics draws heavily on such ideas from ecological theory.

The other 'romantic' idea is that of plenitude, or fullness. This holds that the universe is filled by diverse living things, such that no genuine potentiality of a living being is left unrealised. The idea of plenitude leads to, inter alia, the glorification of diversity – another prominent idea in contemporary ecological economic theory (Nunes & van den Bergh, 2001; Ricklefs, 1990).

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[4] One of the fathers of modern notions of utility maximisation in neoclassical economics.

[5] Soddy, a joint Nobel Prize winner with Rutherford in Chemistry was persistent in his critique of economic theory. In particular, he criticized the inconsistency between Keynes' view of long-term growth and the principles of thermodynamics (Jenkins, 1996).

[6] A leader in post-war neoclassical economic theory.

[7] William Kapp provided the first institutional critique of traditional economics in its focus on environmental externalities.

[8] Daly is well known for his focus on ecological limits to economic growth. Daly proposed the goal of a steady-state economy (where population and economic capital are constant).

[9] That is, ideas that formed the basis of 19th century romanticism (Pepper, 1984).

2.2 Contemporary ecological economics

Contemporary ecological economics emerged in the late 1980s. Around this time, scholars were struggling to address the critiques mentioned above and the problems of sustainability that were not being adequately addressed by existing approaches (Costanza & Daly, 1987). This led to what Burley and Foster (1994) claim is a paradigmatic shift in economics away from reductionism towards holism and complexity. The emergence of ecological economics is a direct result of this paradigmatic shift.

The first published evidence of the emergence of ecological economics is found in a special issue of the journal *Ecological Modelling* (1987, Vol 38, Part 1). The papers presented in that issue were seen as ".. a hopeful first step to the true synthesis of ecology and economics that could lead to better management of renewable and non-renewable natural resources and a sustainable future" (Costanza & Daly, 1987, p. 1). The synthesis of ecology and economics was justified because ".. current economic paradigms have some serious shortcomings when it comes to dealing with natural resources... [and that] ecological paradigms tend to ignore human cultural behaviour as an object of direct study" (Costanza & Daly, 1987, p. 1).

Since 1987, a significant literature has emerged attempting to define what is ecological economics. As the title implies, ecological economics combines ecological and economic theory. In the introduction to the book *Ecological Economics: the Science and Management of Sustainability*, Costanza et al. (1991, p. 3) describe ecological economics as "a new *transdisciplinary* field of study that addresses the relationship between ecosystems and economic systems in the broadest sense" (italics in original). According to Sahu and Nayak (1994, p. 17) ecological economics is "the study of the symbiotic relationship between ecosystems and economics with particular emphasis on stewardship to ensure sustainable development within biophysical constraints." Proops (1989) states that ecological economics is a "dialectical science" dealing with the ever evolving interactions between humankind and nature.

2.3 Main tenets of ecological economics

A review of the literature suggests that the emerging ecological economics discipline is distinguished by its integration of ecological and economic theory, the consequent biophysical and system-based approaches to economics, its focus on sustainable development and its pursuit of pluralism and transdisciplinarity. The following section discusses these themes and their relevance to eco-efficiency.

2.3.1 Integration of economics and ecology

Ecological economics seeks to conflate economic and ecological theory. In doing so, ecological economics emerges as a distinct discipline[10]. Ecological economics differs from neoclassical conventional economics in that it takes a more holistic view of economic-environment interactions. As Costanza et al. (1991, p. 3) points out its "domain is the entire web of interactions between economic and ecological sectors."

Ecological economics also differs from ecology because it places more importance than ecology on the human species and the mutual importance of cultural and biological evolution. Human society is seen to evolve to meet broad ecological opportunities and constraints. Costanza et al. (1991, p. 3) states that "humans have a special place in the system because they are responsible for understanding their own role in the larger system and managing it for sustainability."

The integration of ecological and economic theory is particularly relevant for understanding eco-efficiency. Eco-efficiency[11] appears to be concerned with the interaction of two systems: ecological and economic. In order to understand eco-efficiency it is essential to understand the theories about the functioning of both of these systems, as well as the interaction between them. By combining ecological and economic theory, ecological economics is more likely to be able to identify synergies, develop insights and provide a more complete picture of eco-efficiency than is possible when drawing on either ecology or economics in isolation.

2.3.2 Biophysical approach

A feature of contemporary ecological economics is the resurgence of inquiry into the physical functioning of economic systems, and the biophysical foundations of economic activity (O'Connor, 1991). Indeed, ecological economics is sometimes referred to as physico-economics (van den Bergh, 1996) or bioeconomics (Mayumi & Gowdy, 1999).

Ecological economists present a biophysical view of the economy whereby the economy is considered a sub-system of the biophysical system (see Figure 2-1).

[10] In the sense that it is a distinct "branch of instruction or learning" (after Simpson & Weiner, 1989). Note that some prominent ecological economists refer to ecological economics as a 'transdiscipline.' The definition and implications of this term are discussed later in this chapter.

[11] The meaning of eco-efficiency is discussed in more detail in Chapters 3 to 5.

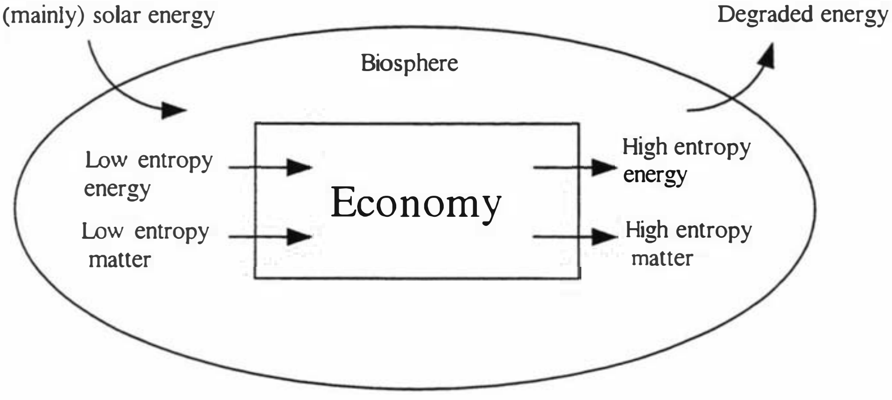

Figure 2-1: A simplified depiction of the energy and matter flows through the economy

The economic system relies on a low-entropy[12] energy[13] and matter as inputs to transformation processes. These inputs are ultimately degraded into high-entropy emissions flowing back into the physical environment.

A biophysical perspective emphasises the materials, energy resources, technology, information flows, feedback and production processes underlying economic activity. Christensen (1991, p. 79) states that the starting point of a biophysical approach is production: "finding and extracting materials and energy, upgrading materials, and producing the machines and services which reproduce the economy." Notions of efficiency (such as eco-efficiency) are an integral part of the production process, and an inherent part of a biophysical approach.

A biophysical perspective also emphasises physical limits, both in terms of the finiteness of physical resources (which leads ecological economists to question, inter alia, the notion of indefinite economic growth) and in terms of efficiency improvements.[14] As Peet (1992, p. 95) acknowledges "most physical scientists would agree that [a biophysical approach] is applicable to the physical constraints and long-term *limits* to social activities, not to the day-to-day activities of people within those limits."

A biophysical focus leads ecological economists to draw on thermodynamics – the science of energy and material processes. In their seminal paper, Underwood and King (1989) suggest that the thermodynamic laws[15] are a first principle of ecological economics and therefore, should be incorporated into the axiomatic foundation of ecological economics (see also Ayres, 1998).

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[12] See Chapter 4.
[13] In a strict scientific interpretation, energy is "the ability to do work" (Peet, 1992, p. 27).
[14] See a discussion of the limits to efficiency in section 4.4.1.
[15] In particular, the first and second laws of thermodynamics. Stated simply, these are the conservation of energy and materials, and the entropy law respectively. These are discussed in more detail in Chapter 4.

Thermodynamic theory furnishes a way of comprehending the resources and structure of our world from the standpoint of potentialities for transformation over time (O'Connor, 1991). In particular, modern thermodynamics,[16] leads to dynamic uncertainty and a disequilibrium view, where physical characteristics dominate the long-run outcome of economic activities (van den Bergh, 1996). A concept in modern thermodynamics that is gaining prominence in ecological economic literature is that of far-from-equilibrium systems. These systems require continuous in-flow of low entropy energy and matter, and are characterised by the emergence of differentiated structures (i.e. organisation), reorganisation of structures and dissipation of the erstwhile free energy. Far-from-equilibrium thermodynamics yields a "picture of turbulent coevolution of interacting structures, energy-dissipating material forms analysable as hierarchies that are interlaced, confounded and concatenated" (O'Connor, 1991, p. 108). In other words, 'complexity' (see section 2.3.3).

A biophysical approach can provide two distinct services to our understanding of eco-efficiency. The first is heuristic and conceptual in that it focuses attention on the material and energy flows of economic-environment interactions, on thermodynamic principles and physical limits and in particular on complex systems. The second is more narrowly analytical. This is to provide the theoretical basis for defining parameters, variables and functional relationships in empirical analysis (see, for example, Chapters 6, 7 and 8).

A biophysical focus is not to say that ecological economics sees life and human interactions as only energy and matter. Far from it. While ecological economics emphasises biophysical processes, there is also an acknowledgement of the importance of other aspects of social and economic activities. Ecological economics accommodates this in their call for pluralism (see below). Multiple perspectives can provide a richer perspective of 'reality' than single perspectives on their own. As Peet (1992, p. 85) states "used together, I believe the biophysical systems approach and the standard economic approach help us gain a perspective that is clearer and more powerful than either used alone."

[16] As opposed to a classical macroscopic thermodynamic view (see Chapter 4).

2.3.3 Systems approach[17]

Ecological economics incorporates a strong systems perspective. Van den Bergh (1996, p. 3) states that ecological economics adopts "a wide perspective on relevant causes and effects in time, space, and parts of economic-environmental systems." In addition, Costanza (1991, p. 4) states that "ecological economics takes a holistic view with humans as one component (albeit a very important one) in the overall system."

Before proceeding to a discussion of the systems approach, its role in ecological economics and relevance to eco-efficiency, it is important to briefly outline what a system is and the common system properties. A system is a "group of interacting, interdependent parts linked together by complex exchanges of energy, matter and information" (Costanza, 1993, p. 29). Further, Ackoff (1972, p. 8) defines a system as "a set of interrelated elements, each of which is related directly or indirectly to every other element, and no subset of which is unrelated to any other subset."

Systems have many common properties. However, Holling (1973, p. 13) notes that different properties of the system are important to different observers and depend on the system itself. From an eco-efficiency perspective, several system characteristics are relevant: interdependence, boundaries, hierarchy and emergence, communication and feedback, and flows and stocks.

Interdependence

The notion of interdependence is central to the system concept. Ackoff (1974, p. 13) identifies three interdependence characteristics that both the elements of a system and the system itself display. These are:

- the properties or behaviour of each element of the system has an effect on the behaviour or properties of the whole system;
- the behaviour and properties of each element and the effect it has on the whole, depend on the behaviour and properties of at least one other element in the system. "Therefore, no part has an independent effect on the whole and each is affected by at least one other part";

[17] The following discussion provides a brief overview of the systems approach. It is beyond the scope of this research to provide a comprehensive review of the vast systems literature. For a more in-depth discussion of systems theory refer to von Bertalanffy (1968), Weinberg (1975), and Prigogine (1980).

- every subgroup of a system has a non-independent impact on the system as a whole. This means that it is not possible to divide the whole system into independent subgroups.

Because of these three interdependency properties, Peet (1992, p. 73) concludes that "a system is a whole that cannot be divided into independent parts."

The idea of interdependence or linkages, is important for understanding eco-efficiency. Linkages lead to the notions of 'direct,' 'indirect' and 'system-wide' eco-efficiency. Direct eco-efficiency can be considered the efficiency of use of the inputs used immediately in a transformation process. System-wide efficiency includes not only the direct use of energy and materials but also the indirect (or embodied) inputs as a result of linkages through the system. Direct, indirect and system-wide concepts are all important when analysing eco-efficiency (see Chapter 7).

Boundaries and open, closed and isolated systems

A systems perspective begins by separating the system from its exterior or environment by defining boundaries (Flood & Carson, 1988, p. 7). Boundaries engender a relationship between the system and its environment. In the context of eco-efficiency for example, boundaries are important because they help to demarcate and define the relationship between the economy and the natural environment.

In understanding a system, the nature of the interaction across the system boundary is important (Kondepudi & Prigogine, 1998, p. 4). In general terms, systems can interact with their environment through the input and output of energy, matter and information. When considering eco-efficiency, the location of the boundary is critical because it defines whether energy, matter and information transfers are regarded as system inputs, outputs or merely internal transactions.

Systems theorists often distinguish between three types of systems depending on the 'permeability' of system boundaries to energy, matter and information (Peet, 1992). Isolated systems do not exchange energy, matter or information with their environment. That is, there are no links or flows to or from the system's environment (Boulding, 1966, p. 4). Following the second law of thermodynamics, the general trend in isolated systems is towards a state of maximum disorder and equilibrium. According to von Bertalanffy (1968, p. 38) classical science deals only with isolated systems. However, isolated systems are almost by definition unknowable, for if there are genuinely isolated systems around us, "we have no way of getting information into them or out of them" (Boulding, 1966, p. 4).

Closed systems on the other hand, exchange only energy with their environment. The Earth can be regarded as a closed system, since the only inflow is solar energy and only heat is emitted to outer space[18].

Open systems are 'open' in two distinct senses. First, they are open to their environment in a physical (thermodynamic) sense. They receive from and provide to other processes, inputs and outputs of material and energy resources. Second, they are open in an informational sense. This means they have "the potentiality for learning and a 'becoming' through time, manifesting an irreversible, unpredictable and more-or-less unique and novel evolutionary behaviour" (O'Connor, 1994, p. 61). In other words, open systems maintain themselves, are in dynamic relation with their environment and evolve by a continual inflow or outflow of energy, matter and information.

The distinction between isolated, closed and open systems is useful in the context of eco-efficiency for two reasons. First, it suggests the need to be explicit about assumptions concerning the interactions between the economy and natural environment. As open systems are ubiquitous on Earth, this thesis takes the position adopted by several theorists (including Peet, 1992) that all living organisms, ecosystems and economies are open systems through which materials and energy continuously flow. However, from the perspective of the biosphere as a whole, the Earth is regarded as thermodynamically closed and a non-materially growing system.

Second, the distinction clarifies the appropriateness of pretences to controlling the system and making future predictions of eco-efficiency. Open systems display not only the production of entropy, but also the import of entropy, which may be negative. Thus, open systems can avoid the increase of entropy, and may even develop towards states of increased 'order,' heterogeneity and organisation (von Bertalanffy, 1968). This explains why a characteristic of open systems is that under certain conditions they can remain far from equilibrium[19] (Prigogine, 1980). In far-from-equilibrium states, the future is neither stable nor predetermined. In such states, it would appear inappropriate to suggest that either the system can be controlled or to make more than short-term predictions about the future path of eco-efficiency.

[18] Peet (1992, p. 258) notes that an exception to this is the minute amount of meteoritic matter that enters the earth's atmosphere.

[19] That is, equilibrium in the closed system, maximum-disorder sense.

Communication and feedback

The maintenance of a system involves the communication of information to control the system and its surroundings. The concept of information is based on the notion of order; the higher the order of a system, the more information it contains (Ruth, 1993, p. 114). Systems can increase knowledge via the transfer of information. This enables the systems to be purposeful, to learn and adapt to changing environmental conditions.

Systems can be characterised as networks with linkages between all parts of the system. This linkage is by feedback loops that channel information (Golley, 1993). Peet (1992, p. 75) defines feedback as the "communication of information about the state of one part of the system to another part so that corrective action can be taken, if necessary, to change that state." Feedback can either be negative or positive. Negative feedback tends to dampen and correct changes to the system. Positive feedback, tends to 'enlarge' any changes to the system.

Eco-efficiency could be considered analogous to information, in a systems sense, for economic systems. In these systems, eco-efficiency can communicate information about system performance. For example, in some production facilities, engineers monitor the eco-efficiency of a process and use this information to fine tune system performance.

If they find waste increasing per unit of output, they would attempt to take corrective action (negative feedback) to decrease waste. Positive feedback would result if the engineer had incorrectly automated the process to respond to increased waste by further increasing waste generation per unit of output. In this situation, feedback increases the departure from 'normality' rather than correcting it.

Hierarchy and emergence

Two other features of systems are hierarchy and emergence. Hierarchy, using O'Connor's (1994) analogy can be described as a set of Chinese boxes where each successive layer of disaggregation discloses many somewhat comparable boxes. According to Peet (1992, p. 74) hierarchy implies that "parts may be arranged in ways that each level of increasing complexity shows emergent properties." Emergent properties are properties that do not appear in the parts but emerge at higher levels of resolution. For example, the properties of an urban system observed by a cyclist riding through the city would be quite different to the properties noted by a pilot in a high-altitude aircraft. In other words, systems have properties that only emerge or become obvious at higher levels.

The concepts of hierarchy and emergence provide a salient reminder that it is important to define an appropriate level of resolution when considering eco-efficiency. This is important, because the 'magnitude' of eco-efficiency is scale dependent. For example, the picture of eco-efficiency that one would gain by looking at a single firm in a sector is likely to be different than the picture of eco-efficiency that would emerge by analysing the sector or economy as a whole.

Flows and stocks

Two essential characteristics associated with system functioning are flows and stocks. Georgescu-Roegen (1971, p. 221) quotes Irving Fisher's dictum "stock relates to a *point* of time, flow to a *stretch* of time" (italics in original). Stock relates to the quantity of energy or matter in a system at a point in time. The flow, on the other hand, relates to the difference between levels of stock in two different instants in time. A systems perspective considers objects as existing in time and space. This distinction helps to highlight one of the limitations of the eco-efficiency concept. That is, eco-efficiency is not directly concerned with the level of stocks, but rather the flow of use (or depletion) of resource stocks.

A systems approach, ecological economics and eco-efficiency

In a general sense, a systems approach is "a way of thinking about the set of interconnected parts that makes up the whole in such a way as to bring out of the properties of the whole rather than those of the parts" (Peet, 1992, p. 25). A systems approach involves the study of systems and uses both systemic[20] and systematic[21] analysis (Flood & Carson, 1988).

A systems approach is appropriate for considering interrelated economic and ecological systems and eco-efficiency in particular. In fact, the systems approach has a number of important methodological implications for a study of eco-efficiency. First, a systems approach to eco-efficiency is necessarily interdisciplinary (Ackoff, 1974, p. 15). Because many systems are complex and because eco-efficiency interpretations are so varied, often it is necessary to involve people from many disciplines in order to understand the richness of eco-efficiency. The need for an interdisciplinary approach to ecological and economic systems is well recognised in ecological economics literature (International Society for Ecological Economics, 2001; van den Bergh, 1996, p. 45).

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[20] Also referred to as 'synthetic' thinking (Ackoff, 1974). Systemic analysis is concerned with holistic thinking. In systemic thinking "something to be explained is viewed as part of a larger system and is explained in terms of that role in that larger system" (Ackoff, 1974, p. 14).
[21] Systematic analysis is concerned with step-by-step procedures. Systematic analysis is an important problem management strategy within a systems framework (Flood & Carson, 1988, p. 16).

Second, systems thinking also reminds the analyst that in order to 'manage' a system it is important to identify the critical leverage points in that system (Russwurm & Sommerville, 1974, p. 15). In the context of sustainable development, Randers (2000, p. 223) identifies eco-efficiency as one of the "few realistic leverage points."

Finally, using a systems framework encourages a view of eco-efficiency as a measure of system performance. This is because efficiency concepts in general are considered to provide useful information on purposive system performance (Ackoff & Emery, 1972, p. 36). It follows that analyses of eco-efficiency could provide useful information on performance of the economy-environment system.

2.3.4 Sustainability[22]

Ecological economics was developed principally to address issues of sustainability. In fact, the International Society for Ecological Economics (ISEE) asserts that the "Society facilitates understanding between economists and ecologists and the integration of their thinking into a transdiscipline aimed at developing a sustainable world" (International Society for Ecological Economics, 2002).

The roots of the concern for the ecological sustainability of an economic system can be traced back to Physiocratic and Classical economic thinking[23] (van den Bergh, 1996). Contemporary concern for environmental limits can be said to have emerged from the history of post-war environmental concern (Davison, 2001) and influential analyses such as the *Limits to Growth* (Meadows et al., 1972) and *Blueprint for Survival* (The Ecologist, 1972). In the latter article a distinguished panel wrote that our "industrial way of life with its ethos of expansion is not 'sustainable' " (cited in Basiago, 1995, p. 110).

More recently, the concept of 'sustainable development' was popularised by the Brundtland Report as a guideline for economic and environmental policy (World Commission on Environment and Development, 1987). Since then, the term has become a key concept in modern environmental policy analysis and ecological economics (van den Bergh, 1996).

So what are 'sustainability' and the popular variant 'sustainable development'? Few words have suffered as much attention as these terms. Costanza and Patten (1995, p. 193) state that the "basic idea of sustainability is quite straightforward: a sustainable system is one which survives or persists." But the question remains: what is to be sustained?

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[22] It is beyond the scope of this thesis to examine the sustainability discourse in exhaustive detail. For excellent reviews refer to Davison (2001) and Pezzoli (1997).

[23] In particular, several classical economists addressed the issue of sustainability including Malthus, Mill, Jevons and Ricardo.

The term 'sustainable development' answers this to an extent by focusing the issue onto sustaining the economic/social system. According to Pezzoli (1997, p. 549) the most widely used definition of sustainable development comes from the Brundtland report:

> *"sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (World Commission on Environment and Development, 1987, p. 87).

Despite the WCED definition and the abundance of literature on the topic, the meaning of sustainable development remains far from clear-cut (Dixon & Fallon, 1989; Holmberg & Sandbrook, 1992; Pezzoli, 1997; Toman, 1992). Indeed, Davison (2001, p. 37) in his erudite review of sustainable development states that any "intellectual clarity in sustainable development discourses is superficial and deceptive." Common and Perrings (1992, p. 7) attribute the lack of agreement to, in part, differences in disciplinary perspectives.

From an ecological economic perspective, two relevant disciplinary perspectives can inform an understanding of sustainable development[24] – ecology and economics. Ecological economics provides a synthetic perspective that attempts to integrate and build on these two approaches to sustainable development.

Ecological economics acknowledges that the neoclassical economic approach to sustainable development (the so called weak sustainability[25]) offers a precise definition of sustainable development. However, weak sustainability is limited from an ecological economics perspective because of, inter alia, its assumption of capital homogeneity. Weak sustainability implies keeping the total (i.e. natural, human-made, human, social) capital constant. This is tantamount to assuming all forms of capital are perfectly substitutable. Pearce and Turner (1990) challenge this assumption and present five reasons why capital substitution is often impossible:

- Natural capital is often required to produce human-manufactured capital. Human-manufactured capital is not independent of natural capital;
- Natural capital fulfils many crucial economic functions that human-manufactured capital cannot simulate, such as life-support systems;

[24] Basiago (1995) and Pezzoli (1997) provided the academic world a service by attempting to group sustainability interpretations in an ordered way. In particular, Pezzoli (1997 p. 554) categorises the literature on sustainable development definitions into ten categories. It is not the objective of this thesis to repeat Pezzoli's work on all ten categories. Rather, this thesis will concentrate on the interpretations of sustainable development that are most relevant to the notion of eco-efficiency – economic, ecological and ecological economic categories.
[25] See Common (1995, pp. 46 –49) for a detailed discussion of weak sustainability based on the Hartwick rule.

- Natural capital provides resilience to environmental shocks experienced by the economic system, and therefore, provides for a more sustainable society;
- Considerations of intergenerational equity require that natural capital stock be maintained over time so as to ensure broadly equal access to it by different generations;
- Conservation of the natural capital stock is consistent with a world view that recognises the rights of other species to co-exist with humans.

In the place of weak sustainability, Pearce and Turner (1990) recommend a definition of sustainable development that focuses on maintaining natural capital constant (referred to as 'strong sustainability'). While more palatable from an ecological economic perspective, strong sustainability suffers from significant measurement problems.

In contrast, ecologists address sustainability at various levels of organisation; the biosphere, ecosystems, community and population. From the biosphere-level literature (see Carson, 1962; Ehrlich, Ehrlich, & Holden, 1973; Hardin, 1968; Meadows et al., 1972) a clear definition of ecological sustainability has emerged. Ecological sustainability requires humans to live within the carrying capacity of the biophysical environment (Patterson, 2002).

Common and Perrings (1992, p. 8) draw on the work of Holling (1973; 1978) to show how ecological theory of communities and ecosystems can help to define sustainable development. In general terms, Holling applies a systems approach to distinguish between two levels of stability. Stability is defined as the propensity of populations within an ecosystem to return to an equilibrium condition. Resilience, on the other hand, "is defined as the propensity of a system to retain its organisational structure following perturbation" (Common & Perrings, 1992, p. 16). Holling-resilience is the broader of the two terms; it refers to the stability of a system in the face of disturbances.

The Holling-resilience of a system is linked to the ability of that system to maintain its 'self-organisation' in the face of dynamic[26] change. That is, its ability to absorb stress, without undergoing some 'catastrophic' change in organisational structure. It follows from this perspective that a system can be said to be sustainable (or Holling-sustainable) "if and only if, it is Holling-resilient" (Common & Perrings, 1992, p. 18). The concept of Holling-resilience is widely used as a definitional basis for ecological sustainability (Patterson, 2002).

[26] Holling (1973) suggests there are four phases that describe the dynamics of ecosystems: exploitation (the early phase of ecosystems development dominated by opportunistic pioneer species); conservation (where the ecosystem consolidates and is relatively stable); release (ecosystem breakdown due to some external perturbation); reorganisation (at this stage the ecosystem can return to the same equilibrium point or flip to another equilibrium point). Holling summarises these four phases in a 'figure-8' diagram.

The notion of Holling-sustainability can be criticised from several fronts. This approach privileges the system over its component parts, which is itself a value judgement. It is also a physical concept (as opposed to social, political or cultural) deriving from the condition of the stability of ecosystems. To some, such a physical approach is an anathema because it ignores the importance social, political and cultural institutions play in sustainable development.

A review of ecological economic literature suggests a tendency to adopt a 'synthetic' approach to sustainable development that draws on ecological and economic theory. Ecological economics acknowledges that the neoclassical economic approaches to sustainable development offer precise definitions. However, weak sustainability is limited by the simplifying assumptions that the definition relies on (principally capital homogeneity), and strong sustainability suffers from measurement difficulties. On the other hand, the ecological perspectives are imprecise "beyond the injunction to maintain the functioning of the ecosystems... that support life" (Common, 1995, p. 55). Further, ecological theory does not emphasise the importance of human society.

Ecological economic literature draws on its biophysical view of the economy and synthesises ecological and economic perspectives of sustainable development. Ecological economics provides a perspective that necessarily involves imprecision, and acknowledges that there is no 'blue-print solution' to the issue of sustainable development. This view is pragmatic:

> *rather than attempting to prescribe a general solution, the appropriate approach is to address particular problems in the light of such knowledge as is available on how the total system functions, and an explicit recognition of the fact that such knowledge is necessarily incomplete, imperfect and changing over time"* (Common, 1995, p. 55).

Rather than provide a definitive definition, ecological economic literature identifies several characteristics of an ecological economic approach to sustainable development. These include:

- the common notion that intergenerational equity lies at the core of the concept of sustainable development (Holmberg & Sandbrook, 1992);
- an acknowledgement of the biophysical basis of economic activity. Since economic activities require inputs of materials and energy and result in the production of waste, sustainable development must consider the biophysical environment as a source of inputs and a sink for wastes as a determinant for long-term economic well-being (Ruth, 1993, p. 84);
- an anthropocentric focus (Common, 1995). This acknowledges that the resilience of the biosphere is important but not the only objective. Human requirements are pre-eminent;

- a precautionary approach. In the presence of uncertainty and complexity an ecological economic perspective of sustainable development adopts a precautionary approach to the future;
- the need for a transdisciplinary approach (discussed below) to addressing sustainable development (Lotspeich, 1995, p. 2);
- an acknowledgement of the complexity of sustainability issues. Sustainable development covers a much broader ground than environmental protection, as is sometimes erroneously thought (van den Bergh, 1996). Instead, sustainable development involves three hierarchically inter-related problems. These are: (1) a sustainable scale of the economy relative to its ecological life-support system; (2) a fair distribution of resources and opportunities, among present and future generations and (3) and the allocation of resources over time that adequately account for natural capital (Norton, Costanza, & Bishop, 1998, p. 194).

This eclectic approach to sustainable development can be criticised as it apparently lacks specificity and the ability to prescribe a course of action necessary for achieving sustainable development. However, this apparent looseness is misleading. A defining characteristic of an ecological economic approach to sustainable development is a focus on the problems themselves, rather than the particular intellectual tools and models used to solve them. As Costanza et al. (1991, p. 3) state 'we must transcend the focus on tools and techniques so that we avoid being "a person with a hammer to whom everything looks like a nail." This stance leads to an approach that suggests action must be taken on a case-by-case basis. Given the dynamic and uncertain nature of economic-environmental interactions, this pragmatic approach has merit.

Sustainable development and eco-efficiency

The linkage of efficiency in general and sustainable development was perhaps most famously articulated in *Our Common Future* (World Commission on Environment and Development, 1987, p. 213). This document urged that "industries and industrial activities should be encouraged that are more efficient in terms of resource use… ." In fact, eco-efficiency is linked to the concept of sustainable development in several important ways[27].

[27] Some criticise this link because eco-efficiency can be seen to cement in a narrow 'techno fix' approach to sustainable development (Davison, 2001). The debate over the appropriateness of this technological optimism and the wisdom of tying eco-efficiency to such an approach are addressed in Chapter 3 (see section 3.5.2).

First, eco-efficiency is often presented as a *strategy* for enhancing sustainable development (see for example Pearce & Turner, 1990, p. 48; Templet, 1999, p. 223). This view is clearly made by several prominent ecological economists. For example, Herman Daly (1991, p. 44) states "technological progress for sustainable development should be efficiency-increasing rather than through-put increasing." John Peet (1992, p. 175) also suggests "we must learn to perform our productive tasks, whatever they may be, in ways that minimise waste and maximise efficiency in the use of physical resources." However, it must be acknowledged that eco-efficiency is not a sine qua non for sustainable development. Rather, eco-efficiency (and efficiency in general) is a necessary but not sufficient condition for sustainable development[28] (Choucri, 1995; Organisation for Economic Co-operation and Development, 1997). This is partly because eco-efficiency essentially deals with flows not stocks. That is, improved eco-efficiency can reduce the flow of resources through the economy. But, eco-efficiency cannot stop the depletion of finite natural resource stocks. For this reason, the OECD (1998, p. 16) states that "eco-efficiency is an essential element, but not the whole, of sustainable development."

Second, efficiency of resource use is also often used as a measure of progress toward sustainable development. For example, the OECD (1998, p. 39) recommended eco-efficiency measures "to indicate the kind of change that is needed... in order to move toward sustainable development."

Finally, Choucri (1995, p. 46) argues that eco-efficiency is an *integrating principle*. Eco-efficiency is a microcosm of ecological economics as it seeks to combine economics with ecology. In the words of Choucri (1995, p. 46) "eco-efficiency seeks to recognise economic efficiency with ecological resilience." Other authors claim that the strength of eco-efficiency is its ability to combine technology with ecological and economic goals (O'Riordan & Voisey, 1998, p. 5). When dealing with complex sustainability issues in general, and eco-efficiency specifically, ecological economics' attempt to promote pluralism and draw on different perspectives is important.

2.3.5 Pluralism and transdiciplinarity

The need for pluralism is commonly referred to in several bodies of theory, including ecological economic literature (Faber & Proops, 1994; Norgaard, 1985; Norgaard, 1989; Soderbaum, 1990; Vedeld, 1994). References to pluralism often go undefined and rely implicitly on its etymological roots (plural meaning 'more than one' or 'multiple'). A more in-depth discussion is required to elucidate the meaning of pluralism as it is used in ecological economics.

[28] This issue is taken up further in Chapter 5.

One way to understand what pluralism is, is to define what it is not. Pluralism can be thought of as the opposite of what will be referred to as 'universalism.' 'Universalism' presumes that there is one correct way of interpreting reality, that correctness can be proven through hypothesis testing, and that progress consists of expanding the range of already correct knowledge (Norgaard, 1985, p. 338). In other words, "knowledge is universal or useless" (Norgaard, 1989, p. 47).

In contrast to universalism, pluralism is a system that recognises more than one ultimate principle (Sykes, 1982). "Pluralism affirms neither that truth is one, nor that it is many" (Panikkar cited in Raine, 2001, p. 32). Truth can neither be one for all world views, nor many within any one particular world view (Raine, 2001). Thus, pluralism requires an acknowledgement that there are multiple perspectives of reality. In the context of this thesis, pluralism would mean recognising that there are many valid perspectives of eco-efficiency.

The motivation for pursuing pluralism is often based on the need to avoid potential 'knowledge cul-de-sacs.' Multiple models, the maintenance of methodological diversity and methodological flexibility are used to 'hedge our bets' in a world of uncertainty (Norgaard, 1985, p. 389; Norgaard, 1989, p. 37). While this rationale is important, the reason for the pursuit of pluralism in ecological economics can be regarded as being more than simply 'risk management.' It is about open mindedness (Soderbaum, 1990) and acknowledging the interrelatedness and complementarity of different multiple perspectives – for example, acknowledging that different perspectives of eco-efficiency are at once many and single, separate and interconnected.

Gustafsson (1998) argues that a pluralistic approach is entirely appropriate for understanding issues of economy-ecology interaction in general, and eco-efficiency concepts in particular. At a general level, clearly no single model has yet been developed that provides a means for understanding how the ends of both economic growth and ecological sustainability might be achieved (Norgaard, 1985, p. 388; Munda, 1996). Because of the complexity of problems faced when dealing with ecological-economic interactions "there is no one mutually agreed upon 'right' approach, model, or paradigm" (Costanza & King, 1999, p. 2). Costanza and King refer to the proverbial blind men and the elephant: "Our limited set of perceptual tools can only touch pieces of the system, and can produce distorted results if they are not sufficiently integrated with alternative approaches, models, and paradigms."

A pluralistic approach also appears appropriate for understanding eco-efficiency concepts. This is because eco-efficiency is a multifaceted, context-dependent concept. As with efficiency in general, it would be excessive to regard eco-efficiency interpretations as belonging peculiarly to any one discipline[29] (Afriat, 1988, p. 251; Randall, 1987). Different disciplines understand and approach the same phenomenon in different ways (Vedeld, 1994). By learning more about how different disciplines interpret eco-efficiency, it may be possible to improve communication between disciplines and deepen our knowledge about economic-environment interactions. Accepting pluralism implies no singular understanding is sufficient; rather, multiple understandings are useful to capture all attributes of the eco-efficiency concept.

A pluralistic approach to eco-efficiency is consistent with the ideas of Grice (1968). Grice distinguishes between the 'occasion' (or context-specific) meaning and 'timeless' (or core) meaning of a concept. Grice suggests specific definitions of concepts should be developed by asking how the notion (in this case, eco-efficiency) can be used in *different contexts*. This is an acknowledgement that interpretations are context dependent and plural.

Peet (1992, p. 206) is critical of the call to pluralism. He suggests pluralism is limited because it implies 'balance': "pluralism balances values but does not judge them." Following from this, he suggests that pluralism leads us to balance the needs of the environment with economic needs. However, he argues that this notion of a trade-off between economic activity and the environment is inappropriate. Rather, the environment is the playing field upon which all other interests compete.

Peet makes a valid point. Pluralism should not be used as an excuse to avoid making difficult decisions. However, pluralism does not necessarily imply 'balance' as Peet suggests. Rather, pluralism is simply an acknowledgement that many perspectives of 'reality' exist, regardless of the relative weights of these different perspectives.

It is also acknowledged that a pluralistic approach will often provide a range of apparently incongruous perspectives (Norgaard, 1985). But that reflects the complex nature, and our limited knowledge of issues regarding economy-environment interactions. The alternative is to attempt to develop a comprehensive theory that potentially provides a distorted picture of reality because of the simplifying assumptions it must rely on. Furthermore, the merging of disparate theories, if it is possible, may be a very lengthy process, and many of the environmental challenges faced today require urgent action. Thus, a pluralistic approach is appropriate and "for the foreseeable future,...multiple models with alternative strengths and insights will be the best we have" (Norgaard, 1985, p. 389). Accepting plurality of perspectives will not unify science. It will facilitate humility, cross-disciplinary respect and reduce the plethora of naive policy prescriptions.

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[29] Eco-efficiency interpretations will also differ between socio-cultural groups. While these perspectives of eco-efficiency are important, it is beyond the scope of this thesis to investigate these in any detail.

Transdisciplinarity

Pluralism calls into question the appropriateness of monodisciplinary approaches to issues such as eco-efficiency. At a more fundamental level, pluralism questions the validity of remaining within the confines of disciplinary boundaries. This is because all disciplines tend to draw tight boundaries around their theories for the purposes of staking out knowledge claims, for quality control, and to establish a 'closed shop' (Sandercock, 1999, p. 537). Such rigid boundary definitions can reduce the possibility of a truly multidimensional eco-efficiency understanding and practice emerging, one that emphasises interrelationships among processes and things. The concept of transdisciplinarity has emerged in ecological economic theory to capture this pluralism ideal to 'transcend disciplinary boundaries.'

The concept of ecological economics as a 'transdiscipline' has become a core phrase in ecological economic rhetoric. For example, an introduction to ecological economics on the ISEE web site (ISEE, 2002) states that the Society for Ecological Economics "facilitates understanding between economists and ecologists and integration of their thinking into a transdiscipline...." Also, the journal of the society is subtitled "The Transdisciplinary Journal of the ISEE."

Despite ecological economics' promotion of transdisciplinarity, the concept is not always clear. Its meaning tends to be implied either by common usage or by its etymological roots (i.e. *trans* meaning beyond or across, and *disciplinary* given its usual meaning) (Wolfenden, 1999, p. 33). Many seem to use transdisciplinary as roughly synonymous with multidisciplinary or interdisciplinary. For example Faber et al. (1996), while arguing for transdisciplinarity in ecological economics, choose to identify interdisciplinary research as the means of achieving this.

The need for ecological economics to adopt a 'multiple-discipline' approach to issues such as eco-efficiency is apodictic. It is less clear whether ecological economics should adopt a 'transdisciplinary' as opposed to an 'interdisciplinary' or 'multidisciplinary' approach. This is because there is confusion in the literature as to what transdisciplinarity is, and whether it is different to other 'multiple-discipline' approaches (Nicolescu, 1997, p. 2).

Multidisciplinarity[30] concerns the parallel study of a topic from several disciplines at the same time (Nicolescu, 1997; Vedeld, 1994). It involves study from within a particular disciplinary perspective, but with the addition of insights from other disciplines. Its goal remains to enrich the 'home perspective' and is limited to the framework of disciplinary research (Nicolescu,

[30] Sometimes referred to as pluridisciplinarity

1997). With multi-disciplinary work, the identity of the individual disciplines remains distinct (Wolfenden, 1999, p. 34).

Interdisciplinarity[31] is similar to multidisciplinarity, but has a different goal. It is concerned with the transfer of knowledge and methods between disciplines. In essence, interdisciplinarity is similar to multidisciplinary in that its goal "still remains within the framework of disciplinary research" (Nicolescu, 1997, p. 1). However, interdisciplinarity involves efforts to develop a common language or set of concepts in order to undertake a joint study. That is, 'creating common ground' (Vedeld, 1994, p. 10).

Transdisciplinary, as described by Costanza et al. (1991) means to go beyond the normal conceptions of scientific disciplines and try to integrate and synthesise many different disciplinary perspectives. "Transdisciplinarity concerns that which is at once between the disciplines, across the different disciplines, and beyond all discipline" (Nicolescu, 1997, p. 1). Transdisciplinarity is not a new discipline or a new superdiscipline. Transdisciplinarity is complementary to disciplinary research. It is nourished by and nourishes disciplinary research.

Transdisciplinarity implies disciplinary integration (Nicolescu, 1997; Wolfenden, 1999, p. 36). The need for integration across methodologically diverse frontiers is asserted by several authors (see Gustafsson, 1998; Luks, 1998). "We would like to see theories that are capable of integrating natural and social processes" (Gustafsson, 1998, p. 260).

There are similarities between transdisciplinarity, interdisciplinarity and multidisciplinarity in that they all involve dialogue among disciplines. However, transdisciplinarity differs from the other approaches because it:

- attempts to go beyond disciplinary boundaries into the realms of cultural spiritual and historical (Nicolescu, 1997);
- is fundamentally more participative (Gill, 1997);
- attempts to integrate understanding of the present world.

A brief critique of 'transdisciplinarity' and its relevance to eco-efficiency

When dealing with complex phenomena a transdisciplinary stance appears to offer several advantages over multi- and interdisciplinary approaches. Nonetheless, transdisciplinarity is not beyond reproach. Transdisciplinarity reflects a degree of academic arrogance - for example, in its suggestion that is possible for researchers to transcend scientific and cultural boundaries.

[31] Perhaps analogous to the phrase 'extended peer communities' used by Funtowicz and Ravetz (1991, p. 149).

The transdisciplinary approach can be taken to connote an approach that is 'superior' to disciplinary approaches.

Advocates of transdisciplinarity imply that the approach should be used in all research. However, it is possible that there are situations where it is not necessary to adopt a transdisciplinary perspective. For example, a transdisciplinary approach is unlikely to be necessary in a study of the nutrient assimilation efficiency of rye grass. The point here is that the appropriateness of transdisciplinarity depends on research purpose.

The implication that transdisciplinarity necessarily involves disciplinary integration raises a conceptual tension. On the one hand, transdisciplinarity embodies a pluralistic approach - the acknowledgement of multiple complementary perspectives. On the other hand, the call for integration implies a tendency towards a single universal, coherent 'truth' - 'universalism.' It is the perspective of this author that disciplinary integration (for example, between thermodynamic, ecology and economics) should be avoided and may not even be possible. These three disciplines are not always concerned with the same phenomena and it is difficult to fully integrate them. This does not mean, however, the common ground between these disciplines should not be acknowledged.

It is questionable whether ecological economic rhetoric surrounding transdisciplinarity has actually been reflected in ecological economic practice. As Costanza (1989, p. 2) states "ecological economics will, in the end, be what ecological economists do." If ecological economics were truly transdisciplinary, one would expect a balanced focus on all disciplines. Also, one would expect to find demonstrated attempts to move beyond disciplinary bounds into cultural and spiritual realms. In reality, ecological economics is predominantly focused on three disciplines (ecology, economics and thermodynamics). For example, a review of the first 10 years of the journal *Ecological Economics* (Costanza & King, 1999) reveals that economists and natural scientists authored most of published papers[32]. Papers first authored by economists dominated the journal. Other examples of ecological economic literature reflect the predominant 'economic-ecology' focus. These include:

- van den Bergh (1996) in his *Ecological Economics and Sustainable Development* focuses on the integration of economics, ecology and thermodynamics;
- Costanza and Bartholomew (1991) list five topics of an ecological economic research agenda – all of which focus on ecology and economics;

[32] Around 70 percent of the 518 papers published were by economists or natural scientist (based on information presented by Costanza & King, 1999, p. 4). The remaining papers were by social scientists, 'miscellaneous' and 'business' and 'other science.'

- The ISEE web site explicitly states ecological economics focuses on integrating ecology and economics.

Ecological economic literature pays little attention to socio-cultural, spiritual or ethical realms as required by transdisciplinarity. For example, very few papers (less than 1 percent) were classified as covering 'ethics' in the review of ten years of the *Ecological Economics* journal. These examples demonstrated that ecological economics is not mono-disciplinary as it does attempt to draw on more than one discipline; because of ecological economics' attempts to integrate ecological and economic theory it could be considered interdisciplinary. The limited evidence of actual 'transcendence' of disciplinary boundaries in the revealed practice of ecological economics suggests it has not reached its transdisciplinary goal. Rather, ecological economics in practice is best described as interdisciplinary, that is at times nourished by transdisciplinary insights.

2.4 Limitations of ecological economics for the analysis of eco-efficiency

The above sections present a case for using ecological economics as a theoretical base for analysing eco-efficiency. However, ecological economics is not beyond reproach. Before a final conclusion can be reached about the appropriateness of ecological economics in a study of eco-efficiency, some criticisms of ecological economics must be confronted.

First, ecological economics relies on the *systems approach* as effectively 'best practice' when it comes to dealing with complex problems. However, "not all authors are quite so sanguine about the systems approach" (Wolfenden, 1999, p. 55). The systems approach has been criticised because it lacks explanatory power (von Bertalanffy, 1968, p. 35). Those looking for simple projections (or forecasts) normally level this criticism at systems theory. However, forecasts are limited in their ability to explain behaviour beyond a couple of years especially in systems far-from-equilibrium (as already mentioned). This means that other analytical techniques – such as systems analysis – are required. Also, in a complex world, with many possible futures, models should not be judged on their explanatory power, but rather on their ability to investigate the many possible futures.

Another criticism levelled at systems thinking is that it does not include an 'intentional explanation,' which is important to the extent systems theory is used in an attempt to explain human action (Vedeld, 1994, p. 5). This criticism is not entirely valid. Systems thinking does involve the consideration of the 'telos' or goal (von Bertalanffy, 1968). Indeed, Ackoff (1972) is clear about the importance of considering 'purposive' systems.

Systems thinking tends to place the whole above the individual – which is itself a value judgement. This highlights the role of values in systems thinking. It is beyond the scope of this research to address the issue in detail, except to note that adoption of a systems perspective involves an implicit value judgement.

Complex systems are just that – complex. This means that a systems-based approach to complex problems may have difficulties in articulating the problem (Common, 1995, p. 220). Given this, it would not be appropriate for ecological economics to adopt a single methodology for addressing issues such as eco-efficiency. Instead, ecological economics is necessarily eclectic.

A second issue that should be confronted is whether ecological economics offers *any new insights* into issues like eco-efficiency than the already established discipline of neoclassical environmental economics. Both ecological economics and environmental economics share a common concern for the sustainability of humans' habitat, and both are concerned with the impact of economic activity on the environment. Therefore, is ecological economics just a new name for an existing discipline, or does it incorporate new substance? Sahu and Nayak (1994) address this question by comparing the 'paradigm,'[33] scarcity perceptions, problem-solving orientation and range of integration of neoclassical environmental economics and ecological economics. They conclude that the two approaches do differ sufficiently and provide "a unique example of 'niche diversification'... within... economics" (Sahu & Nayak, 1994, p. 17). In particular, Sahu and Nayak (1994) point to several differences that highlight the cleavage between the two disciplines. These include:

- paradigmatic differences (such as a market-based approach of environmental economics versus the biophysical approach of ecological economics);
- differences in world views (mechanistic versus evolutionary and holistic);
- different scarcity perceptions (relative versus absolute).

In the words of Sahu and Nayak (1994, p. 17), "humankind is richer" for the insights provided by ecological economics. Based on the findings of Sahu and Nayak, it can be concluded that ecological economics can provide unique insights into eco-efficiency that are overlooked by neoclassical environmental economics.

[33] They appear to use this term loosely without defining it. Thomas Kuhn (1962) introduced the concept of a 'paradigm,' to define the structures and work of a scientific profession. A paradigm is a set of fundamental assumptions that form a scholar's picture of the world (Jablonsky, 1995, p. 3). It is a shared framework that provides instruction about the scope, method and purpose of a particular science. Further, the paradigm determines the problems studied, the questions, the nature of evidence and the principles of interpretation for "the majority of people in the discipline" (Marris, 1982, p. 94).

A third criticism of ecological economics is that its attempts to pursue 'pluralism' and transdisciplinarity can be seen as wishful thinking. Very few individuals have the capacity to be professionally familiar with more than one discipline. And given the call for transdisciplinarity, even interdisciplinary team-based research does not appear to be satisfactory because ecological economics seems to require the ability to *transcend* disciplinary bounds. Does this make ecological economics unusable except to a few pundits? Common (1995, p. 220) acknowledges the difficulty faced by ecological economics; "at one level the goal of a genuinely comprehensive understanding of the sustainability problem in all of its dimensions is clearly unattainable." However, this does not mean ecological economics should be discarded. As Common (1995) points out, some physicists recognise the limits to understanding physical laws, but they do not conclude that physics should be abandoned. In the case of ecological economics, the operative point seems to be that "uncertainty is fundamental, and there is no uniquely correct way to proceed in the face of it" (Common, 1995, p. 220).

In the face of such limitations ecological economics adopts two approaches. First, it is appropriately eclectic and attempts to take a more pluralistic approach in its analysis than other single disciplines. Attempts to move towards pluralism are appropriate because "for the foreseeable future ... multiple models with alternative strengths and insights will be the best we have" (Norgaard, 1985, p. 389)[34]. In the case of eco-efficiency, a pluralistic approach also appears appropriate for at least one reason; because of the many and varied interpretations of the eco-efficiency concept. Second, pragmatism appears to be a hallmark of an ecological economic approach. As already discussed above, ecological economics attempts to focus directly on problems, rather than particular intellectual tools used to solve them.

2.5 Conclusions

Ecological economics "studies how ecosystems and economic activity interrelate" (Proops, 1989, p. 60). This chapter has demonstrated that ecological economics is an appropriate theoretical base for approaching eco-efficiency for many reasons. These reasons are summarised in the table below.

[34] The issue of pluralism in ecological economics is addressed in more detail in Chapter 5.

Table 2-1: The relevance of ecological economics' main tenets to eco-efficiency

Ecological economic tenets	Relevant to eco-efficiency because:
Linking of ecological and economic theory	The realm of eco-efficiency is the environment-economic nexus. Understanding of both ecological and economic theory is essential to fully understand eco-efficiency.
Biophysical perspective and emphasis on thermodynamics	This focuses attention on material and energy flows and thermodynamic principles that are fundamental to understanding eco-efficiency Emphasises limits – both in terms of finite resources, but also limits to efficiency. This provides a theoretical basis for selection of variables in an empirical analysis of eco-efficiency.
Systems approach	
Interdependence	This concept helps to distinguish between direct and system-wide efficiency.
Boundaries	Definitions and measurements of eco-efficiency are boundary dependent.
Open, closed and isolated systems	This concept forces clarity about the nature of interaction between the economy and environment. The distinction between systems clarifies pretences to controlling the system and the ability to make future predictions about eco-efficiency.
Complexity	Complexity leads to the conclusion that there is unlikely to be a single, all-encompassing definition of eco-efficiency.
Communication and feedback	Eco-efficiency could be considered analogous to information in economic systems. Eco-efficiency can communicate information about an economic system's performance.
Hierarchy and emergence	Eco-efficiency is scale dependent.
Flows and stocks	This highlights the limitation of eco-efficiency as it relates only to flows.
Sustainability	Eco-efficiency is a strategy for enhancing sustainability. Eco-efficiency is a (partial) indicator of progress towards sustainable development. Eco-efficiency is an integrating principle. Eco-efficiency is a necessary but not sufficient condition for achieving sustainable development.
Pluralism and transdisciplinarity	Pluralism is appropriate for concepts such as eco-efficiency that are multifaceted and context dependent. The appropriate multiple-disciplinary approach to this analysis of eco-efficiency is interdisciplinarity that is at times nourished by transdisciplinary insights.

Furthermore, ecological economics appears to stand up to the various challenges levelled against it. In particular, ecological economics is appropriately pragmatic and eclectic. It also attempts to pursue a more pluralistic and interdisciplinary approach than other disciplines, which appears appropriate for an investigation of eco-efficiency.

3 Eco-efficiency - a critique of the eco-industrial épistémé interpretation

"You must get the most out of the power, out of the material, and out of the time" (McDonough & Braungart, 2000, p. 83-84).

"Weaving eco-efficiency into the very fabric of how businesses, governments, NGOs, and consumers think and act is essential if we are to reap the vast rewards of this concept and tool" (Maurice Strong quoted in DeSimone, Popoff, & World Business Council for Sustainable Development, 2000, p. viii).

The main purpose of this chapter is to provide a critique of the commonly-held perspective of eco-efficiency that has emerged from business-management (or what will be referred to as the eco-industrialist épistémé (EIE)) literature. To achieve this, the chapter outlines the contemporary origins of the eco-efficiency concept, and explains why the concept has been adopted so widely. Next, the chapter introduces and describes the EIE interpretation of eco-efficiency and the épistémé (or world view) that underlies these interpretations. This provides the basis for a detailed critique of the EIE perspective of eco-efficiency.

3.1 Eco-efficiency – emergence and popularity

The term eco-efficiency was coined in Schmidheiny's (1992) *Changing Course*. This book was "about the steps required of business, and of the governments that set the frameworks for industry, to ensure that humans and all other species continue to occupy a safe and bountiful planet" (Schmidheiny, 1992, p. 4). Eco-efficiency has been described as the "business contribution to sustainable development" (OECD, 1998, p. 15).

Since 1992, the eco-efficiency concept has been adopted rapidly throughout the business world. And now, the notion of eco-efficiency is beginning to take hold in wider circles than just business. Scientific, government and international organisations as well as businesses regard eco-efficiency as "an essential answer to the global ecological challenge" (Hinterberger & Stiller, 1998, p. 275). For some, eco-efficiency is "the most effective method of promoting sustainable development in business" (Hilson, 1999, p. 191).

The popularity of the eco-efficiency concept is not surprising. One of the reasons for the popularity of the concept is that businesses have demonstrated impressive improvements in the eco-efficiency of their activities. DeSimone et al. (2000) provide a long list of business initiatives that have improved eco-efficiency. For example, Rank Xerox has demonstrated that reusing parts in its low-volume copier cartridges returned estimated savings in raw material costs of over $US 2 million in 1994 (DeSimone et al., 2000, p. 75).

However, the evidence of gains associated with eco-efficiency must be treated carefully. For example, Peck & Gibson (2000, p. 21) state that "the significance of positive experiences so far can easily be exaggerated, and many large corporations continue to ignore or deny environmental concerns." Some authors are suspicious of the claim made by Barber (1999), OECD (1997) and Gilkinson (1999) that the business world can 'drive' sustainable development. This claim appears to be based on the frail and recent evidence of less intensive resource use by industrial countries since the oil shocks of the 1970s (Ekins, 1989).

The popularity of eco-efficiency can also be explained by the term itself, by its technical and practical nature, by its focus on machines and technology and by its apparent simplicity. These are each discussed below in turn.

The eco-efficiency term itself represents another example of a popular feature of recent English. That is, the shortening of a word to a part that is then used as a combining form for the original word (Algeo & Algeo, 1988). In this case, the prefix *eco-* from *ecology*. The usage usually implies some connection with the environment. Russell and Porter (1972) note that the popular use of the *eco-* prefix dates back to the late 1960s with such words as 'eco-action' and 'eco-awareness.' Now Golley (1993) claims, the *eco-* prefix is fixed in English language. It has become a particularly popular combining form in this time of environmental concerns, and contributes to the popularity of words that use it.

The eco-efficiency term is also successful because it rests on the powerful 'efficiency' notion. In general terms, efficiency means fitness, power or success in accomplishing the purpose intended (Simpson & Weiner, 1989). It is loaded with powerful connotations such as 'usefulness,' 'effectiveness' and 'productive.' That which is efficient (in economics, for example) is optimal and (excluding equity considerations) is beyond reproach. And, as Hardin (1991, p. 51) explains, "like it or not, the connotations of a term affect the ease with which people accept it."

Efficiency within the Western scientific tradition is referred to with 'reverence.' The reverence with which efficiency is treated can be traced down the same path as modern technological zeal. The reverence given to efficiency could be seen as a manifestation of the Christian dogma of people's struggle to achieve transcendence over nature (White, 1967).

The status of efficiency is not just an unspoken code. The term has been enshrined in New Zealand's resource management legislation. For example, section 7 of the Resource Management Act, 1991 states that in achieving the purpose of the Act, "...all persons ... shall have particular regard to – (b) the efficient use and development of natural and physical resources."

Another possible reason for the popularity of the eco-efficiency term is because it emphasises a technical and practical concept. It provides an easily applicable approach for businesses to reduce their effect on the environment. This practical legacy has contributed to the successful uptake of the eco-efficiency concept by technically-minded business engineers.

The pragmatic nature of eco-efficiency has another implication – a focus on machines and technology. Indeed, many efficiency concepts, including eco-efficiency, are commonly associated with improving the operation of machinery and equipment. This focus is powerful and appealing because it narrows the field of vision of eco-efficiency to that of the mechanised production process, whose behaviour is not random but is a knowable and predictable outcome of structure. A focus on machines, therefore, reduces complex problems to problems that can be known and conquered by logical, scientific method. In effect, the eco-efficiency concept has been successful because it ostensibly reduces the complex issue of sustainability to a technical management problem.

Finally, the eco-efficiency term is successful because of its apparent simplicity. Managers in environmentally friendly businesses like simple solutions and "eco-efficiency fits the bill" (Welford, 1997, p. 34). Eco-efficiency ignores social issues[1] and essentially reduces the sustainability debate to a technical-fix problem that is understandable and accessible to business managers with limited time. Indeed, Welford (1997, p. 34) claims that eco-efficiency actually encourages technical and scientific solutions to environmental problems "and is therefore welcomed."

As a result of the popularity of this term, Hinterberger and Stiller (1998, p. 275) conclude, "eco-efficiency is broadly accepted as the most promising strategy towards sustainable development. Science, governments, international organisations, and business see eco-efficiency [as] an essential answer to the global ecological challenge."

3.2 Interpreting the eco-efficiency concept

Despite the widespread adoption of the eco-efficiency concept, there is "less unanimity when it comes to the detailed definition of eco-efficiency" (Hinterberger & Stiller, 1998, p. 275). Indeed, the literature includes various authors questioning the strength of current definitions of the term. Even eco-efficiency proponents DeSimone et al. (2000, p. xxi) acknowledge "the concept of eco-efficiency needs further refinement." Welford (1997, p. 30) is more forceful: "I have never found a very clear definition of what this (eco-efficiency) really means and that in

[1] See section 3.4.1 below

itself reflects the confused and often contradictory thinking of eco-modernists." This lack of a clear interpretation leads to what could be described as a 'chaos of terminology.'

Part of the reason for the lack of unanimity on an eco-efficiency interpretation is the absence of a detailed definition in Schmidheiny's (1992) seminal work. Schmidheiny (1992, p. xii) did provide a loose interpretation:

> *"Corporations that achieve ever more efficiency while preventing pollution through good housekeeping, materials substitution, cleaner technologies, and cleaner products and that strive for more efficient use and recovery of resources can be called 'eco-efficient'."*

However, this interpretation is confused by his use of the term 'environmental efficiency.' He appears to use the two terms as synonyms. Schmidheiny (1992, p. 98) defines environmental efficiency as "the ratio of resource inputs and waste outputs to final product."

The minimalist definition provided by Schmidheiny suggests using the traditional business tools of audits and technology improvement can enhance eco-efficiency. As a result, it appears that businesses can achieve eco-efficiency by simply appending ecological concerns to a business-as-usual management approach. "Rather than being center stage, ecological issues are appendages which drop off when the going gets tough" (Welford, 1997, p. 30).

Because of Schmidheiny's (1992) lack of a concise interpretation of the eco-efficiency, the concept had rather vacuous beginnings. Interpretations of eco-efficiency tend to be restricted to 'business-management' related literature and range from the relatively simple to the more detailed definition developed by the WBCSD (DeSimone et al., 2000).

Simple interpretations of eco-efficiency are, not surprisingly, more common. They tend to appear as off-hand comments in business-management related magazine articles. While these simple interpretations may be appropriate for the magazine audience, they do belie several leitmotifs inherent in this body of literature. Williams (1999, p. 37) defines eco-efficiency glibly as "endeavouring to get more from less for longer." Metti's (1999, p. 83) interpretation introduces the notion of 'value': "eco-efficiency is simply creating more value with fewer materials and less waste." In a similar vein, but also introducing the issue of ecological impact, DeSimone et al. (2000, p. xix) state that eco-efficiency is used to "describe activities that create economic value while continuously reducing ecological impact and the use of resources." Some of the interpretations introduce the notion of optimality. For example, Glauser and Muller (1997, p. 201) state eco-efficiency is "the optimal use of material, energy, human resources, and capital to supply innovative products to the market."

A more detailed definition of eco-efficiency comes from the WBCSD. The WBCSD and its predecessors[2] developed the definition through a series of publications and workshops (for example, Business Council for Sustainable Development, 1993; World Business Council for Sustainable Development, 1995; World Business Council for Sustainable Development, 2000). The full definition to emerge from the work is:

> *"Eco-efficiency is reached by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing environmental impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity"* (DeSimone et al., 2000, p. 47).

This definition has five core themes: (1) an emphasis on service, (2) a focus on needs and quality of life, (3) consideration of the entire product life cycle, (4) a recognition of limits to carrying-capacity, and (5) a process view (DeSimone et al., 2000, p. 47).

Despite the plethora of interpretations, Hinterberger and Stiller (1998, p. 275) note that they all have an obvious theme in common: "All concepts call for a more efficient use of natural resources." A closer examination reveals several other common assumptions that underly these interpretations. These characteristics are consistent with a world view that will be referred to as an eco-industrial épistémé (EIE). The next section describes the EIE and the characteristics of the EIE that inflect its understanding of eco-efficiency. This sets the scene for an extensive critique of EIE interpretations of eco-efficiency.

3.3 The epistemology of eco-efficiency: the eco-industrial épistémé

Schmidheiny's eco-efficiency concept can be said to have emerged from two interrelated 'épistémés'[3]; eco-modernism and the 'industrial production épistémé.' At the corporate level, eco-efficiency emerges from what several authors (Davison, 2001; Dryzek, 1997; Welford, 1997) call 'eco-modernism.' Davison (2001) traces eco-modernism to the events following the 1979 OPEC oil crisis which revitalised economic growth as the preeminent concern in global politics. This, coupled with increasing attention on environmental issues led to what Davison refers to as the 'second wave of environmental concern.' This second wave attempted to reconcile economic growth and the environment and proposed that economic development and

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[2] The Business Council for Sustainable Development and the World Industry Council for the Environment

[3] Épistémés can be described as "the system of concepts that defines knowledge for a given intellectual era" after Michel Foucault (Gutting, 1995, p. 9). In other words, it describes 'ways of knowing reality' (Ingram, 1994).

environmental protection policies "can be combined for synergistic effect" (Davison, 2001, p. 15).

Eco-modernism describes the response to concerns over the environment by those people and institutions that are committed to the business-as-usual path of economic development. Eco-modernism thus has a deterministic view of the future – the future is held to be simply a product of the past. Welford (1997, p. 28) claims that "eco-modernism represents not a break with what went before but a continuation of it." It adds an environmental dimension to the conventional business-as-usual economic development path, but does not allow that dimension to radically change the path. Eco-efficiency is the 'flagship' tool of eco-modernism. As Welford (1997, p. 30) claims "at the centre of eco-modernism we find the search for eco-efficiency."

When focused on the task of production, we find evidence of what O'Connor (1994) calls the 'industrial production épistémé' (IPE). O'Connor (1994) coined the term industrial production épistémé in his critique of theories of production. The IPE describes the predominant Western theory of production. It encapsulates both neoclassical economic theories of production and industrial ecology[4] and is naturally concerned with the efficiency of the production process (Lowe, 1995). The basic picture of 'production' in the IPE view is "that engineers/managers regulate the inputs and environmental conditions with a view to obtaining a predetermined output from a " 'black box' process" (O'Connor, 1994, p. 64).

Assumptions about the controllability of the 'production' process are a key theme of the IPE. "Taken together, the whole ensemble of control assumptions amounts to a particular mode of conceptualising production activities" (O'Connor, 1994, p. 64). In particular, the IPE includes an implicit assumption of the essential controllability of nature through the agency of technology. That is, the common theme in the IPE literature is a Panglossian view of the ability of technology to solve (control) environmental 'problems.'

An implication of the IPE assumptions of controllability is that economic production processes are seen as independent from environmental processes (although the rhetoric may state otherwise). In the words of O'Connor (1994, p. 64) "the effect of the industrial épistémé assumptions is systematically to negate, or to 'bracket out'... the mutual conditioning and interdependency of production processes." This assumption, together with the controllability assumptions give rise to a view that allows any commodity production process to be considered

[4] Industrial ecology is "a conceptual framework and organising principle for making environmental factors an integral part of economic and business decision making" (Pezzoli, 1997, p. 572). For more detail on industrial ecology, see Lowe (1995).

in isolation, "and hence the economic system taken as a whole, to be represented as a closed... system."

The eco-modern and IPE frameworks overlap in that they attempt to describe aspects of current Western capitalist political economy. Whereas eco-modernism is broadly focused on institutional, policy-making and corporate organisational responses to the 'environmental challenge,' the IPE is more keenly focused on the world view underlying the task of production and its relation to the environment. In order to capture the unique insights into eco-efficiency offered by both frameworks, the term eco-industrial épistémé (EIE) has been coined. The 'eco-' prefix attached to 'industrial' connotes corporate or industrial interests claiming environmental concerns. Following O'Connor (1994) the term industrial is used to indicate that this view of production has emerged from the rapid industrialisation of Western societies in the last 200 years. He notes that "other societies have understood production and technology, or the action of transformation of material reality, in quite different ways" (O'Connor, 1994, p. 64). The term *épistémé* is used to specify a particular way of knowing and understanding reality.

Following from the discussion above, the main characteristics of the EIE that determine its view of eco-efficiency are:

1. commitment to the business-as-usual (BAU) path relying on unfettered markets and economic growth;
2. assumptions about the controllability of the production process and an optimistic view of the role of technology;
3. assumptions about the independence of the production and environmental processes.

3.4 Critique of the eco-industrial épistémé and its interpretations of eco-efficiency

There is no one unequivocal EIE interpretation of eco-efficiency. However, section 3.3 identified three common assumptions about the environment and economy that are incorporated in the EIE interpretation of eco-efficiency. The following pages critically examine these three assumptions, the rhetoric of the EIE and the influence this has on its interpretations of eco-efficiency.

Before proceeding, it is important to note that any attempt to 'categorise' a world view is difficult. Boundaries are sometimes vague and certain perspectives will be common with other 'ways of knowing' presented in later chapters. For the purposes of this critique, the list of prominent authors subscribing to the EIE include, but is not limited to Barber (1999), DeSimone et al. (2000), Gilkinson (1999), Hilson (1999), the OECD (1998) and Schmidheiny (1992).

3.4.1 Business as usual (BAU) assumptions of the eco-industrial épistémé

In the last 20 years industry has faced pressure to become involved in the environmental debate. It is not surprising that it has sought out a discourse on the environment that fits its aims and objectives. This discourse putatively claims that "eco-efficiency is more than business-as-usual" (DeSimone et al., 2000, p. 91). However, Hilson (1999, p. 195) states quite clearly that "eco-efficiency does not require companies to abandon their current practices and systems, but calls for them to restructure ...." The underlying message suggests the EIE is in fact promoting a model of eco-efficiency that is closely aligned to four characteristics of a BAU approach. These characteristics include:

- the paramountcy of economic growth;
- laissez-faire market solutions and economic rationality;
- working within status quo institutional arrangements;
- a disregard for social and cultural values.

First business-as-usual characteristic – paramountcy of economic growth

The EIE view of eco-efficiency is inflected by the assumption of continuing and unlimited economic growth[5]. To the EIE, economic growth is essential. In this vein, Schmidheiny (1992, p. xi) states "economic growth in all parts of the world is essential to improve the livelihoods of the poor... . While the basic goal of business must remain economic growth, as long as world population continues to grow rapidly... we are recommending a different course toward that goal." This different course is 'clean growth.'

In the EIE view, 'clean growth' is fundamental for sustainable development. As Schmidheiny (1992, p. 9) states "the requirement for clean, equitable economic growth remains the biggest single difficulty within the larger challenge of sustainable development." This view is not unique to Schmidheiny. As proponents of eco-efficiency, DeSimone et al. (2000, p. 3) state that sustainable development "means economic growth that does not deplete irreplaceable resources, does not destroy ecological systems, and helps reduce some of the world's gross social

[5] For the purpose of this thesis, economic growth is interpreted to simply mean rising levels of economic activity. Over time, the levels of production and consumption rise, due to population growth and/or higher per capita material living standards (Common, 1996, p. 15).

inequalities" (see also Elkington & Burke, 1987). This view is based on the assumption that the most efficient company does not pollute, and therefore, by extrapolation, that economic growth can be decoupled from environmental effects. The prominent economist Edward Shapiro (1982, p. 465) expressed this sentiment: "economic growth and improvement in environmental quality are not only not necessarily inconsistent but may be mutually reinforcing."

If the EIE deifies economic growth, it also ties eco-efficiency and growth together. Welford (1997, p. 30) claims "eco-efficiency must fit within the growth paradigm and actually, it is subtly designed to reinforce it." The reference in several EIE eco-efficiency interpretations of the delivery of "competitively-priced goods and services" (DeSimone et al., 2000) and "of the... supply [of] innovative products to the market" (Glauser & Muller, 1997, p. 201) indicates a preoccupation with (growing) markets.

The EIE reliance on 'clean' economic growth can be criticised from three perspectives: internal tension, the debate over whether the goal of unlimited economic growth is achievable and the lack of evidence on whether economic growth can be decoupled from environmental damage. These criticisms all have implications for the credibility and scope of an EIE interpretation of eco-efficiency.

Tensions in the 'pursuit of economic growth' argument

There are clear tensions in the EIE literature's discussion of economic growth. On the one hand, Schmidheiny (1992, p. 6) acknowledges that "development is more than growth, or quantitative change. It is primarily a change in quality." On the other hand, Schmidheiny (1992) and others pursue economic growth as their primary goal. For example, DeSimone et al. (2000, p. 6) are clear about the place of economic development; "pollution must be controlled in ways that comprehend *essential economic growth*" (emphasis added). Despite the rhetoric about the importance of environmental concerns, ecological action (including eco-efficiency) appears to become an add-on feature of BAU. The 'clean' theme is overshadowed by the economic growth goal.

The dominance of the economic growth imperative of the EIE leads some to question the EIE's motivations for pursuing eco-efficiency. For example, Ekins (1989) claims that reasons other than environmental altruism lead the EIE to pursue environmental goals. These 'covert agendas' include the need to pre-empt environmentalists and attempt to gain hegemony of the environmental agenda. An implication of such covert agendas is that there is the need to convince skeptics that industrialists are being proactive in the quest for sustainable development. Hence, there is a tendency to present eco-efficiency as 'new' and innovative. For example, DeSimone et al.'s (2000, p. 79) comment that "eco-efficiency is a new concept...." The notion of eco-efficiency is not new and nor is the associated concern over resource scarcity.

In fact, the focus on the efficient use of resources has been a preoccupation of industry since early industrialisation in the eighteenth century (Khalil, 1990). Furthermore, O'Connor (1994, p. 60) states "there is ... nothing new... in the modern preoccupation with natural resource scarcity." With respect to the term itself, the term "ecological efficiency" was used as early as 1925 by Lotka (1925) (see Chapter 4).

Other tensions in the EIE discussion of economic growth relate to the issues of whether unlimited economic growth is possible and whether economic growth can be decoupled from decreasing environmental quality.

The question of whether 'unlimited economic growth' is achievable

There is considerable debate over whether unlimited economic growth is actually achievable. Much of this debate suffers from what O'Riordan (1981, p. 100) calls "a serious deficiency of unequivocal ... evidence and from liberal dosages of ideological blindness." Common (1996, p. 15) identifies three indicative perspectives on this debate. One perspective is essentially 'Malthusian' in nature. It argues that economic growth cannot go on indefinitely because of physical environmental constraints (for example Daly, 1992b; Ehrlich & Ehrlich, 1974; Georgescu-Roegen, 1971; Meadows, Meadows, Randers, & Behrens, 1972; Ricker, 1997). In this view, the real problem of neoclassical economic growth is, as Daly (1992b, p. 19) points out that "absolute limits are absent from economists' paradigm"; economies in mathematical theory can grow forever (Harris, 1995). Daly's view is based on the observation that natural resources exist in finite amounts so that the continually increasing flows of natural resources and production implied by continuing economic growth cannot be sustained indefinitely.

Another view sees economic growth not being limited by finite resources, but by increasing levels of pollution impairing the supply of natural resources and/or the flow of amenity services from the environment (for example Carson, 1962; Trainer, 1990). In this view, indefinite prolonged economic growth may be impossible due to finite natural resource stocks. However, this is not the immediate problem. The problem is rather one of growth becoming progressively more polluting and damaging to the environment. In this view, damage to the environment that will constrain economic growth before any physical limits are encountered.

From an EIE perspective there need be no conflict between economic growth and the environment. This is not to say that this view ignores that environmental problems exist. The EIE argue that environmental problems are not the consequence of economic growth as such. Rather, they are either the consequence of inappropriate patterns of economic activity, due to an improperly functioning price mechanism, or a result of the country's lack of development and consequent location on the rising part of the environmental Kuznets curve (discussed below).

When considering the biophysical nature and interdependence of economic and ecological systems, one must necessarily call into question the feasibility of the indefinite economic-growth goal. From a biophysical perspective, unlimited economic growth is unattainable because the material and energy resources upon which economic activity depends are limited. Thus, "all types of economic growth are limited" (Ricker, 1997, p. 157). In this context, the prudent approach is to treat economic growth with caution and to orient it "more towards increasing production efficiency and less towards using more natural resources" (Ricker, 1997, p. 157).

In addition, from a systems perspective, the interdependence of economic and ecological systems makes clear the pervasive uncertainty involved in considering future prospects for economic and ecological systems. This uncertainty arises because the feedbacks between the economic activity and the state of natural systems are complex and not clearly understood (Common, 1996, p. 402; Hukkinen, 2001; Lélé, 1991). In light of this uncertainty, it is imprudent to pursue unlimited economic growth that relies on, as yet, undeveloped technological fixes and theoretically-perfect pricing mechanisms (Costanza, 2000).

Also, from the perspective of eco-efficiency, Peck and Gibson (2000) argue that an implication of pursuing economic goals and economic growth is that eco-efficiency initiatives tend to include only those ecologically desirable measures that offer an attractive short-term return on the investment for the firm involved – the proverbial 'low-hanging fruit.' These initiatives may bring immediate benefits, but they may also delay the more fundamental changes to products, processes and systems that are essential to address the environmental problems. Thus, it would be imprudent to yoke eco-efficiency with the dubious economic growth goal since this could potentially undermine the credibility and limit the scope and application of the EIE interpretation of eco-efficiency.

The myth of decoupling economic growth and decreasing environment quality

Even if unlimited economic growth were possible, it is debatable whether economic growth can be significantly decoupled from decreasing environmental quality. However, "at the cognitive level, eco-efficiency assumes that an individual's concern for the environment can be decoupled from his or her material dependency on ecosystem services" (Hukkinen, 2001, p. 311). To Schmidheiny (1992), for example, pursuing economic growth and improved environmental quality does not pose a problem, because there is evidence of a convergence between environmental and economic goals.

Proponents of this view have made their claim firmly in recent years after the finding of a so-called environmental Kuznets curve (EKC) (Arrow et al., 1995; Grossman & Krueger, 1995; Torras & Boyce, 1998). The EKC derives its name from the work of Kuznets (1955) who postulated an inverted-U curve relationship between income inequality and income levels. The EKC describes a similar inverted-U curve relationship between levels of income and certain measures of environmental quality (Figure 3-1). The curve traces increasing levels of pollution in lower-income countries and declining levels of pollution for higher per capita income levels (Rothman & de Bruyn, 1998).

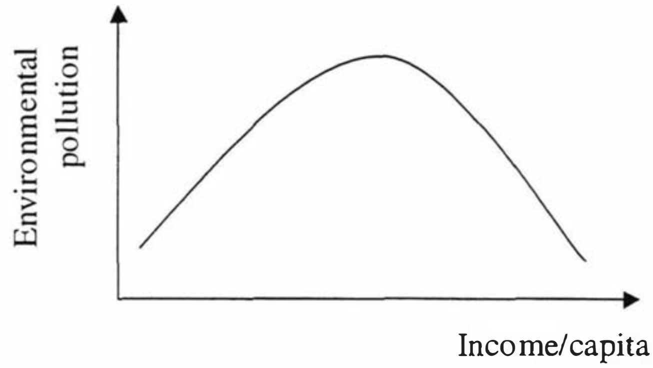

Figure 3-1: A depiction of the environmental Kuznets curve

The current status of the EKC is best described as a hypothesis addressing the relationship between economic growth and environmental impact that has not been adequately tested (Rothman & de Bruyn, 1998). The EKC hypothesis is open to criticism on several counts. First, the inverted-U curve has been found in only a few pollutants and those pollutants that are local in nature and for which abatement is relatively inexpensive (Arrow et al., 1995; Rothman, 1998; Rothman & de Bruyn, 1998).

Second, empirical work on the environmental Kuznets curve has focused on the relationship between income and emissions of pollutants, not resource stocks. The relationship is less likely to hold when feedback effects of resource stocks are significant (Arrow et al., 1995). Due to the resource depleting nature of many environmental problems, the EKC work does not fully account for environmental impacts.

Third, many of the empirical analyses of the EKC consider the impacts on a per capita or per unit of economic activity basis. These studies do not address the question of changes in the total impact on the environment (Rothman, 1998). Finally, it is important to understand the actual conclusions that can be drawn from these empirical findings (Grossman & Krueger, 1995). Some interpret the results as implying that only when incomes rise can effective environmental policies be implemented (World Bank, 1992). These criticisms lead Arrow et al. (1995) to provide a warning to those who are predisposed to superficially concluding that economic growth is, by nature, a benefit to the environment:

> *"While they [empirical findings] do indicate that economic growth may be associated with improvements in some environmental indicators, they imply neither that economic growth is sufficient to induce environmental*

> *improvement... nor that the environmental effects of growth may be ignored, nor, indeed, that the Earth's resource base is capable of supporting indefinite economic growth. In fact, if this base were to be irreversibly degraded, economic activity itself could be at risk"* (Arrow et al., 1995, p. 520, comments in brackets added).

The evidence in favour of the EKC hypothesis is frail (Rothman & de Bruyn, 1998). This evidence serves to reinforce the conclusion that in tying eco-efficiency to the goal of economic growth, the EIE interpretations are limited in their credibility, application and ken.

Second characteristic of a business-as-usual approach – laissez-faire market policies and economic rationality

A second characteristic of a BAU approach is the importance of laissez-faire market policies. These policies are at the heart of the EIE conception of sustainable development and their interpretation of eco-efficiency. This view is based on neo-classical economic theory (discussed in the next chapter) and is intimately tied to the issues surrounding economic growth. If economic growth is the 'end' for the EIE, then laissez-faire market policies are the means.

Neo-classical economic theory postulates that an ideal perfectly-competitive market will lead to the most efficient allocation of resources (Lipsey, 1983). Elkington and Burke (1987, p. 210, comments in brackets added) reflect this view when they state that "it is only the inevitable consequences of the efficient working of the marketplace that society should develop mechanisms for transferring them [the real costs to the community of pollution] back [to industry]. There are no free lunches in the environment." At an international scale, Schmidheiny (1992, p. 9) extends this view and suggests

> *"open, competitive markets create the most opportunities for the most people. It is often the nations where markets most closely approach the ideal of "free," open, and competitive that have the least poverty and the greatest opportunity to escape from the poverty."*

Thus, "open trade leads to the most efficient use of resources and to the development of economies" (Schmidheiny, 1992, p. xii). These views lead the EIE approach to argue for laissez-faire market policies in order to achieve targets like maximum eco-efficiency. For example, DeSimone et al. (2000, p. 17) argue for "maximising freedom of choice for business and consumers to determine the best ways to reduce pollution and environmental impacts."

Evidence of the laissez-faire tendency, and consequent economic rationality, exists within the WBCSD interpretation of eco-efficiency. Their interpretation states that eco-efficiency will be "reached by competitively priced goods and services..." (DeSimone et al., 2000, p. 47).

Tying eco-efficiency so closely to the 'logic' of free markets can be counter-productive and again undermine the potential usefulness of the EIE interpretation of eco-efficiency. Laissez-faire policies (or 'free trade') do not necessarily deliver better environmental outcomes, although this position is not unanimously held. Evidence suggests that the promise of improved environmental quality from free trade is not being delivered. Several reasons for this can be identified.

First, open competitive markets tend to lead to 'permanent international environmental quality standard lowering' which in turn leads to lower environmental quality per se (Chatterjee & Finger, 1994; Daly, 1999; Nader, 1993; Townsend & Ratnayake, 2000). Many environmental policies present impediments to the absolute free flow of goods and services between countries (Wallach, 1993). These environmental policies face continual pressure from free-trade proponents to reduce their stringency.

The free trade regime can subtly undermine a country's ability to establish, maintain and enforce strong environmental measures. Under this regime, products of New Zealand companies, for example, which are complying with environmental laws, may be at a competitive disadvantage to products imported from countries that have lower, or no, product or process standards. Often trade liberalisation significantly undercuts domestic environmental policies through trade diversion, and relocation of the key industries to "pollution havens"[6] (Daly & Goodland, 1994; Townsend & Ratnayake, 2000, p. 2).

Another reason that free trade does not deliver improved environmental outcomes is the presence of market failure in the form of environmental externalities. Ironically, even within the confines of conventional neoclassical economics, 'market failure' and environmental externalities in particular are a legitimate concern. Therefore, by their own admission, proponents of free trade realise that the market does not always deliver the optimal level of environmental quality.

The laissez-faire model also leads to a technocratic approach to sustainable development. A laissez-faire approach implies that market-logic techniques[7] are sufficient for achieving sustainable development. This approach is limited in its ability to deal with complex problems and is only able to provide very partial solutions (Welford, 1997).

These criticisms of laissez-faire policies undermine wider adoption of the eco-efficiency concept. While eco-efficiency is accepted in the business fraternity, it is viewed with suspicion by many environmentalists (for example Chatterjee & Finger, 1994) because of its links to

[6] For example, Nader (1993, p. 6) cites the results of free trade in North America. Many US companies have relocated to Mexico where the workforce is cheaper, and "environmental and workplace standards are either lax or largely unenforced."

[7] For example, cost benefit analysis, non-market valuation techniques and restricting government's role of market lubricant through the provision of information.

laissez-faire solutions. This essentially limits wider adoption of the potentially beneficial eco-efficiency concept.

Third and fourth characteristics of a business-as-usual approach – working within status quo institutional structures and a disregard for social/cultural values

A third characteristic of the BAU approach is the need to work within status quo institutional structures. Pursuit of BAU limits interpretations of eco-efficiency to those that fit within the current institutional structures of the market and are consistent with business-as-usual motivations of increasing market share and economic benefits. The EIE interpretation is tied to current market structures because its frame of reference is the "here and now" (Welford, 1997, p. 29). Schmidheiny (1992, p. 99) reflects this when he argues: "companies *now* have to work with governments to spread environmentally efficient production processes throughout the global business community..." (emphasis added). Such a conservative view overlooks the existence of more radical solutions to sustainable development, and more broad-reaching interpretations of eco-efficiency. In the words of Cramer (1997, p. 58) "they are looking, first and foremost, for possibilities to increase eco-efficiency without having to make extensive changes to existing products, processes and social structures."

The BAU focus also tends to ignore the importance of social and cultural values (Hukkinen, 2001, p. 312). By promoting an EIE approach to eco-efficiency planet-wide, economic rationality is being extended to everything that previously had social, cultural, and natural values attached. Chatterjee and Finger (1994, p. 136) are particularly critical of this. They state:

> *"the planet-wide extension of economic rationality under the cover of eco-efficiency will therefore further cultural destruction and erosion. It will promote the ideology of rational choice with the self-interested individual at its core, and destroy the remaining cultural restraints on individualism. It will destroy the local by imposing upon it a global market rationality."*

The world market manifests itself as purely objective, as an impersonal space within which producers and consumers interact freely. In reality, it is a powerful force promoting homogenisation in line with world market imperatives (Altvater, 1994). Tying eco-efficiency to market-based policies means that eco-efficiency becomes an unwitting promoter of this homogenising process.

> *"Eco-efficiency is a northern approach. It is an approach particularly geared to reducing pollution problems for which there are indeed technological solutions. But in the South environment and development problems are of a different nature.... the primary problems in the South are resources problems... access, control, participation and governance of natural resources at local and regional levels. And this is primarily an equity and not a technological issue"* (Chatterjee & Finger, 1994, p. 135).

Chatterjee and Finger (1994) suggest that by declaring the eco-efficiency approach to be universal and exporting it to the South, the EIE is guilty of ethnocentricism.

3.4.2 Controllability assumptions and a reliance on technology

The second main characteristic of the EIE is its assumptions about controllability. Controllability is a central theme in the EIE interpretation of eco-efficiency. For example, Hilson (1999, p. 192), an advocate of eco-efficiency states "a greater emphasis must be placed on controlling environmental problems." In the context of eco-efficiency, controllability refers to the production process, and its perceived dominance over the natural environment. Implications of the controllability assumption for eco-efficiency interpretations include a reliance on technological fixes and seeing eco-efficiency as an end, not a means.

The nature of control

The EIE conception of eco-efficiency relies on the assumption that the production process and the 'natural environment' are in fact domains that can be controlled. For example, the eco-efficiency literature advocates a range of management and control approaches from 'environmental management systems' to improving technology so as to "progressively reduce environmental impacts" (DeSimone et al., 2000, p. 47). For the EIE, the ability to improve eco-efficiency relies on the assumption of dominance (or control) by production managers over each process of commodity production (Funtowicz & O'Connor, 1999). In the words of O'Connor (1994, p. 63) "the inputs are transformed according to determined rules or know-how, so that the process can be conceived as leading to determinate output results. Perfect functionality is the norm. Unpredictability is attributed to error or 'accident' ." This approach perpetuates the image of 'nature-as-a-controllable machine.'

While the EIE assume control of a system in order to, inter alia, increase the eco-efficiency of production, the épistémé goes beyond simple manipulation of system levers and knobs. The EIE assume control to such an extent that it believes it can transcend the physical laws of thermodynamics. For example, the EIE ignores the second law of thermodynamics and its implications for time and irreversibility. For the EIE "time connotes continuity and predictability" (O'Connor, 1994, p. 66). More specifically, it implies a continual, unlimited and irreversible improvement in the eco-efficiency of capital[8]. Time, therefore, implies pretensions

[8] The author has found no evidence in the literature that the EIE acknowledge the existence of a limit to eco-efficiency improvements. Indeed, Glauser and Muller (1997, p. 201) state that "a totally eco-efficient process would not generate wastes or emissions."

to determine the future by perpetuating current trajectories. The implication of this view is that eco-efficiency can be expanded infinitely, ignoring the second law of thermodynamics.

The EIE view of controllability is flawed. As was pointed out in Chapter 2, complex interactions, and feedback between economic activities and the environment are ubiquitous. For example, production activity leading to material resource exhaustion and pollution which then impact on the production activity itself is a well-known phenomenon. Seemingly small changes in the surrounding environment can significantly change the modes of activity of the system. In other words, there will always be a degree of indeterminacy associated with the behaviour of elements of any economy-environment system. This makes pretences to control the natural environment unrealistic and leads Peet (1992, p. 14) to include that "in no sense should the natural environment be seen as some form of 'grand machine'."

The neglect in mainstream economics of this interdependency and indeterminacy was bought to our attention by theorists such as Boulding (1966) and Georgescu-Roegen (1971). However, this understanding has not led to the EIE questioning its underlying controllability assumptions. On the contrary, the EIE extend the same assumptions it makes about the production process to the environment. Perrings (1987, p. 4-5) calls this the "strong environmental assumption" which "supposes that the economy completely dominates its environment." According to Perrings (1987, p. 4-5) this is "tantamount to an assumption that the environment does not exist."

Capital does not and cannot actually control all aspects of the production system. Changes and feedback effects on and within the production system must remain indeterminate. The attempts to reinforce the EIE interpretation of eco-efficiency through its assumptions of control simply avoids confronting the essential problem of the environmental crisis; "namely, the openness of any system of production to unanticipated and uncontrolled perturbations arising from the environment that conditions it" (O'Connor, 1994, p. 65).

Basing an eco-efficiency interpretation on flawed control assumptions invariably influences both the interpretation and how eco-efficiency is implemented. In particular, they lead to misplaced attention on inappropriate policy instruments. For example, the EIE reliance on laissez-faire policies is questionable in the face of complex economic systems (Arthur, 1989)[9].

Reliance on technology

[9] Arthur (1989) demonstrated that in the presence of increasing returns to adoption, laissez-faire policies give no guarantee that superior technologies will be the ones that are adopted.

The eco-efficiency interpretation of the EIE is firmly rooted in a reliance on technology to solve environmental problems and to achieve sustainable development (Choucri, 1995; Davison, 2001; Folke, 1995; Gilkinson, 1999). As Tadahiro Sekimoto[10] (cited in DeSimone et al., 2000, p. xii) states

> *"Thus, we place our faith in human knowledge, and, in particular, the application of technology. We are committed to achieving sustainable development by providing environmentally conscious products, that is, pursuing eco-efficiency and contributing to society by fully utilizing our technological ability."*

Schmidheiny (1992, p. 10) does point out that "eco-efficiency is not achieved by technological change alone." This sort of rhetoric is common throughout the épistémé. It demonstrates a broader perspective than some of the critics give the EIE credit for.

Nevertheless, it can be argued that eco-efficiency actually encourages technical and scientific solutions to sustainable development (Davison, 2001). Technology in the EIE world view is seen as a covert vehicle to control the environmental agenda. Within the EIE framework "the tool of eco-efficiency sees no alternative to business controlling the greening of development through the vehicle of technology" (Welford, 1997, p. 28). Behind the rhetoric, reliance on technology goes unquestioned and technology plays a central role in the eco-efficiency world.

In contrast to the EIE's Panglossian view of technology, many authors are very critical of the 'techno-fix' school of thought (Costanza, 1989; Costanza, 2000; Daly, 1996; Davison, 2001; O'Connor, 1994; Peet, 1992; Welford, 1997). For example, Welford (1997, p. 30) suggests it is essentially a defensive school where science and technology are seen "as supreme in the defence of traditional notions of capitalism." However, to describe an innately beneficent (as the EIE) or innately malign (as in Welford) potentiality to the forces of technology abandons any claim of being critical. Nothing can be presumed a priori about the role of technology. Technology has the potential to either alleviate or worsen the ecological crisis.

The debate on the role of technology alleviating resource scarcity has continued for several decades (Costanza, 2000)[11] and there is nothing new in the technical-fix approach. O'Connor (1994, p. 60) states "the recognition of a "resource depletion" problem has frequently been the occasion for simple restoration of the techno economic "fix" of better control and improved efficiency of natural resource use."

An optimistic view of technology is based on two related assumptions. The first assumption is that natural and manufactured (i.e. technology) capital are substitutes. Several authors have

[10] Chairman of the board of NEC Corporation.

questioned the appropriateness of this assumption (see for example Pearce & Turner, 1990, cited in Chapter 2). If manufactured capital were a perfect substitute for natural capital, then natural capital could substitute for manufactured capital in which case, Daly (1996, p. 76) suggests "there would have been no reason to accumulate man-made capital. But historically we did accumulate manufactured capital – precisely because it is complementary to natural capital." In other words, one cannot build the same house by substituting more tools for less wood. If technology is not a substitute for natural capital, then manufactured capital is limited in its ability to 'solve,' or alleviate, natural capital scarcity.

The second assumption is that resource constraints can be circumvented by new ideas (better technology). Norgaard (1988) notes that widespread belief in continued technical progress is increasingly in doubt. It is not clear whether technological progress will continue forever, or even for a very long time (Huesemann, 2001; Pearce & Turner, 1990). Furthermore, new technology is not necessarily less polluting than older machines, nor is it necessarily able to totally alleviate environmental problems. This is because the second law of thermodynamics dictates that new technologies – while possibly successful in solving specific environmental problems – can cause unavoidable negative environmental impacts elsewhere or in the future (as demonstrated by Huesemann, 2001). It is intrinsically impossible to design industrial processes that have no environmental impacts (Huesemann, 2001; Peet, 1992).

The debate surrounding technology remains largely unresolved. The bottom line is that there is significant uncertainty about both the proximity of resource constraints and the ability of humanity to continue to come up with 'good ideas.' In this context, an optimistic view of technology's ability to solve the world's environmental problems is theoretically suspect and imprudent. Given this uncertainty, Costanza (1989, p. 4) argues for "prudent pessimism" with respect to technology. But perhaps pessimism is inappropriately negative. What would be more appropriate is an approach based on 'prudent *scepticism*' when it comes to considering the future role of technology.

A means, not an end

Assumptions of control over a system imply the existence of a goal or telos. Too often eco-efficiency is seen as the goal, rather than a means to achieve an 'intermediate' end[12]. The OECD (1998, p. 16) and WBCSD (2000, p. 4) do acknowledge that eco-efficiency is a means,

[11] Costanza (2000) traces the beginning of the contemporary debate to Barnett and Morse (1963) and *The Limits to Growth* by Meadows et al. (1972).
[12] In the sense of Daly (1992b). Daly (1992b, p. 19) distinguishes between ultimate ends (the realm of ethics and philosophy) and intermediate ends (health, comfort, education etc).

not an end. But the rhetoric that surrounds most EIE discussions seems to place eco-efficiency on a pedestal higher than a means would justify[13]. "The strive for eco-efficiency is too often seen as an end in itself" (Welford, 1997, p. 38).

The problem with elevating eco-efficiency to goal status is that environmental action based on models of eco-efficiency may take us a little way along the road towards sustainable development but then may actually block any further progress.

> *"Without a fundamental rethinking of the structure and the reward system of commerce, narrowly focused eco-efficiency could be a disaster for the environment by overwhelming resource savings with even larger growth in the production of the wrong products, produced by the wrong processes...and delivered using the wrong business models"* (Hawken, Lovins, & Lovins, 1999, p. x).

Chatterjee and Finger (1994, p. 135) support the view that the EIE sees technology and efficiency as an end in itself. "Elevating efficiency and technological solutions to become the goal itself, as Schmidheiny does, will fail, because it promotes a technocratic management approach to a problem... which is not fundamentally technical in nature." It will also fail because eco-efficiency is not a sufficient condition for sustainable development (Peck & Gibson, 2000). Eco-efficiency can at best, only slowdown the acceleration of global environmental degradation, but not reverse it. The point here is that we ignore eco-efficiency at our peril. However, eco-efficiency, properly understood is a means, not an end. It should be seen as a vital tool for achieving the overall goal of sustainable development, not an end in itself.

3.4.3 Independence and isolated-system assumptions of the EIE

The EIE interpretation of eco-efficiency relies on the assumption that economic production processes are independent (Funtowicz & O'Connor, 1999). At first glance, this may appear to be an unusual comment. Surely the WBCSD interpretation of eco-efficiency, for example, hints at the links between economic activity and the environment? The answer is yes, to an extent. Behind the rhetoric, it is clear that the view of interdependence is limited. The EIE literature focuses on eco-efficiency of single products (as in Sony's Resource Productivity Index or Dow's Eco-Compass (DeSimone et al., 2000, p. 80)) or individual companies (for example, Novo Nordisk's Eco-Productivity Indices). There is little mention of, for example, overall economy or system wide eco-efficiency.

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[13] Interestingly, this phenomenon on is not restricted to eco-efficiency alone. Stein (2001, p. 3) suggests that efficiency in general "has become an end in itself."

Economic production processes exhibit two levels of interdependencies. They are linked with one another throughout the production cycle. Outputs from one process are required as inputs to another product and so on. At a second level, economic production processes are intimately linked with their environment; relying on it for a source of materials and resources and a sink for waste. The implication of the EIE's limited view of interdependency is that it leads to a conception of the economy as an isolated system consisting of separate processes and companies. The effect of the EIE's view is to systematically

> *"negate, or to 'bracket out' ... the mutual conditioning and interdependency of production processes. Taken together, these assumptions allow any commodity production process considered singly, and hence the economic system taken as a whole, to be represented as a closed information system... one that in reality or by definition, is not in an essential relation of feedback to environment."* (O'Connor, 1994, p. 65)

Quite apart from the fact that isolated systems do not exist (see Chapter 2), such a view leads one to ignore aspects of the wider environment-economy system that are important to eco-efficiency. For example, the EIE's focus on the economic system tends to lead it to diminish the importance of the physical limits of ecological systems. This myopic view limits the EIE's ability to address eco-efficiency in an 'holistic' sense.

3.5 Conclusions

Eco-efficiency has achieved significant popularity in the business world. Yet its definition is not clear. This lack of clarity has led eco-efficiency to become vulnerable to the 'hegemony' of the EIE agenda. The EIE literature has attempted to define eco-efficiency in a way that serves the épistémé's own interests. In doing so, eco-efficiency is interpreted within a world view that:

- is committed to a business-as-usual path;
- assumes controllability of production processes;
- sees technology as a fix for environmental problems;
- assumes independence of economic and environmental production processes.

Interpretations of eco-efficiency based on these assumptions are limited. In particular, such eco-efficiency interpretations can undermine the credibility of the eco-efficiency concept, limit the ken of eco-efficiency (by ignoring the complex social and cultural milieu), lead to inappropriate policy prescriptions, and limit the ability of resource users to address eco-efficiency in an 'holistic' sense.

The critique offered above is not a call to abandon the eco-efficiency concept. Rather, it lays down the challenge to take a broader perspective of eco-efficiency. Other interpretations of eco-efficiency are possible. The next chapter attempts to provide a range of perspectives of eco-efficiency that are well grounded in theory.

4 Disciplinary approaches to eco-efficiency

Once a royal retinue was stopping at a village to spend their afternoon. The village folks came there and amongst them there were six blind men. All had heard a lot about elephants but none had ever been able to see one. They requested the caretaker to allow them to touch the elephant so that they may be able to make out what the elephant could be like. They were permitted to do so. The first who came across the ears stated that the elephant was like a fan. The other caught hold of the trunk and stated that the elephant was like a big windpipe. The third touched the tusks and said it was like a big tusk-weeding tool. The fourth touched the legs and said it was like a big pillar. The fifth felt the stomach and said it looked like a water bag. The sixth had a tail in his hand and said it appeared to him like a broom. Each thought that his version was right and others were wrong. The caretaker said that none of them had ever seen the elephant fully. Each one had merely seen one limb and from that experience each one had given his surmises about the whole elephant. This was, therefore, the cause of their quarrel. He explained the whole position, and all the blind men became silent and departed.

The parable of the blind men and the elephant

The term 'efficiency' has come to represent a multiplicity of meanings. Like the blind men and the elephant, any single interpretation of efficiency is contextually bounded to a particular set of disciplinary and epistemological assumptions. The purpose of this chapter is to illuminate the insights into the eco-efficiency concept that emerge from the core disciplines of ecological economics[1]; thermodynamics, economics and ecology[2].

The chapter begins by tracing the origins of the 'efficiency' concept. It then describes the different meanings efficiency has taken on in each discipline, and how these meanings might inflect an understanding of the somewhat narrower eco-efficiency concept. The chapter also identifies the epistemological assumptions and limitations that would underpin each disciplinary perspective of the eco-efficiency concept. These two aspects (efficiency meaning and their underlying assumptions) describe the lens through which each discipline views eco-efficiency. In doing so, they help to highlight the disciplinary insights into eco-efficiency.

The intent is to frame the discussion of eco-efficiency in a theoretical analysis of its meaning. This theoretical foundation has largely been ignored in the modern-day eco-efficiency literature, which has tended to have a practical and empirical focus.

[1] See Chapter 2 for a discussion of the importance of thermodynamics, economics and ecology in ecological economic theory.

[2] It is important to recall Georgescu-Roegen's (1971, p. 43) pertinent reminder that "the boundaries of every science in fact are moving penumbras." Disciplinary boundaries are sometimes vague and certain perspectives will inevitably overlap conceptually. This overlap is reflected, for example, by the same references appearing within different disciplines. The discrete disciplinary distinctions of thermodynamics, economics and ecology used in this chapter, are for convenience and demonstration purposes only.

4.1 Origins of the efficiency concept

Although efficiency is a concept associated with the project of modernity, its use in public discourse has a long history. The ancient Greeks spoke of efficiency as a means (not an end) of politics and society. Long before the industrial revolution, Platonic thinking associated the pursuit of efficiency with virtue (Stein, 2001, p. 17).

The English word efficiency is derived from the Latin word *efficientia*, the present participle of the verb *efficere*. *Efficere* means to bring about, accomplish, execute or produce (Barnhart, 1988; Klein, 2000; Morris & Morris, 1988; Shipley, 1984; Simpson & Weiner, 1989; Skeat, 1961). The infinitive is itself derived from a combination of *ex-* (after) with the Latin verb *facere,* to do or make (Barnhart, 1988; Klein, 2000).

The interpretation of efficiency has evolved in two directions. Efficiency was used in a philosophical and theological context to refer to the action of an 'operative agent' – God. "The manner of this devine efficiencie being farre [sic] above us" (Hooker, 1593 cited in Simpson & Weiner, 1989, p. 83). This use of the term is now generally obsolete.

The other direction of efficiency's evolution also derives from theology, and is the basis for our contemporary use of the term. Efficiency came to be used to mean "fitness or power to accomplish, or success in accomplishing, the purpose intended" (Simpson & Weiner, 1989, p. 84). The first recorded use of efficiency in this way is found in theological literature dating back to 1633: "the very frame of it... had an efficiency... to cary (sic) up the heart to God" (Ames, 1633 cited in Simpson & Weiner, 1989, p. 84). Efficiency's theological legacy suggests it is no surprise that the term is spoken of in 'reverence' in modern parlance. However, what is of interest is the strength of association efficiency has with a 'logical positivist' frame.

The 'fitness or power to accomplish' interpretation of efficiency was taken from theological themes and, in the context of the rationalist spirit of the Enlightenment and the commercial activity of 18th century Europe, applied more widely to the transient world. In doing so, the centre of gravity of efficiency interpretations shifted from a theological, spiritual basis to a Western-scientific, 'logical-positivist' realm. Evidence of this burgeoned in the literature of the 1800s.

Two threads are evident within this new approach to efficiency. First, efficiency is applied to the 'productive machine.' In 1827 Gilbert used the word efficiency in relation to physics: the work done by a force in operating a machine or engine (Simpson & Weiner, 1989). He stated "therefore a machine is efficient in producing duty, or effect, in proportion to the force applied, multiplied into the space through which it acts, I propose to denominate this function ($f \times s$) *efficiency*." In 1858, Buckle (cited in Simpson & Weiner, 1989, p. 84) reports that "the Navy was... more than doubled in efficiency." Similarly, 'efficiency' was used in relation to the 'organic machine' in biological literature as early as 1925 (Lotka, 1925). Borrowing from thermodynamics, he defines efficiency as the fraction of energy (Q) converted to work (W).

A second thread in contemporary efficiency is to do with the economics of resources and welfare. Efficiency began to enter the economic lexicon in the 1800s. Fawcett (cited in Simpson & Weiner, 1989) stated in 1863 that "nothing more powerfully promotes the efficiency of labour than an abundance of fertile land." The most widely used interpretation of economic efficiency is related to the work of Vilfredo Pareto. His work led to what is now referred to as allocative efficiency or simply Pareto efficiency[3].

Since the 1800s and the wider application of the efficiency term, the number of efficiency concepts have burgeoned. As discussed below, efficiency concepts now include technical efficiency, production efficiency, profit efficiency, x-efficiency, allocative efficiency, scale efficiency, thermal and finite-time efficiency, managerial efficiency, dynamic efficiency, ecological efficiency and many more.

The term efficiency is now tied to the rationality of a logical-positivist world view. In fact rationality and efficiency are often used synonymously as Daly (1992a, p. 192) shows: "this argument is raised against economists who [argue that] ... intertemporal allocation via discounting the future is the *rational (efficient)* way to deal with provision for the future" (emphasis added). However, efficiency has still retained a notional link to spiritual zeal. Efficiency, along with concepts such as 'productivity', 'usefulness' and 'thrift' in Western cultures, embodies the Christian dogma of transcendence over nature (White, 1967) (see Chapter 3).

In sum, the modern interpretation of efficiency can be traced to both spiritual and scientific roots. It is a powerful concept that embodies the notion of "fitness or power to accomplish, or success in accomplishing, the purpose intended." However, Stein (2001) is at pains to remind us that the modern efficiency concept is context-dependent. Efficiency embodies two aspects: 'fitness or success' and 'the purpose intended.' Both of these parts depend on the context. What is success for one person may not be success for another. Similarly, it is important to ask 'what is the purpose intended'? Is the purpose to improve the productivity of a machine, or enhance the welfare of our community? The yardstick of efficiency "is relative and rooted in context" (Stein, p. 12).

[3] Although it is interesting that Pareto himself does not appear to have used the word 'efficiency' for his work on maximum ophelemity or utility (Kaldor, 1939; Pareto, 1927).

A relatively new derivation of the 'efficiency' concept is the idea of 'eco-efficiency', which is the focus of this thesis. The 'eco-' prefix is commonly used in words borrowed from Greek such as *economy* which originally referred to household management, and from 1651, the first recorded extension of the concept to the management of resources (Barnhart, 1988; Skeat, 1961). Another example is *ecology.* This was first coined by Haekel in 1866 and represents an early example of the extension of the concept of 'house' to the 'environment-within-which-we-live' (Golley, 1993)[4]. In modern coinage the 'eco-' prefix has continued Haekel's tradition of broadening the meaning from the notion of 'house' to the "environment and relation to it"[5] (Barnhart, 1988, p. 313).

Adding the 'eco-' prefix to efficiency concepts makes eco-efficiency distinct from the other efficiency concepts. The 'eco-' prefix focuses efficiency on the 'environment and relation to it.' Specifically, the prefix adds a lens to the 'success in accomplishing' component of the efficiency concept. Through this lens, 'success' is seen to extend beyond simply whether the goal is achieved or not, to encompass a concern for the impact on 'the environment and relation to it' associated with the activity of achieving the goal. Often, in modern use of the term, this 'efficiency-success' is measured using a ratio of useful outputs to inputs (see section 4.2.2). The concern for environmental impact inherent in 'eco-'efficiency suggests a focus on those activities with environmental repercussions. Since economic activities impose significant pressures on the environment, it is reasonable to consider that economy-environment interactions[6] form an important focus of the eco-efficiency concept.

Given the environment-economy interaction focus, the 'eco-' prefix also appears to align efficiency's 'purpose intended' towards sustainable development. This focus on sustainable development is implicit in many interpretations of eco-efficiency (such as the WBCSD interpretation). Following from these observations about the effect of the 'eco-' prefix on efficiency, a 'core meaning'[7] of the term eco-efficiency can be identified. Eco-efficiency could be generically described as "a measure of the success (accounting for wider environmental impacts) of economic activities aimed at promoting sustainable development that is quantified as the ratio of useful outputs to ecological inputs".

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[4] See section 3.2 for further discussions on the use of the eco- prefix.

[5] Interestingly, the usage of 'eco-' for 'environment' comes from misuse of ecology as a synonym for environment by the American media. According to Golley (1993), the shorter word 'ecology' fitted the column width of a printed page better than the longer 'environment.'

[6] Here the term "interactions" is intended to be very wide. It extends beyond the eco-industrial épistémé's focus on business or market economic activity (see for example DeSimone, Popoff, & World Business Council for Sustainable Development, 2000, and ; Hilson, 1999) to encapsulate all human activity concerned with production and consumption of economic goods and services.

[7] This core meaning is similar to Grice's (1968) term 'timeless meaning' discussed in Chapter 2.

4.2 Thermodynamic[8] approaches to eco-efficiency

In order to understand how this discipline informs us about eco-efficiency, the following discussion will draw on areas from the thermodynamicist's gallery relating to the concepts of efficiency and the physical environment. This is done to understand how this discipline views the interaction of the economy and environment which in turn inflects its understanding of eco-efficiency.

4.2.1 The role of efficiency in thermodynamics

Efficiency has been a core focus of classical thermodynamics since the beginning of the science. This is primarily because of classical thermodynamics' conception during the industrial revolution and its preoccupation with increasing the efficiency of industrial-revolution machines (Khalil, 1990; Kondepudi & Prigogine, 1998; O'Connor, 1994). The concept of thermodynamic efficiency was first developed in connection with steam engines: an engine was more efficient if it could, for example, pump more water while using the same quantity of coal (Ayres & Nair, 1984).

Significant contributors to the development of thermodynamic efficiency concepts include Sadi Carnot and Rudolf Clausius (among others). Sadi Carnot's (1796-1832) main interest was to raise the efficiency of heat engines. He developed the Carnot cycle – an abstract analysis of steam engines and used the Carnot cycle to establish the maximum efficiency of a cyclic process in frictionless (or 'reversible'[9]) conditions (Battino & Wood, 1968). Carnot's conclusions, now known as Carnot's Theorem, showed that any heat engine absorbing heat from a higher temperature reservoir to produce work must transfer some heat to a sink reservoir of lower temperature (Wu, 1988). The theorem also showed that (Fong, 1963, p. 60-61)[10]:

- all 'reversible' engines operating between two fixed temperatures have the same efficiency;
- efficiency of a heat engine can not exceed one;
- reversible heat engines have maximum efficiency.

---

[8] This section focuses on efficiency concepts in classical (or macroscopic) thermodynamics rather than statistical thermodynamics. This is because most of the work on efficiency concepts has emerged from classical thermodynamics. For a detailed discussion of thermodynamics refer to Spiegler (1983) or Kondepudi and Prigogine (1998).

[9] A process is called reversible if, after its conclusion, the system may be restored to its initial state along a path differing in no way from that of the direct process, and the surroundings restored to their initial condition (Beattie & Oppenheim, 1979, p. 9). Reversible processes do not involve friction, heat transfer across finite temperature boundaries, mixing, inelastic deformation or free expansion (Ruth, 1993, p. 53).

[10] These points are detailed below.

Rudolf Clausius (1822-1888) proposed the axioms now called the first and second laws of thermodynamics. The first law states that energy[11] is conserved in a closed system (Ruth, 1993); energy can be neither created nor destroyed, only converted from one form to another.

The second law is stated in various ways. Equivalent statements of the second law are:

1. in any transformation of energy, some of it is always degraded;
2. any process which consists solely of the transfer of heat from one temperature to a higher one is impossible;
3. it is not possible to convert a given quantity of heat (thermal energy) into an equal amount of useful work (mechanical energy);
4. the availability of a quantity of energy can be used only once;
5. all physical processes proceed in such a way that the availability of the energy decreases.

The second law is important because it helps us to understand why, if energy cannot be destroyed, we cannot reuse the same amount of energy after a transformation. According to the second law, although the total energy remains constant, "the potential (or quality) of each subsequent form to do work is not the same as at the start of the process" (Peet, 1992, p. 35).

The second law is also referred to as the entropy law because it introduces the entropy concept. Technically, the term entropy[12] is an extensive state variable (i.e. it is proportional to the size of the system) that is definable for any substance or system (Ayres, 1998). The second law of thermodynamics states that "at constant energy and volume, every system evolves to a state of maximum entropy" (Kondepudi & Prigogine, 1998, p. 124). Or, in terms of processes, the entropy of an isolated system will increase and in the case of a reversible process, remain constant (Ruth, 1993, p. 53).

The work of the early thermodynamicists has led to an empirically precise definition of efficiency that is based on measures of physical, often observable, systems. Although efficiency concepts within thermodynamics are all based on the same formulation (ratio of useful outputs to inputs), the concept has several dimensions. Concepts of efficiency can be divided into several groups: thermal efficiency, efficiency based on ideal limits, finite-time efficiency and energy quality adjusted efficiency measures.

[11] Defined as the 'ability to do work' (see Chapter 2). That is, "energy has the ability to cause changes in the physical or chemical nature, structure or location of matter or things" (Peet, 1992, p. 27).
[12] Entropy can be shown to be a measure of the 'disorder' of a system. But care needs to be taken with the term 'disorder.' From a thermodynamic perspective, Peet (1992, p. 43) states that order is bound up with the probability. "Disorder is represented by a situation in which the outward appearance of an object is consistent with a large number of different possible internal arrangements".

4.2.2 Thermodynamic interpretations of efficiency

The following discusses the four groups of efficiency concepts identified above. The aim of the discussion is to identify the key characteristics of these concepts that could inform thermodynamic perspectives of eco-efficiency.

Thermal efficiency

The first and second laws of thermodynamics provide a basis for developing thermodynamic concepts of efficiency. First, consider a generic steady-flow process, for which the energy equation resulting from the first law is

$$W=Q-\Delta H-\Delta E_P-\Delta E_K$$ **Equation 4-1**

Where:

W = work

Q = heat (for example, in the case of a steam engine)

Δ = change in

H = enthalpy (for example, in the case of coal-fired power plant)

E_P = potential energy (for example, in the case of a hydro-power turbine)

E_K = kinetic energy (for example, in the case of a wind turbine)

Figure 4-1 is a schematic representation of this generic process, which exists in surroundings that constitute a heat reservoir at the constant temperature T_0. This process may be simple or complex.

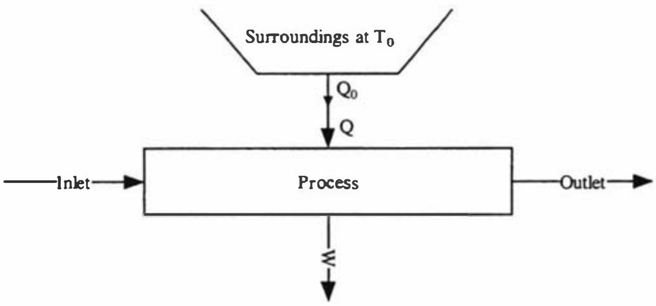

Figure 4-1: A schematic representation of a generic steady flow process

Real world processes are usually complex, and consist of all of these energy flows (Q, ΔH, ΔE_P, ΔE_K). However, in order to define the concept of thermal efficiency, it is useful to employ an idealised reversible heat engine which is a specialised form of Figure 4-1 where the only flow is Q.

Consider the heat engine[13] in Figure 4-2 below, and assume, for the moment, that the transfer of energy to and from the environment is infinitely slow and is reversible.

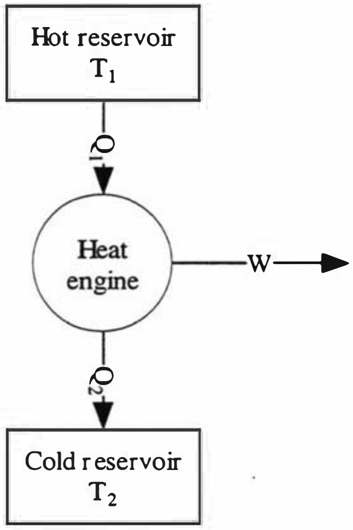

Figure 4-2: A stylised heat engine

Where:

Q_1 is the amount of energy in the form of heat[14] that enters the heat engine from its environment;

Q_2 is the amount of energy in the form of heat that flows from the heat engine to its environment;

W is the amount of physical work[15] done on the environment by the heat engine;

T_1 is the absolute temperature of the hot reservoir;

T_2 is the absolute temperature of the cold reservoir.

The purpose of a heat engine is to produce maximum work transfer from a given positive heat transfer. The measure of success for the engine in Figure 4-2 is called the thermal efficiency[16] (η) of the engine and is defined by the ratio:

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[13] Defined as a continuously operating system producing work transfer (Bacon, 1972, p. 93). A steam plant is a practical example of a heat engine.
[14] Heat is a form of energy. Energy transferred by the heat method occurs due to a difference in temperature (Bacon, 1972, p. 11).
[15] "The act of producing a change in configuration in a system in opposition to a force which resists that change" (Spiegler, 1983, p. 1).
[16] Note that the thermal efficiency ratio only measures the 'useful' output. If the 'waste' output of the process is added to the 'useful' output, the total output then equals the total inputs, i.e. energy conservation. For this reason, thermal efficiency is sometimes referred to as 'first-law efficiency' (see for example Patterson, 1996). Strictly speaking this is misleading because all the first law states is that energy is conserved. The first law does not include any reference to efficiency unlike the second law (see the third statement of the second law on page 65).

$\eta = W/Q_1$ **Equation 4-2**

Equation 4-2 essentially measures the ratio of useful output (in the case of a heat engine, work (W)) to inputs (Q_1). Thus, a generic efficiency ratio can be defined stemming from Equation 4-2:

$$\eta = \frac{\text{useful output}}{\text{input}}$$ **Equation 4-3**

Equation 4-3 serves as a foundation for all efficiency concepts (including eco-efficiency) in all sciences as well as in common usage.

Efficiency based on ideal limits

The second law of thermodynamics is useful in that it establishes limits on the efficiency of any process. This is relatively straightforward to demonstrate in the context of heat engines (Figure 4-2). That is, it would be reasonable to expect that the thermal efficiency of any real heat engine that could be devised to work between two given reservoirs would not exceed the efficiency of a reversible engine working between those reservoirs. To illustrate this, consider two heat engines, one reversible and one irreversible, operating in reverse directions between the same temperatures T_1 and T_2 (see Figure 4-3) (Smith & Van Ness, 1978, p. 143).

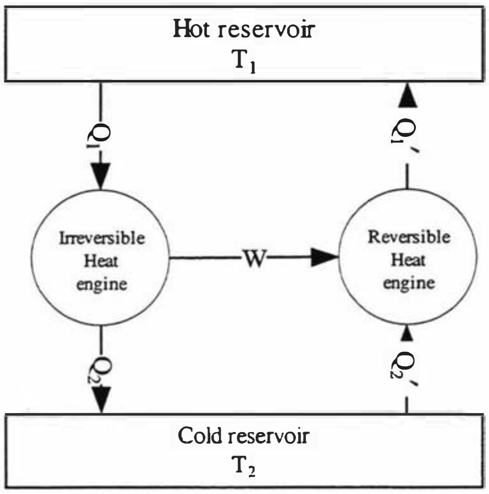

Figure 4-3: The efficiency of reversible and irreversible heat engines

The irreversible engine will operate in the conventional manner. The reversible heat engine runs in the opposite direction and is directly connected to the irreversible one using the work (W) produced by the irreversible engine to absorb the heat Q_2' at the low temperature T_2 and discards the heat Q_1' at T_1. If it were possible for the irreversible engine to have the greater efficiency, $\eta_{irr} = W/Q_1$ would be greater than $\eta_{rev} = W/Q_1'$ for the reversible engine. Since W is the same in both cases, the Q_1' for the reversible engine would be greater than Q_1 for the irreversible, and Q_2' must be greater than Q_2 by the same magnitude. Therefore, the net result is that an amount of heat $Q_2' - Q_2$ has been transferred from the low temperature T_2 to the high temperature T_1. This is impossible according to the second statement of the second law (stated above). No violation of the second law is encountered if $\eta_{irr} < \eta_{rev}$. Therefore, following from the second law, these findings for a heat engine can be generalised for all processes:

$$\eta_{actual} < \eta_{ideal} \qquad \textbf{Equation 4-4}$$

where η_{actual} is the thermal efficiency of a real-world process that is irreversible and occurs in finite time, with finite temperature differences and energy loss through the induction, convection, and radiation to the surroundings and friction loss and η_{ideal} is the efficiency of the equivalent ideal reversible process. In the case of heat engines, for example, η_{ideal} is defined by the Carnot efficiency $\eta_{Carnot} = (T_1-T_2)/T_1 = 1-T_2/T_1$[17].

Using the concepts of η_{actual} and η_{ideal} a measure of efficiency based on ideal limits can be defined as the "minimum theoretical available energy input divided by actual energy input" (Ayres & Ayres, 1999, p. 46). Mathematically, this ideal efficiency can be defined by the following ratio (Patterson, 1996):

$$\eta_{ideal\ limit} = \eta_{actual}/\eta_{ideal} \qquad \textbf{Equation 4-5}$$

Where:

$\eta_{ideal\ limit}$ = thermal efficiency of a process in performing a specified task based on ideal limits;

η_{actual} = actual thermal efficiency of a process in performing a specific task;

η_{ideal} = ideal thermal efficiency to perform a task reversibly by a perfect device.

A key characteristic of efficiencies based on ideal limits is their usefulness in identifying the theoretical energy savings that can be achieved by engineering and technical improvements compared to the most efficient process possible (Patterson, 1996). Also, a benefit of efficiency measures based on ideal limits is that they can identify proximity to those limits. This is especially helpful in both an engineering and policy sense when crucial, timely decisions are essential.

Finite-time efficiency

Finite-time thermodynamics[18] provides another perspective on thermodynamic efficiency. Finite-time thermodynamics relaxes the classical assumption of infinitely slow, reversible

[17] Note that this must be less than one because T_2 cannot equal absolute zero.

[18] The origins of finite-time thermodynamics can be traced to Curzon & Ahlborn (1975).

processes (Christie, 1994). Finite-time thermodynamics deals with the fact that real world processes must occur in finite time periods (Andresen, Berry, & Salmon, 1977). For example, the production of steel from iron ore must take place within a specified period if it is to be of any economic value. The 'human impatience' that this explicitly accounts for introduces a whole series of unavoidable losses such as friction. Finite-time thermodynamics has been developed to address these losses.

In a classical Carnot cycle, for example, the theoretical efficiency is achieved by carrying out the isothermal parts of the cycle infinitely slowly. Under this condition the power[19] output is zero since it takes an infinite time to do a finite amount of work.

To obtain a finite power output, the cycle is sped up. However, if the process occurs instantaneously, the heat flows straight from the source to the sink and the engine performs no mechanical work. Hence, the power output is zero and the engine has zero efficiency. Somewhere between these extremes of zero power (i.e. optimum or zero efficiency) the engine has a maximum power output.

It can be shown that the efficiency of a Carnot engine operating at maximum power output is given by the following equation (Wu, 1988):

$$\eta_{finite} = \frac{P_{max}}{\left(\frac{Q_1}{T_1}\right)} = 1 - \left(\frac{T_2}{T_1}\right)^{\frac{1}{2}}$$

Equation 4-6

Where

η_{finite} = efficiency of a process occurring in finite time at maximum power;

P_{max} = maximum power output;

Q_1 = the heat flow from the high temperature reservoir to the system.

This efficiency is lower than the efficiency of a reversible engine (see the equation for Carnot efficiency on p. 69).

A finite-time perspective of eco-efficiency would highlight the trade-off between efficiency and speed of transformation[20]. For example, Curzon and Ahlborn (1975) highlighted this trade-off by comparing the Carnot, finite time and observed thermal efficiencies of three thermal power plants. Their results are presented in the table below.

[19] The rate of flow of energy

[20] Finite-time thermodynamics leads to similar conclusions to Odum & Pinkerton's (1955) 'maximum power principle' (see section 4.2.3 below).

Table 4-1: Comparison of eco-efficiencies for electricity generation (Source: Curzon & Ahlborn, 1975, p. 24)

Power source	T_2 (°C)	T_1 (°C)	η_{Carnot}	η_{finite}	$\eta_{observed}$
West Thurlock (UK) Coal fired steam plant	~25	565	64.1%	40%	36%
CANDU (Canada) Nuclear reactor	~25	300	48.0%	28%	30%
Lardello (Italy) Geothermal steam plant	80	250	32.3%	17.5%	16%

These results led to the claim that large electricity generation power plants are operated closer to η_{finite} than to the ideal Carnot efficiency.

Efficiency measures adjusted for energy quality

The second law of thermodynamics also emphasises the importance of energy quality[21]. If inputs or useful outputs of two processes are of different qualities their relative efficiencies cannot be meaningfully compared; the proverbial 'apples and oranges' problem.

Measures of efficiency that adjust for energy quality could be considered superior to thermal efficiency measures because the latter do not take energy quality into account. High quality (low entropy) energy inputs such as electricity are more productive than low quality (high entropy) energy inputs such as coal, both in a thermodynamic and economic sense. Thermodynamically, electricity can be converted to a higher proportion of a range of energy end-uses than a lower quality energy input[22].

Several measures can be used to convert the inputs (Q_I)[23] and useful outputs (W) in Equation 4-3 to a common quality numeraire (Patterson, 1996).

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[21] Or, in common usage, 'usefulness' (Patterson, 1996). The subtleties of quality from a scientific and social perspective are poetically laid out by Funtowicz and O'Connor (1999). Despite the well-known deficiency of thermal measures with respect to energy quality, many studies such as the Ministry of Economic Development (2000) still use these measures in macro-level 'energy efficiency' studies. "Such studies are misleading as they treat different energy inputs as being homogenous in quality terms. They are only strictly homogenous in terms of heat equivalents" (Patterson, 1996, p. 378). The issue of energy quality is taken up in Chapter 6.

[22] This point is empirically demonstrated by the data contained in Table 6-1, which describes energy end-use conversion processes in the New Zealand economy. For a range of end-users (heat, light, electronics, mechanical drive, chemical reduction), electricity in general is more efficiently converted to a specific end-use than coal because it is of higher quality.

[23] Patterson (1993a) focuses on the commensuration of different energy inputs. However, attempts to compare two processes with different outputs also encounter the energy quality problem. Commensuration of outputs is also necessary to allow a valid comparison of the efficiency of the two processes.

Gibbs free energy

The International Federation of Institutes for Advance Study (1974) suggests that Gibbs free energy change (ΔG) be used to measure the relative energy qualities[24]. When a reversible transformation is carried out isothermally[25] and at constant pressure, the maximal useful work that can be gained from the transformation is the difference between the initial and final values, respectively, of the total Gibbs free energy (Spiegler, 1983, p. 19)[26]. The Gibbs free energy (G) is defined by:

$$G = H - TS$$ **Equation 4-7**

where:

G = Gibbs free energy

H = enthalpy

T = temperature of the system

S = entropy.

Thus, the efficiency ratio, adjusted for energy quality by using Gibbs free energy (η_G) becomes:

$$\eta_G = \frac{G_{useful\ outputs}}{G_{inputs}}$$ **Equation 4-8**

Where:

$G_{useful\ outputs}$ = the Gibbs free energy of the useful output (often work)

G_{inputs} = the Gibbs free energy of the inputs

Similarly, Helmholtz free energy (F) could be used as a numeraire to account for energy quality. That is, for a change at constant temperature and volume, the maximal work is the difference between the system's initial and final Helmholtz free energy, where (Spiegler, 1983):

$$F = U - TS$$ **Equation 4-9**

Where U = the internal energy.

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[24] According to Kondepudi and Prigogine (1998, p. 128) ΔG is mostly used to describe chemical processes because the usual laboratory situation corresponds to constant P and T.

[25] At constant temperature.

[26] Another way to explain Gibbs free energy is given by Kondepudi and Prigogine (1998, p. 127). "If both pressure and temperature of a closed system are maintained constant, the quantity that is minimised at equilibrium is the Gibbs free energy."

And

$$\eta_F = \frac{F_{useful\ output}}{F_{input}}$$ **Equation 4-10**

Exergy[27]

Ayres (1998) advocates another work potential for commensurating energy qualities; exergy (Λ)[28]. The exergy content of a resource can be thought of as a general measure of its quality or ability to perform work (Ayres & Ayres, 1999, p. 34). Exergy is formally defined as "the maximum amount of *work* that a subsystem can do on its surrounding as it approaches thermodynamic equilibrium reversibly" (Ayres, 1998, p. 192). Exergy is proportional to the future entropy production, but has the units of energy. Furthermore, according to Ayres (1998) exergy is the most general measure of 'distance' from thermodynamic equilibrium[29].

Proponents of exergy (see for example, Ayres & Ayres, 1999; Spiegler, 1983) suggest that it can give important information on the 'exergetic efficiency'[30] (η_Λ) of a system, where:

$$\eta_\Lambda \equiv \frac{\text{recoverable exergy}}{\text{introduced exergy}} \leq 1$$ **Equation 4-11**

The exergetic efficiency is unity for a reversible process and decreases with increasing reversibility. Thus, its value indicates the degree of reversibility of the process considered (Spiegler, 1983, p. 34).

There are a number of concerns with using work potentials to adjust for energy quality (Patterson, 1996). These concerns include:

- The fact that 'work' is not the only useful desired energy output in the economy. For example, modern economies have a significant use for heat in its own right;

[27] Thermodynamicists distinguish between energy 'available' to do work (*exergy*) and energy 'unavailable' to do work. The *exergy* of a system is the maximum useful work which the system can produce until it reaches final equilibrium with a reference system of given temperature and pressure (Spiegler, 1983 p. 11). Useful work is the work produced by the system, except for the work due to volume changes of the system against the reservoir pressure.

[28] Also referred to as *available work, availability, essergy* (for 'essence of energy') (Spiegler, 1983 p. 4).

[29] There are four components of exergy: kinetic exergy, potential-field exergy, physical exergy and chemical exergy. When considering energy and mass flows into and out of economic processes, Ayres (1998, p. 193) suggests only the latter is relevant. To calculate the chemical exergy of a mass flow, it is only necessary to have data on the chemical composition of the flow vis-à-vis the environment into which it flows.

[30] Defined as (exergy embodied in all material products and by-products – not by-product fuel) divided by (exergy embodied in all inputs – both materials and fuels).

- The lack of clarity over what type of work (e.g. chemical, electrical, mechanical etc) should be used as the quality numeraire. This is important because not all forms of work (chemical, electrical, mechanical etc) are the same or necessarily commensurable with each other. Because of this criticism, Patterson (1996, p. 379) notes that "commensurating energy inputs in terms of some work potential still does not provide a rigorous solution to the energy quality problem";
- to compile generic exergy tables, it is necessary to adopt a general convention on reference states (Ayres, 1998, p. 193). This introduces an arbitrary and subjective element into the calculations.

An important aspect of formulating efficiency in terms of Gibbs free energy, Helmholtz free energy or exergy is that these concepts emphasise the importance of work potential as a measure to account for energy quality.

4.2.3 Assumptions underlying thermodynamic approaches to eco-efficiency

Classical thermodynamic interpretations of efficiency, and the consequent lessons for eco-efficiency, are a product of the discipline's assumptions and the way it views reality. Assumptions of particular relevance to the eco-efficiency concept are the view of nature as an equilibrium-seeking machine and the idea of reversibility and entropy that affect the actual efficiency measurement.

Nature and machines

Classical thermodynamics is the progeny of a particular time and place, "spawned in the heart of the nineteenth-century industrialisation process of Western Europe" (O'Connor, 1994, p. 58). As such, classical thermodynamics reflected the 19th-century preoccupation with the capacity of men and machines to do 'useful work.' This preoccupation was extended to nature and the machine became a metaphor for nature. "Once nature itself had been perceived as a working machine, all its forces could be compared and evaluated by their ability to perform work" (Sachs, 1983 as cited in O'Connor, 1994, p. 59). In this way, thermodynamics helped propagate the model of nature as a machine. Nature is also seen as an 'inert' reservoir "which cannot furnish work by itself" (Spiegler, 1983, p. 3). In this sense, thermodynamics sees the environment as 'useless' except as a source of resources and a sink for waste.

These views of nature have implications for classical thermodynamics' formulation of efficiency concepts such as eco-efficiency. First, the view of nature as a controllable machine could imply that eco-efficiency is likewise controllable. In complex systems with non-linear feedback, this may not be the case.

Second, thermodynamics focuses attention on the machines of work. Efficiency becomes focused on the performance of that machinery, rather than on broader resource allocation issues. Thus, a reliance on thermodynamic interpretations of the eco-efficiency concept could be open to misadventure, as a result of the myopia it may induce.

Equilibrium, complex systems and efficiency

The concept of equilibrium[31] is at the core of classical thermodynamics (Fong, 1963, p. 16). Equilibrium, in classical thermodynamics, is the ultimate end point of any interaction. The second law is an example of the equilibrium conditions: "the entropy Law states that if a system is left alone, it drifts towards equilibrium..." (Khalil, 1990, p. 165). Classical thermodynamics is therefore, deterministic in the sense that it postulates a predetermined response to disturbances or changes.

Assumptions about whether a system tends to equilibrium or not have important consequences for understanding the 'eco-' variants of thermodynamic efficiency concepts. In particular, equilibrium assumptions influence views about how and why efficiency levels change over time. The efficiency of a reversible system that reaches equilibrium is computable and unique. Thus, in the equilibrium world of classical thermodynamics, efficiency concepts (including 'eco-' variants) are assumed to converge on a unique final level through the relentless march towards equilibrium.

Proximity to equilibrium also dictates the ease with which explanations can be found for the levels of, or changes in, efficiency. For example, deterministic systems tending towards equilibrium are assumed to be understood and controllable. Explanations of, say, thermal efficiency levels simply rely on knowledge of the intensive[32] and extensive[33] variables describing the system. In complex far-from-equilibrium systems, simple monocausal explanations of efficiency changes are inadequate. Since non-equilibrium systems are ubiquitous in nature, a classical thermodynamic equilibrium-based approach to concepts such as eco-efficiency must be treated with caution.

The role of efficiency in complex systems is not clear[34]. Bak (1996, p. 197) cites the work of Kai and Maya who studied the complexity of traffic jams and made an interesting observation

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[31] A system is in a state of thermodynamic equilibrium when each of its thermodynamic properties is time independent and when there are no fluxes within the system or across its boundary (Beattie & Oppenheim, 1979, p. 2).
[32] Those whose values are independent of the system size.
[33] Those whose values increase in direct proportion to the system size.
[34] It is beyond the scope of this research to define the place and role of efficiency in complex systems. This would be a fruitful area of future research.

with respect to efficiency in complex systems. They observed that the critical[35] far-from-equilibrium state, with traffic jams of all sizes, is the most efficient state. That is, they found the system self-organised to the critical state with the highest throughput of cars. If the density were slightly less, the highway would be underutilised. If the density were slightly higher, there would be one big permanent traffic jam. In both cases, the throughput of cars would be less. More precisely, Bak (Bak, 1996, p. 198 /d) concludes that the critical state is "the most efficient state *that can actually be reached dynamically* [italics in original]."[36]

This finding seems to be corroborated by the study of Papadopoulos et al. (2001) of the British National Health Service (NHS). They find that the NHS exhibits characteristics of a self-organised critical system. Consequently, they conclude that "no matter how many managers are appointed they will be unable to enhance efficiency... [and may actually] shift the NHS from an efficient, self-organised critical system to a mediocre, highly ordered one" (Papadopoulus et al., p. 615). Efficiency in the NHS study is defined as patient throughput.

However, both of these studies seem to have confused 'throughput' with efficiency. Both studies are looking at the rate of flow (of cars or patients) through the system. What they seem to be concluding is that complex systems evolve to situations that maximise throughput in line with Odum's Maximum Power Principle (see section 4.4.2).

It could be argued that the concept of efficiency has less relevance in a complex system than in a simple, deterministic system. This is because the 'purpose intended' part of the efficiency definition is less clear in complex systems than in deterministic systems. While systems theory does consider the system 'telos' or goal, in complex systems at the edge of chaos, identifying the goal can be difficult. Complex systems far from equilibrium exhibit different efficiency characteristics than equilibrium systems. Non-equilibrium systems continually fluctuate, and so it can be expected that the level of efficiency will fluctuate. In these systems, efficiency does not deterministically tend towards a final value. Rather, efficiency changes as levels of organisation in self-organising dissipative structures[37] change (Proops, 1983).

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[35] A state where the system is "way out of balance, where minor disturbances may lead to events, called avalanches, of all sizes" (Bak, 1996, p. 1).

[36] Bak (1996) notes that a carefully engineered state where all the cars were moving at maximum velocity would have higher throughput, but it would be catastrophically unstable. This very efficient state would collapse long before all the cars became organised.

[37] The details of the theory of self-organising dissipative structures are complicated. But in outline, the physical mechanism underlying dissipative structures is not difficult (Proops, 1983, p. 356). In far-from-equilibrium, structures are engendered by associated energy dissipation. Hence, the term dissipative. Such far-from equilibrium structures are maintained in that state by interaction with its environment in the form of energy flux. These structures have a degree of 'organisation' which is associated with its rate of entropy generation and can be self maintaining. For a more detailed discussion of these concepts refer to Kondepudi and Prigogine (1998).

Reversibility, entropy and efficiency

Classical thermodynamic interpretations of efficiency are limited because they are based on the notion of an ideal 'reversible' system. Processes occurring in nature are never reversible. It can be shown that entropy generation is greater than zero for irreversible processes (see Kondepudi & Prigogine, 1998). This increase of entropy introduces explicitly the notion of time into the description of a system and the idea that there is a trade-off between entropy generation and the speed and efficiency at which processes occur (Ruth, 1993, p. 70). In fact, entropy generation is inversely proportional to efficiency. A decrease in efficiency implies an increase in the rate of entropy production[38]. Hence:

$$\delta S \underset{\propto}{\frac{1}{}} \eta \qquad \textbf{Equation 4-12}$$

Where δS is the change in entropy.

This result leads to an important conclusion with respect to the thermodynamic motivations for pursuing eco-efficiency. Given that what occurs in nature are irreversible processes, leading to entropy generation, contemporary thermodynamicists focus *both* on the scarcity of material resources (following the first law), and on the availability of high-quality, low-entropy energy and matter (the second law). Thus, given the relentless march of second-law entropy generation, thermodynamics suggests attention must be given to reducing the rate of entropy generation. Improving eco-efficiency is one method for reducing entropy generation.

4.2.4 Summary of thermodynamic interpretations of efficiency and insights into eco-efficiency

The efficiency concept is central to thermodynamic theory. Classical thermodynamics provides a number of interpretations of efficiency and each of these interpretations rests on a core theme: the ratio of useful outputs to inputs. These interpretations have influenced efficiency interpretations in other disciplines.

Thermodynamic efficiency concepts can be grouped into thermal, ideal limit, finite time and energy-quality adjusted efficiency. These are summarised in Figure 4-4:

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[38] Following from Equation 4-2, $\eta=(Q_1-Q_2)/Q_1=1-(Q_2/Q_1)=1-T_1/T_2$ and for a reversible process in a closed system, $Q_1/T_1=Q_2/T_2=0$ and $Q_1/T_1-Q_2/T_2=0$. That is, entropy change is zero (Kondepudi & Prigogine, 1998, p. 80). In a less efficient irreversible cycle a smaller fraction of Q_1 (the heat absorbed from the hot reservoir) is converted into work (Kondepudi & Prigogine, 1998, p. 81). This means the amount of heat delivered to the cold reservoir by an irreversible cycle, Q_2^{irr}, is greater than Q_2. Therefore $Q_1/T_1 - Q_2^{irr}/T_2 < 0$. And the total change of entropy of the reservoirs is $\Delta S = (-Q_1)/T_1 - (-Q_2^{irr})/T_2 > 0$. If efficiency is increased, then a greater fraction of Q_1 is converted to work, and Q_2 decreases. Thus, ΔS decreases.

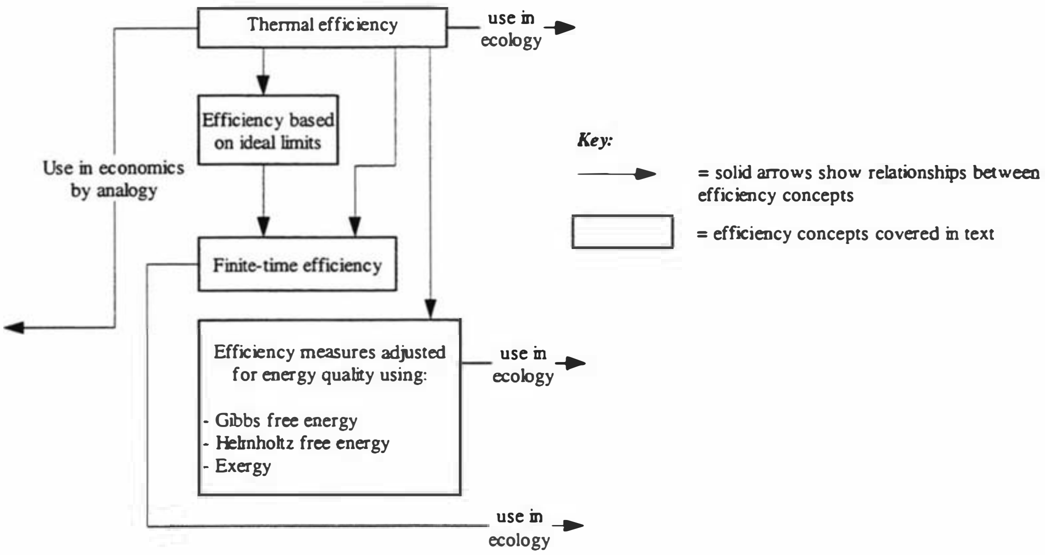

Figure 4-4: Interrelationships between thermodynamic efficiency concepts

Applying thermodynamic efficiency concepts to eco-efficiency highlights several important insights. These are summarised in the table below.

Table 4-2: Summary of the insights and lessons for eco-efficiency from thermodynamics

Efficiency concept	Insights and lessons for eco-efficiency
Thermal efficiency	Provides a formulation for eco-efficiency concepts as the ratio of useful energy output to inputs;
Efficiency measures based on ideal limits	Emphasises that there are limits to eco-efficiency; Useful for identifying the theoretical savings that can be achieved in eco-efficiency; Useful for identifying the proximity to eco-efficiency limits;
Finite-time efficiency	Emphasises the trade-off between efficiency and speed of transformation;
Efficiency measures adjusted for energy quality	Highlights the importance of energy quality; Emphasises that useful work should form the basis for an eco-efficiency that accounts for energy quality;
Assumptions	Nature is controllable therefore eco-efficiency is controllable; Eco-efficiency is focused on machines of work; Equilibrium implies the level of eco-efficiency is computable and unique; The motives for pursuing eco-efficiency are both limited resources and a decrease in entropy generation.

4.3 Neoclassical economic[39] approaches to eco-efficiency

There are few, if any, explicit references to eco-efficiency in neoclassical economics literature. In order to understand how this discipline informs us about eco-efficiency, the following discussion will draw on areas from neoclassical economic theory relating to the concepts of efficiency.

4.3.1 The role of efficiency in neoclassical economics

A focus on natural resource scarcity has been a major theme of economics since its inception (Randall, 1987, p. 3). Such a concern naturally leads to a concern for the efficiency of resource use.

Economics was one of the first 'disciplines' to put resource depletion on the research agenda (Jager, Janssen, De Vries, DeGreef, & Vlek, 2000). As early as the Physiocrats (1750-1780) notions of the environment and efficiency of resource use were alluded to. To the Physiocrat, the 'laws of nature' governed human society (Oser & Brue, 1988, p. 35). This view led them to perceive a world where wealth was derived from natural resources alone.

The classical school of economics (1775-1875) pointed out that all resources (capital, labour, land) contribute to wealth. Another feature of early classical economists' thinking (Ricardo, Malthus) was their focus on natural resource constraints. However, following Adam Smith's treatise[40] outlining (among other things) a system for achieving efficient allocation of resources, emphasis on the importance of natural resource constraints waned. Neoclassical economists have continued this trend, tending to focus efficiency concepts on the human-welfare implications of resource allocations rather than the imperative to avert resource extinction.

Efficiency remains a core concept of neoclassical economics (Leibenstein, 1966, p. 392; Gustafsson, 1998, p. 260). In fact, "many mainstream economists regard the domain of economics to be limited to matters of efficiency" (Woodward & Bishop, 1995, p. 104).

While efficiency is core to economics its meaning can be problematic (Afriat, 1988). One reason for this is that there are many different efficiency concepts within economics. At the most general level efficiency is used to describe the results of the process of competition for and/or allocation of scarce resources in a way which maximises the production of desired goods at least cost (Caragata, 1989, p. 17). However, efficiency in economics is not a single notion

[39] Since the current predominant theory in the economic discipline is neoclassical economics (Christensen, 1991, p. 75; Norgaard, 1989), this section will focus on a neoclassical interpretation of eco-efficiency. Neoclassical economics is interpreted loosely to include marginalism, mathematical economics, microeconomics, welfare economics and (the relatively recent) resource and environmental economics (see Sahu & Nayak, 1994, p. 11).

[40] Smith, A. 1776. An Inquiry into the Nature and Causes of the Wealth of Nations.

but rather, it is "a multidimensional concept" (Helm, 1988, p. 13). Indeed, in the process of this research, 16 interrelated types of economic efficiency were identified[41].

Second, efficiency concepts within economics are often less empirically precise than efficiency concepts in the physical sciences. Where engineers test and measure, economists make use of the production function or the utility function. "But the bases for these are less systematic than the engineer's measurements, and this creates problems" (Afriat, 1988, p. 252).

Efficiency concepts in neoclassical economics are found in two main bodies of theory; production theory and welfare economics.

4.3.2 Neoclassical economic interpretations of efficiency and insights into eco-efficiency

Production theory efficiency concepts

Production theory seeks to describe the relationship between production inputs and outputs. In doing so, a focus on the efficiency of the production process is inevitable (Clarke & McGuinness, 1987, p. 164; van den Broeck, 1988, p. 63). Indeed, Koutsoyiannis (1979, p. 68) states "the basic theory of production concentrates only on efficient methods. Inefficient methods aren't used by rational entrepreneurs."

The following sections discuss three key efficiency concepts in production theory[42] and highlight their salient characteristics that could be brought to bear on a production-theory perspective of eco-efficiency. A characteristic of production efficiency concepts is that they all draw on the familiar 'useful output to input' ratio of classical thermodynamics.

Technical efficiency in production theory

Technical efficiency is concerned with the utilisation of inputs into the production process (Helm, 1988). Economists use production functions to describe the relationship between a firm's input of productive resources (defined in contemporary economic texts (see for example Thompson & Formby, 1993) as capital, labour and natural resources) and its output of goods and services per unit time. This relationship can be expressed as:

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[41] These include: x-efficiency, managerial efficiency, production efficiency, technical efficiency, price efficiency, allocative efficiency, scale efficiency, scope efficiency, competitive efficiency, distributional efficiency, static efficiency, dynamic efficiency, intertemporal efficiency, profit efficiency, cost efficiency and revenue efficiency.

[42] Many more efficiency concepts can be found in production theory literature including price efficiency, managerial efficiency, scale and scope efficiency. In the interests of brevity, only the fundamental concepts of technical, production and x-efficiency will be discussed. For more detail on production theory efficiency concepts refer to Helm (1988).

$U=f(x_1, x_2, \ldots x_i, \ldots x_n)$ **Equation 4-13**

Where:

U[43] = an output from the production process;

x_i = inputs to the production process.

Technical efficiency measures the ratio of all inputs to total output and each input to total output[44] (Caragata, 1989, p. 20). Achieving maximum technical efficiency with a particular technology or production recipe requires (i) obtaining the maximum output from a given combination of inputs or (ii) minimising the amount of input that is required to produce a designated amount of output (Thompson & Formby, 1993, p. 140; Koutsoyiannis, 1979).

Consider a production unit employing variable inputs $x \equiv (x_1,\ldots,x_n) \in R_+^n$ in the production of outputs $u \equiv (u_1,\ldots,u_n) \in R_+^m$. Technology is modelled by an input correspondence $u \rightarrow L(u) \subseteq R_+^n$ [45] or inversely by an output correspondence $x \rightarrow P(x) \subseteq R_+^m$ [46]. Consider also the adjusted production possibilities sets, or the graph of technology of the input-output vector (x,u), as defined as:

$GR \equiv \{(x,u): x \in L(u),\ u \in R_+^m\} = \{(x,u): u \in P(x),\ x \in R_+^n\}$ **Equation 4-14**[47]

Now the efficient subset can be defined as:

$Eff\ GR \equiv \{(x,u): x \in GR,\ (v,y) \notin GR,\ v \geq u,\ y \leq x\}$ **Equation 4-15**

Equation 4-15 can be interpreted as follows: the efficient production possibilities set *Eff GR* exactly equals a situation where, if a company wanted to increase output (i.e. the new output v was greater than u) with less input (i.e. the new input y is less than the original input, x), it could not because v and y don't belong to *Eff GR*.

Thus, the input-output vector (x,u) is called technically efficient if and only if $(x,u) \in Eff\ GR$ (Lovell & Schmidt, 1988, p. 7). Technical efficiency is sometimes used as a synonym for production efficiency. However, the concepts are different because the former ignores input factor costs.

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43 'U' is used, rather than the conventional Q notation to avoid confusion with the thermodynamic use of Q as heat.

44 This is analogous to the thermal efficiency ratio of useful outputs to inputs mentioned above.

45 L(u) is the subset of all input vectors capable of producing at least output vector u.

46 P(x) is the subset of all output vectors obtainable from input vector x.

47 That is, the production possibility sets exactly equals a situation where x (input vector) belongs to $L(u)$ (the subset of all input vectors capable of producing at least output vector u) where u is a positive real number, or where u (the output vector) belongs to $P(x)$ – the subset of all output vector slot table from an input vector x.

There are several salient characteristics that could be bought to bear on a technical efficiency perspective of eco-efficiency. Technical efficiency places emphasis on the production process and the importance of technology, as embodied in the production possibility set. Specifically, it focuses on those inputs and outputs that are commodified as part of the production function. A further implication from the production-function focus is its focus on *direct* inputs to the production process. Indirect inputs would generally not be considered in a technical efficiency analysis.

Production efficiency in production theory

The general principle in production theory is that firms aim to maximise profit (π) given i) the constraint set by factors of production (x), (ii) the production possibility set (GR) and (iii) the prices of commodities $P \equiv (P_{u1}, P_{u2}) \in R_+^m$ and prices of factors of production $w \equiv (P_{x1}, P_{x2}) \in R_+^n$ (Koutsoyiannis, 1979, p. 104) where:

P_{u1} and P_{u2} = the commodity prices of outputs u_1 and u_2 respectively;

P_{x1} and P_{x2} = the prices of factors of production x_1 and x_2 respectively.

Consider a firm producing two products u_1 and u_2 using two factors x_1 and x_2. A firm could be said to be production efficient if it allocates its resources such that the ratio of prices of the outputs (P_{u1} and P_{u2}) equals the marginal rate of product transformation for u_1 and u_2:

$$MRPT_{u_1,u_2} = \frac{MP_{x_1,u_1}}{MP_{x_1,u_2}} = \frac{MP_{x_2,u_1}}{MP_{x_2,u_2}} = \frac{P_{u_1}}{P_{u_2}}$$ **Equation 4-16**

Where:

$MRPT_{u1,u2}$ is the marginal rate of product transformation of u_1 and u_2;

$MP_{x1,u2}$ etc are the marginal products of x_1 (say labour) for producing u_2.

Graphically, this is shown as the point of tangency (ε) of the iso-revenue curve[48] (R with slope=P_{u1}/P_{u2}) and the production possibility frontier (with slope $MP_{x1,u1}/MP_{x1,u2}$= $MP_{x2,u1}/MP_{x2,u2}$=$MRPT_{u1,u2}$).

[48] Locus of points of various combinations of quantities of u_1 and u_2 whose sale yields the same revenue to the firm.

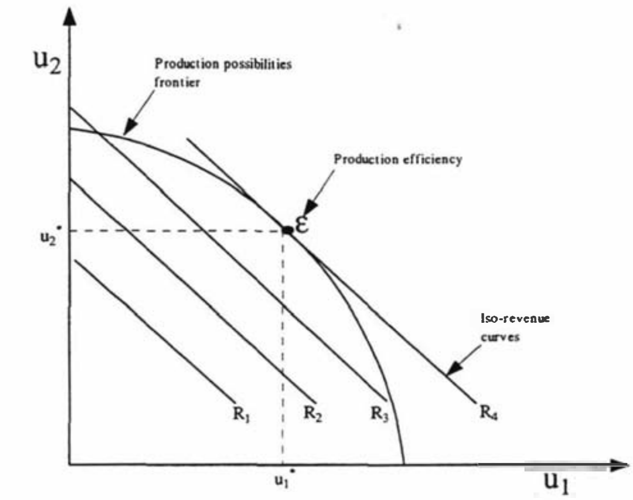

Figure 4-5: Graphical presentation of production efficiency

In other words, given that *(x,u)∈Eff GR*, a firm earns maximum profit (and is called production[49] efficient) if and only if:

$$(p^T u - w^T x) = \pi(p,w)$$ **Equation 4-17**

and

$$\pi(p,w) \equiv \max\{p^T u - w^T x : (x,u) \in Eff\ GR\}$$ **Equation 4-18**

where:

$p^T u$ = price vector multiplied by the outputs (revenue);

$w^T x$ = cost vector multiplied by inputs (costs).

Two key characteristics emerge that would influence a production efficiency perspective of eco-efficiency. Production efficiency emphasises the profit motive of the firm engaged in production. There is also a consequent focus on the prices of inputs and outputs.

X-efficiency in production theory

The general concept of x-efficiency is defined by the outermost production possibility frontier (PPF) (Leibenstein, 1966, p. 206). When a firm sits on the outermost PPF, it is said to be x-efficient.

X-*in*efficiency is the estimate of the 'distance' between where a firm currently operates at and the outermost production frontier (DeAlessi, 1983, p. 69; Leibenstein, 1966) (see Figure 4-6).

[49] Because at point ε the firm maximises profit, this point is sometimes called profit efficiency (Lovell & Schmidt, 1988, p. 7).

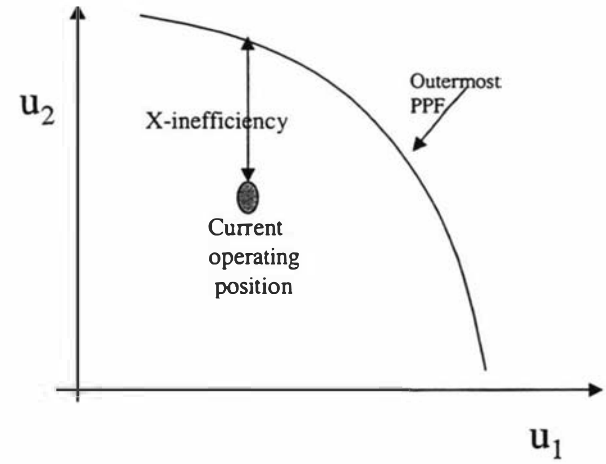

Figure 4-6: Graph showing x-inefficiency as the distance between the current operating position and the outermost production possibility frontier (PPF)

The x-efficiency concept helps to describe the phenomena of why firms do not operate on the outer-bound of their production possibility frontier. In the context of eco-efficiency, the difference between x-efficiency[50] and x-*in*efficiency could be due to waste to the environment that has not been eliminated. Such waste reduction depends, in part on managerial efficiency and, in part, on new or enhanced technological inputs (Caragata, 1989; Helm, 1988).

Welfare economics

Welfare economics is the branch of economics concerned with discovering principles for how to use limited resources to maximise social well-being (or in economic terms, 'efficiency') (Oser & Brue, 1988; Stiglitz, 1988). In order to evaluate alternative economic situations, there is a need for some criterion of social well-being or welfare. Economists have suggested various criteria of social welfare at different times. For example, Adam Smith implicitly accepted the growth of GNP as a welfare criterion. Jeremy Bentham argued that welfare is improved when 'the greatest good (is secured) for the greatest number.' Modern welfare economics is mainly concerned with the examination of the allocative-efficiency[51] criterion (Koutsoyiannis, 1979, p. 524).

[50] There is now considerable evidence in favour of the existence of x-inefficiency (see Frantz, 1998).

[51] Also referred to as Pareto efficiency or Pareto optimality after the famous Italian economist Vilfredo Pareto (1845-1923) who "did much to help economists understand the conditions for, and the welfare significance of, economic efficiency" (Oser & Brue, 1988, p. 391).

Allocative efficiency[52] *in welfare economics*

According to this criterion, allocative efficiency[53] is achieved when resources are arranged such that no rearrangement of those resources can make someone better off without making another worse off (Stiglitz, 1988, p. 63). Following standard welfare economic theory, it can be shown that allocative efficiency requires three marginal conditions to be satisfied[54]:

- the marginal rate of substitution (MRS) between any two goods (u_1 and u_2) should be equal for all consumers (A, B ...). That is, $MRS^{A}_{u1,u2}= MRS^{B}_{u1,u2}$;
- the marginal rate of technical substitution (MRTS) between any two inputs (x_1 (say labour) and x_2 (say capital)) should be equal in the production of all commodities (or, $MRTS^{u1}_{x1,x2}= MRTS^{u2}_{x1,x2}$)[55];
- the marginal rate of product transformation (MRPT) should be equal to the $MRS_{u1,u2}$ for any two goods (or $MRPT_{u1,u2}= MRS^{A}_{u1,u2}= MRS^{B}_{u1,u2}$).

Allocative efficiency is a broad term and is interlinked with other neoclassical efficiency concepts. It encompasses other notions of efficiency such as technical, production and profit efficiency (Helm, 1988).

The standard formulation of allocative efficiency can be extended to incorporate environmental costs and benefits (the realm of eco-efficiency). Optimal allocative efficiency implicitly assumes that all benefits and costs to producers and consumers are reflected in market prices and that there is no divergence between private and social costs and benefits (Koutsoyiannis, 1979, p. 496). In other words, no external economies exist. In real world economies, environmental externalities are ubiquitous (Koutsoyiannis, 1979, p. 541). In this context the standard allocative efficiency criterion falls down. Economists have defined an alternative approach to addressing these externalities.

This new criterion can be developed by way of an example that demonstrates how the standard formulation breaks down, and how an amended allocative efficiency criterion could rectify the situation. Assume that commodity 'u_1' is petrol, which for simplicity is assumed to be manufactured in a perfectly competitive market. Each firm is in equilibrium when the (private) marginal cost (MC_{u1}) equals price (P_{u1}). This does not include the cost of pollution from the

52 Again, welfare economics includes many more efficiency concepts such as static and dynamic efficiency and intergenerational efficiency in allocation of exhaustible resources. However, in the interests of brevity, only the fundamental allocative efficiency s discussed here. For a discussion of the other concepts please refer to Randall (1987).
53 Allocative efficiency is what economists usually mean when they refer to efficiency (Stiglitz, 1988).
54 Refer to any standard microeconomic text for the proofs of this (for example, Lipsey, 1983).
55 This is related to production efficiency mentioned above, since the MRTS gives the slope of an isoquant, and isoquants can be used to establish the PPF.

production or use of petrol. Suppose that the Ministry for the Environment obtains an estimate of these pollution costs. The marginal social cost (MSC_{ul}) is the sum of the private cost (MC_{ul}) and the marginal external cost (MEC_{ul}), that is

$$MSC_{ul} = MC_{ul} + MEC_{ul}$$ **Equation 4-19**

There is now a divergence between private and social costs of petrol as shown in the diagram below.

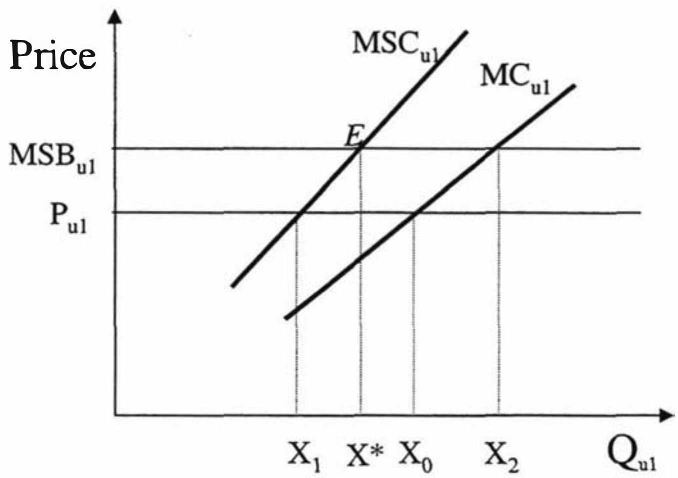

Figure 4-7: An allocative efficiency criterion that explicitly accounts for positive and negative environmental externalities

Since $MC_{ul} = P_{ul}$, then $P_{ul} < MSC_{ul}$. This implies that the allocation of resources to the production of petrol is not socially optimal since at $P_{ul} = MC_{ul}$, X_0 is being produced rather than X_1 (where $P_{ul} = MSC_{ul}$).

Even if the price is equal to the MSC there is no guarantee that social welfare is maximised. This is because the price may be different than the social benefit. For example, consider a person using an energy-efficient vehicle and paying P_{ul} for the petrol. By driving an energy efficient vehicle, the person produces less harmful air emissions per km of travel (ceteris paribus), thus creating a benefit to others who breathe in a less-polluted atmosphere. Since they do not pay for this benefit the marginal social benefit (MSB) is greater than P_{ul}. Again, we have a solution that is less than the socially optimal level of petrol consumption.

The marginal social benefit curve is above P_{ul} at all levels of output. If consumers pay the full MSB_{ul}, the firm would increase its output by the amount X_0X_2. If external costs of petrol are taken into account, the marginal cost curve would shift to MSC_{ul}. A new equilibrium point would be reached at point E where $MSC_{ul} = MSB_{ul}$.

Thus, when environmental externalities exist, the criterion for allocative efficiency is equality of the MSB and MSC. In a multi-product economy the condition for optimal allocative efficiency is:

$$\frac{MSB_{u_1}}{MSC_{u_1}} = \frac{MSB_{u_2}}{MSC_{u_2}} = \ldots = \frac{MSB_{m}}{MSC_{m}} = 1$$ **Equation 4-20**

In sum, when extended to include environmental externalities, an allocative efficiency approach can be said to provide two important foci for eco-efficiency:

- a focus on the importance of allocating resources so as to maximise welfare;
- an emphasis on the importance of internalising environmental externalities into the market mechanism.

Intertemporal efficiency in welfare economics

Intertemporal efficiency addresses the question 'under what conditions do decisions of rational individuals ensure allocative efficiency for the whole economy over time'? (Randall, 1987). The concept of intertemporal efficiency is based on the notion that there is a trade-off between current and future consumption, and this trade-off can be shown by the intertemporal indifference curve. The intertemporal indifference curve defines the set of combinations of future and present consumption such that an individual is indifferent between any combination in the set (see Figure 4-8). A higher indifference curve (I_2) implies greater satisfaction than (I_1)[56]. Intertemporal efficiency also introduces the idea of an intertemporal budget line (or constraint), which shows the trade-off between income (or consumption) across time. Consider the two-period example in Figure 4-8 below.

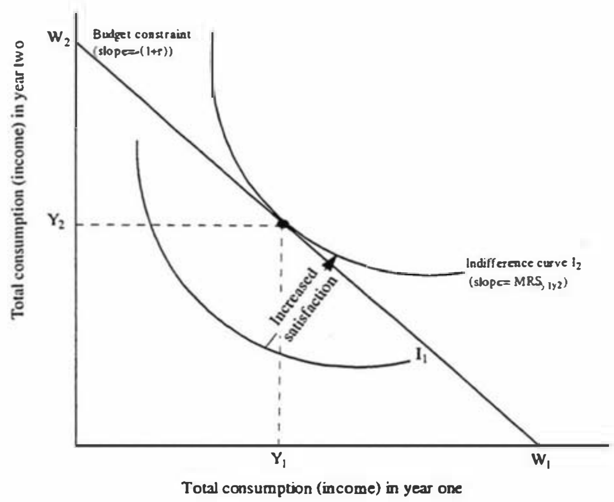

Figure 4-8: Indifference curves and budget constraints used for identifying intertemporal efficiency

[56] Generally, intertemporal efficiency is based on the assumption that consumers have positive time preferences (that is, where the present is valued more highly than the future). Individuals can have negative or neutral time preferences, however positive time preferences are generally accepted as the norm in neoclassical economics.

If $W_1 = W_2$ this would imply that income could be transferred across time on a one for one basis. This is generally not the case because future income undergoes diminution when transferred to the present because the borrower pays interest. The slope of the budget constraint is proportional to the interest rate (the higher the interest rate the steeper the line).

If it is possible to reallocate consumption across periods, individuals would do so to achieve the highest indifference curve given the budget constraint. It can be shown that[57] an individual will locate the trade-off of consumption at the intersection of the budget line and highest indifference curve. The necessary condition for the intertemporal efficiency of consumption is:

$$MRS_{Y1,Y2}=P_{Y1}/P_{Y2}=(1+r)/1=1+r$$ **Equation 4-21**

Where:

$MRS_{Y1,Y2}$ = the marginal rate of substitution between consumption in year one and consumption in year two;

P_{Y1} and P_{Y2} = the 'prices' of consumption in year one and year two respectively;

r = the interest rate.

Equation 4-21 gives the conditions for intertemporal efficiency for an individual transferring income using capital markets. Now consider an individual who transfers income using productive opportunities. The individual may take income and invest in productive opportunities such as land or a factory. It can be shown that the efficiency condition of an individual facing only productive opportunities is given by the intersection of the intertemporal production possibility frontier and the intertemporal indifference curve:

$$MRS_{Y1,Y2}=MRPT_{Y1,Y2}$$ **Equation 4-22**

It follows then, that for an individual enjoying both market and productive opportunities for intertemporal transfer, the intertemporal efficiency condition is:

$$MRS_{Y1,Y2}=MRPT_{Y1,Y2}=1+r$$ **Equation 4-23**

for a two-period case. In other words, an individual who enjoys both market and productive opportunities for intertemporal transfer will allocate consumption (income) across time such that their marginal rate of substitution equals their marginal rate of product transformation subject to the interest rate. Equation 4-23 is a special case of the allocative efficiency condition established above.

[57] In the interests of brevity, this section does not present the detailed proofs of intertemporal efficiency. For more detail, see any standard economic text (for example Randall, 1987).

The specification of intertemporal efficiency highlights an important insight for eco-efficiency. This concept emphasises that economic agents consider time in their decisions about using natural resources and that these decisions are influenced by the interest rates. The higher the interest rates, the less likely are firms to delay their use of natural capital.

4.3.3 Assumptions underlying neoclassical economic approaches to eco-efficiency

A neoclassical economic approach to eco-efficiency is influenced by a number of underlying assumptions about the relationship between economic activity and the environment[58].

Mechanistic, deterministic and atomistic assumptions

Neoclassical economics is characterised by mechanistic, deterministic and atomistic views of the economic system. These views were "explicitly and purposely copied from classical mechanics" (Söllner, 1997, p. 178). Classical mechanics saw nature as a sophisticated machine, whose behaviour is not random but is a knowable and predictable outcome of structure (Pepper, 1984, p. 38).

The implication of the mechanical analogy is that neoclassical economics regards the market as essentially clockwork and deterministic[59]. The general approach in neoclassical economics is to assume that once the conditions are in place (including internalising all externalities such that all prices equal MSC and MSB), the market will progress to some predetermined (deterministic) optimal solution; market equilibrium[60] and allocative efficiency. As a result, the neoclassical economic interpretations of efficiency concepts assume that given the right conditions, the market machine will inevitably and instantly achieve equilibrium levels of efficiency in its many guises. The implication is that neoclassical economics assumes control over efficiency within a complex economic system. This in turn gives economists the confidence to make

[58] There are significant similarities between the assumptions underlying the eco-industrial épistémé (EIE) and neoclassical economics. This is because neoclassical economics provides a formal theoretical expression for many of the policies advocated by the EIE. However, the overlap between the EIE and neoclassical economics is not complete. For example, the EIE embodies modern business management theory as well as aspects of industrial ecology. This section will focus on the specifically neoclassical assumptions and attempt to avoid repeating the critique presented in Chapter 3.

[59] Determinism is implicit in a mechanistic system. A deterministic system progresses towards a single outcome from a given set of circumstances or initial conditions (Cole, 1996; Medio, 1992, p. 4). Determinism also implies that the future is a product of the past.

[60] Waldrop (1994, p. 255) states "(neoclassical) economics had come to mean the investigation of equilibrium".

predictive statements about future eco-efficiency levels over time. Pretences to control are unrealistic (see section 3.5.2).

It is hard to find justification for economists' overwhelming preoccupation with equilibrium states. There is little empirical evidence to suggest that economic systems in particular, or systems in general, actually reside in equilibrium (see 4.2.3 and Cole (1996)). Instead, we see an economy characterised by "non-equilibrium (and) self-reinforcing behaviour" (Christensen, 1991, p. 75). An implication of rejecting an equilibrium perspective is that one can no longer 'predict' the future. This is important for policy. The reduced ability to 'predict' places greater onus on analysts to monitor current levels of eco-efficiency.

Neoclassical economics is also epistemologically predisposed towards an atomistic view of resources and their utility (Vedeld, 1994, p. 11). For example, the neoclassical model is atomistic in its assumption that land, labour and capital are separate components. Such an atomistic perspective ignores wider system interdependencies, which can lead to eco-efficiency being seen as separate to other concepts of efficiency. This is unrealistic given the concatenation of many of the efficiency concepts (see Figure 4-9 below).

A mechanistic, reductionistic approach means neoclassical economics does not account for all of the complex economic behaviour exhibited in economies. This brings into question neoclassical economics' reliance on perfectly competitive 'ideal' markets (Norgaard, 1989, p. 50). Indeed, Norgaard (1989, p. 40) suggests that no universal policy recommendations applicable to the real world (and by implication, eco-efficiency) flow directly from the neoclassical model. Instead, he argues that economists need to understand strengths and weaknesses of their methodologies and work towards an epistemology appropriate to the nature of investigating issues such as eco-efficiency in complex systems.

Diminished role the of physical environment and boundaries

Neoclassical economic approaches to eco-efficiency assume a diminished role of the physical environment in the economy. At least three reasons for this can be identified.

Concern with the abstract

Neoclassical economists have become focused on the role of money in the economy. This is symptomatic of a general trend in neoclassical economics, towards more concern for the abstract rather than physical goods (Kneese, Ayres, & d'Arge, 1970). Consequently, interest in the physical environment, from which physical goods are extracted, waned.

This is reflected in the narrow formulation of the neoclassical economic production function. For example, the Cobb-Douglas production function can be presented as

$$U=K^{a1}R^{a2}L^{a3}$$ **Equation 4-24**

Where U is output, K is capital, R is natural resource flow used in production and L is the labour supply, and $a_1+a_2+a_3=1$ and $a_i>0$. This formulation has been criticised on several grounds including its inappropriate assumption that natural resources are perfectly substitutable with manufactured capital (Ayres & Nair, 1984; Daly, 1997; Georgescu-Roegen, 1979) (see section 3.5.2). These authors have argued that the production function should be extended to incorporate energy and matter and the laws of thermodynamics.

Capital subsumes nature

Second, the role of the physical environment in neoclassical economic theory diminished as economists expanded the conceptual domain of capital to subsume nature. For example, when working on environmental issues of the 1970s, economists placed environmental concerns within, but did not radically alter, the set of economic models. By maintaining the logic of their models, economists expanded the reach of their view of the world. Now, capital and markets encapsulate nature. In the words of O'Connor (1994, p. 55) neoclassical environmental economists see that "nature is capital, or, rather, nature is conceived in the image of capital. The logic of the system is thus the subsumption of all of the elements of nature-considered-as-capital to the finality of capital's standard reproduction".

As a result, economists focus on that part of physical nature that has value; that can be commodified. By capitalising natural resources, "there no longer remains any domain external to capital" (O'Connor, 1994, p. 55). Neoclassical economics effectively excludes the non-capital natural environment from the economic system.

A decline in the importance of the biophysical basis of the economy means that neoclassical economics' interest in the physical sciences such as thermodynamics has diminished. Sahu and Nayak (1994, p. 15) state that neoclassical economics' interest in thermodynamics extends only to the first law of thermodynamics, and then principally by analogy (Boulding, 1966; Mirowski, 1989)[61]. Consequently, economic interpretations of efficiency only draw on thermal efficiency

[61] Economics has a long history of employing concepts of physics both as analogies and in the form of physical principles (Faber & Proops, 1985; Ruth, 1993, p. 63). In contrast to materials-based classical economic theory, neoclassical economists reconstructed economic theory using the methods, concepts and mathematical tools of 19th-century analytical mechanics (Christensen, 1991, p. 76). It is plausible that the neoclassical economic concepts of efficiency were developed as an analogue to the nineteenth century classical physical science's definition of efficiency. The similarities between concepts such as technical and production efficiency in production theory and the thermal efficiency of a machine are straightforward. The case is less obvious for concepts such as allocative (eco-)efficiency. However, evidence suggests *all* economic efficiency concepts can be viewed as analogies to physical-science efficiency (Afriat, 1988, p. 252).

concepts (for example, technical efficiency). Energy quality implications for eco-efficiency are essentially ignored in neoclassical economics[62].

Technological optimism

The third reason for the decline in importance of the physical environment can be attributed to the neoclassical economist's technological optimism (Costanza, 1991). Neoclassical economics shares with the eco-industrial épistémé a Panglossian view of technology's ability to avert Ricardian scarcity[63] (Sahu & Nayak, 1994; Underwood & King, 1989, p. 316). Neoclassical economics considers resource constraints are 'relative' to society's technological ability to offset Ricardian scarcity. "Natural-resource limitations, according to this viewpoint, are simply not fundamental" (Randall, 1987, p. 20). It has already been noted that an optimistic view of technology is imprudent (see section 3.5.2).

Closed-system assumptions

From a system's perspective, neoclassical economics implicitly views the economy as a closed system. It is an implicit view because neoclassical economics does not attempt (or does not view it as important) to explicitly define the boundaries of the economic system (Ruth, 1993, p. 5). Some economists acknowledge the fact that the closed-system view is restrictive. For example, Norgaard (1985, p. 388) quotes Sir John Hicks as stating "it is because the range of phenomena with which economics deals is so narrow that economists are so continually butting their heads against its boundaries."

The implications of this for eco-efficiency are two-fold. First, a neoclassical approach to eco-efficiency is restricted to the immediate, direct effects of an action within the closed system. Wider flow-on effects within and between the environment and economy are simply ignored. Second, closed-system assumptions lead to resource misallocation (Amir, 1994). The only way to avoid resource misallocations is to recognise that the economy is an open system from both economic and thermodynamic perspectives (Amir, 1994, p. 140).

Scale, time and thresholds ignored

The assumption of the limited role of the physical environment leads neoclassical economic theory to neglect scale, time and environmental threshold issues (Söllner, 1997). Neoclassical

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[62] However, Amir (1994 p. 136) suggests that "nobody claims that economic or ecological systems operate in violation of thermodynamic laws. Rather, the claim is that economic and policy theorists are precluded from suggesting appropriate measures to curb the excessive use of natural resources because in their theories they ignore constraints imposed on these systems by these laws".

[63] That is, land scarcity after David Ricardo's (1772-1823) seminal work on the theory of rent and diminishing marginal productivity of land. Ricardian scarcity is now taken to refer to natural resources in general.

economists have largely ignored issues of scale (the physical volume of the throughput of matter and energy). Scale issues are considered 'outside the domain' of economics (Daly, 1992a; Jenkins, 1996; Norton, Costanza, & Bishop, 1998). Yet they are important ingredients in sustainable development decision making, and many suggest they must be considered ahead of efficiency considerations.

Similarly, an implication of the mechanistic, deterministic view of neoclassical economics is that it ignores the important role of time. All physical processes relevant to the functioning of economies require energy, involve time, and are irreversible. These concepts have not been given the attention they deserve in economic theory (Faber & Proops, 1985). Instead, neoclassical economics assumes perfect reversibility (Faber & Proops, 1994, p. 10; Farmer, Kahn, McDonald, & O'Neill, 2001; Söllner, 1997). Regardless of what is done to nature, it is assumed able to be undone. From this point of view, potentially catastrophic developments (such as the greenhouse effect) cannot be appreciated. In this way, it could also be argued that neoclassical economics ignores environmental thresholds.

These views undermine the importance attributed to eco-efficiency. Ignoring scale, time and environmental thresholds trivialises the environmental problems that provide the rationale for pursuing eco-efficiency.

An anthropocentric approach to an anthropocentric concept

Eco-efficiency, from its core definition, is an anthropocentric concept. Likewise, economics is anthropocentric because it is concerned with how *people* manage scarce resources. Indeed, in van den Bergh's (1996, p. 24) attempts to classify different economic perspectives, he notes that neoclassical economics is the most anthropocentric of all the perspectives he considers. This focus manifests itself in two ways relevant to eco-efficiency.

The anthropocentric focus influences the numeraire economists use to measure eco-efficiency; principally money. Money is a medium of exchange and a useful unit for commensuration. For this reason, economists tend to reduce measures of eco-efficiency to monetary units (for example, see Hilson, 1999, p. 195). However, in understanding ecological-related issues such as eco-efficiency, adherence to monetary values can have limitations. In particular, a reliance on monetary values biases against ecological objectives. For example, if quantifying eco-efficiency was to rely on dollar values, then relevant ecological issues that are difficult to monetise, such as the contribution of biodiversity, would be difficult to accommodate. Relying on purely monetary values to quantify eco-efficiency could lead to a false conclusion that one had accounted for all environmental concerns. That is, one would, erroneously, see the part as the whole; '*pars pro toto*'.

An anthropocentric view also inflects what neoclassical economists see as the tradeoffs with eco-efficiency. Neoclassical economists have played an important role in highlighting the trade off between equity and efficiency concepts. Given the importance of equity considerations, efficiency (and eco-efficiency) can only be a necessary but not sufficient condition of maximising society's welfare (Randall, 1987).

4.3.4 Summary of neoclassical economic efficiency interpretations and insights into eco-efficiency

Efficiency is core to economics. However, the meaning can be problematic because of its multidimensional nature. Neoclassical economic efficiency concepts can be grouped into production theory and welfare economics. These bodies of theory provide many interrelated concepts of efficiency as shown in the diagram below.

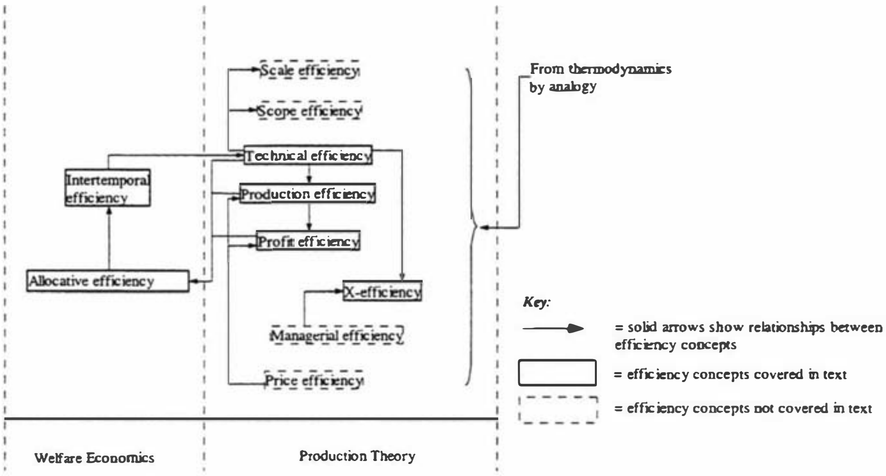


Figure 4-9: Interrelationships between neoclassical economic efficiency concepts

A neoclassical economic perspective of eco-efficiency would highlight several important characteristics. These are shown in the table below.

Table 4-3: Insights and lessons for eco-efficiency from a neoclassical economics perspective

Efficiency concept	Insights and lessons for eco-efficiency
Neoclassical economic production theory	
Technical efficiency	Focuses on the efficiency of the production process; Focuses on those inputs and outputs that are commodified as part of the production function; Focuses on direct inputs and outputs; Emphasises on technology;
Production efficiency	Emphasises the need to consider prices when allocating resources Focuses on profit objective;
x-efficiency	Helps to identify why the firm is not on the outermost production possibility frontier (for example, because unnecessary waste has not been eliminated); Helps to identify waste reduction that can be achieved;
Neoclassical welfare economics	

Allocative efficiency	Eco-efficiency should be focused on arranging resources to maximise welfare; It is important to internalise externalities to achieve optimal eco-efficiency;
Intertemporal efficiency	Rational consumers consider time in their decisions to use natural capital, and these decisions are influenced by interest rates.
Assumptions	Eco-efficiency achieved when the 'right context' is set; Predictive statements about eco-efficiency are appropriate in an equilibrium world; Atomistic focus implies that neoclassical economic approach to eco-efficiency ignores wider system interdependencies; Assumed reduced importance of the physical environment implies that eco-efficiency is less important than other efficiency concepts; Focus only on 'capital' inputs that can be commodified; Time and physical scale issues are not important.

These insights and characteristics of eco-efficiency could lead some to criticise the neoclassical economic approach to eco-efficiency as being narrow. However, this is not a reason to dismiss the interpretations out of hand. They merely add to the rich tapestry of eco-efficiency interpretations.

4.4 Ecosystem ecology approaches to eco-efficiency

Ecology adds yet more efficiency-related terms to what is already a crowded lexicon. As prominent ecologist Howard Odum (1971, p. 92) states, "many names have been used to describe various kinds of efficiency, and definitions are not always clear."

According to Odum (1992, p. 542), ecology is a "separate discipline that integrates organisms, the physical environment, and humans." Ecological science has tended to take two different orientations (Edwards-Jones, Davies, & Hussain, 2000, p. 6): community ecology[64] and ecosystem ecology[65]. Community ecology includes little reference to efficiency. In contrast, ecosystem ecology is rife with discussions of efficiency ranging from the efficiency of energy and matter transfers between trophic levels to the efficiency of human interaction with the environment (as in the case of Odum, 1996). Consequently, this section draws on efficiency concepts in ecosystem ecology.

4.4.1 The role of efficiency in ecosystem ecology

Concern for efficiency in ecosystem ecology theory has a shorter history than in thermodynamics or economics. According to Martinez-Alier (1987, p. 9) it wasn't until the

[64] Predominantly focused on themes such as patterns of behaviour, individual species relationships and the dynamics of population.
[65] Predominantly focused on systemic behaviour, and investigating relationships between elements of an ecosystem.

mid-19th century that ecologists came to consider the efficiency and transformation of energy by plants and animals as a central question in their research. Lotka (1925) was among the first to apply the idea of efficiency directly to biological systems. Following thermodynamics, he defined efficiency as the fraction of energy (Q), converted into work (W). By the 1940s, a variety of efficiency ratios were being calculated by ecologists. For example, Juday (1940) looked at, *inter alia*, the efficiency of solar energy utilisation in Lake Mendota, Wisconsin, USA. But perhaps the most important contribution to the concept of ecological efficiency came from Raymond Lindeman (Lindeman, 1941; Lindeman, 1942).

Lindeman was the "first to implement Tansely's ecosystem concept in a quantitative effort to define the system and described and understand its dynamic behaviour" (Golley, 1993, p. 50). His quantification was an effort to define and understand the dynamic behaviour of his study site, Cedar Bog Lake in Minnesota, USA. The contribution of Lindeman's coupling of thermodynamics and ecology was a watershed for ecosystem ecology's notion of efficiency. In particular, it enabled ecologists to quantify the energy and material flows through trophic levels[66] and therefore, to develop mathematical models. By applying efficiency ratios, Lindeman found that higher trophic levels had higher efficiencies than lower trophic levels[67] (Golley, 1993, p. 94). Lindeman's work also enabled ecosystem ecology to parallel economics by adopting a single numeraire (i.e. energy) (Golley, 1993). As a result of Lindeman's work, ecologists could answer two research questions related to the first and second laws of thermodynamics: 1) did energy inputs equal energy outputs (i.e. first law system balance)? And 2) what is the efficiency of energy transfer between different trophic levels (i.e. first and second law analysis)?

By applying energetic analysis, Lindeman extended Juday's approach into a more detailed analysis and definition of efficiency ratios (Golley, 1993, p. 52)[68]. In particular, Lindeman defined ecological efficiency as:

$$\textit{Efficiency}\ (\eta) = \frac{\textit{secondary consumers (or producers)}}{\textit{primary consumers (or producers)}} \qquad \textbf{Equation 4-25}$$

Lindeman's work also led to a proliferation of research into the levels and rate of efficiency in ecosystems (see for example, Chew & Chew, 1970; Golley, 1960; Golley, 1961; Golley, 1967;

[66] Hagen (1992) terms this a holological (or top-down) analysis.
[67] Ricklefs (1990) explains why this is the case. Animal food is more easily digested than plant food with assimilation efficiencies of predatory species varying from 60 to 90 percent. Vertebrate prey are digested more efficiently than insect prey because the indigestible exoskeletons of insects constitute a larger proportion of the body than the hair, feathers, and scales of vertebrates. The assimilation efficiencies of insectivores vary between 70 and 80 percent, whereas those of most carnivores are about 90 percent.
[68] Golley (1993) suggests that Lindeman's use of efficiency ratios was encouraged by two of his colleagues, Hutchinson and Deevey. Indeed, Deevey discussed efficiency with Lindeman in a letter dated 31 October 1940 to Lindeman (Golley, 1993, p. 212).

Golley, 1972; Kay & Schneider, 1992; Slobodkin, 1962; Wulff & Ulanowicz, 1989). The term ecological efficiency soon became popularised, and clearly entered the ecology lexicon as a result of Odum's book "Fundamentals of Ecology" (Odum, 1959).

Definitions of efficiency in ecology have received significant attention. Wiegert (1988, p. 34) defines efficiency in general terms as "the ratio of some defined output or product to the input or cost." Howard Odum (1971, p. 92), focuses on power[69] flows for his definition. In his view "any ratio of power flows is an efficiency and there are many kinds of power ratios." In a similar vein, Eugene Odum (1959, p. 53) defines ecological efficiency as "ratios between energy flow at different points along the food chain. Such ratios, when expressed as percentages, are often called ecological efficiencies." In ecological terms then, ecological efficiency is defined uniquely as a ratio of energy and matter flows.

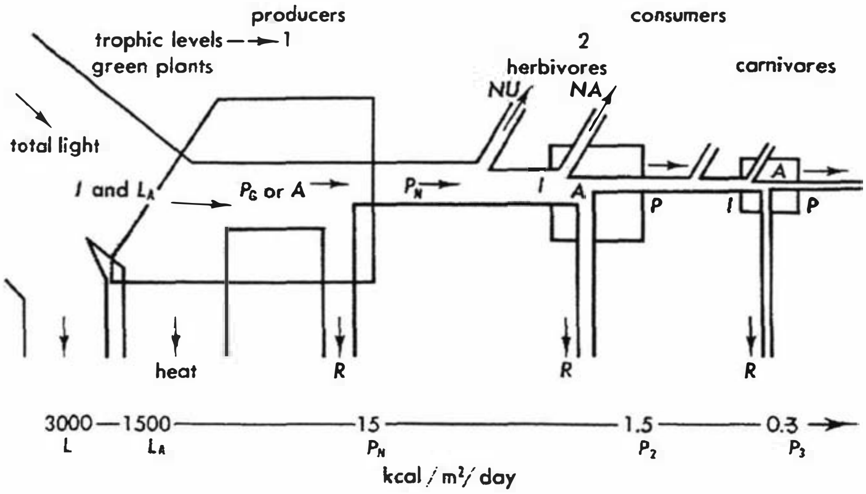
Discussion of efficiency concepts in ecological literature can be grouped into three areas: Eugene Odum's (1959; 1983) 'efficiency between and within trophic levels', Howard Odum's transformity (Odum, 1971; Odum, 1996) and the maximum power principle.

4.4.2 Ecosystems ecology interpretations of efficiency

Ecological efficiencies – between and within trophic levels

Ratios of energy flows at different points in the food chain are of interest to ecologists. Odum (1959; 1983) has grouped the ratios (or ecological efficiencies) into ratios 'between trophic levels and ratios within trophic levels.' These ratios are calculated by measuring the energy and matter flows through different trophic levels (as in Figure 4-10) and are presented in Table 4-4 below.

[69] The rate of flow of energy.



Standard notations for successive energy flows are as follows: I = total energy input; L_A = light absorbed by plant cover; P_G = gross primary production; A = total assimilation; P_N = net primary production; P = secondary (consumer) production; N_U = energy not used (stored or exported); NA = energy not assimilated by consumers (egested); R = respiration. Bottom line in the diagram shows the order of magnitude of energy losses expected at major transfer points, starting with a solar input of 3000 kcal per square metre per day.

Figure 4-10: A simplified energy flow diagram depicting three trophic levels (boxes numbered 1, 2, 3) in a linear food chain (Source: Odum, 1983, p. 123, Figure 3-9)

Table 4-4: Ecological efficiencies between and within trophic levels (based on Odum, 1983, p. 139 table 3-12)

Ratio	Designation and explanation	
Ratios between trophic levels		
$\frac{I_t}{I_{t-1}}$	Trophic level energy intake (or Lindeman's) efficiency. For the primary level this is $\frac{P_G}{L}$ or $\frac{P_G}{L_A}$	
$\frac{A_t}{A_{t-1}}$	Trophic level assimilation efficiency	For the primary level P and A may be in terms of either L or L_A as above; $A_t/A_{t-1}=I_t/I_{t-1}$ for the primary level, but not for secondary levels
$\frac{P_t}{L_{t-1}}$	Trophic level production Efficiency	
$\frac{I_t}{P_{t-1}}$ or $\frac{A_t}{P_{t-1}}$	Utilisation efficiency	
Ratios within trophic levels		
$\frac{P_t}{A_t}$	Tissue growth or production efficiency	
$\frac{P_t}{I_t}$	Ecological growth efficiency	

$\frac{A_t}{I_t}$	Assimilation efficiency

Where: L = light input (total); L_A is absorbed light; P_G is total photosynthesis (gross production); P is production of biomass; I is energy intake; R is respiration; A is assimilation t is trophic level; t-1 is preceding trophic level.

These ratios essentially focus on the capture and use of energy and matter by biological systems. In an eco-efficiency context, these ratios would focus on those biological systems with close links to human economic activity. These systems are commonly called 'primary production sectors' and include forests, agriculture and fisheries. A significant amount of research has gone into understanding and improving the ecological efficiency of primary production sectors such as poultry (see for example, Tomas, Pym, McMurtry, & Francis, 1998), marine prawns (see for example, Carvalho & Fowler, 1994), pea production (see for example, Adgo & Schulze, 2002) and wheat (Osborne & Rengel, 2002; Zhu, Smith, Barritt, & Smith, 2001).

Transformity

Another ecological perspective of efficiency is provided by Howard Odum's (1971; 1996)[70] concept of transformity. The concept of transformity emerged as part of his work on energy flows, energy quality and systems. Odum develops concepts that attempt to deal with the energy quality problem, and can be used to measure an aspect of ecological efficiency. Of particular interest in this discussion are his concepts of 'emergy', 'solar emergy' and 'transformity.'

E*m*ergy[71] is "the available energy of one kind of (sic) previously used up directly and indirectly to make a service or product" (Odum, 1996, p. 7). In order to deal with the energy quality problem, Odum (1996) converts all forms of energy to units of solar energy that would be required to generate all inputs; hence 'solar emergy'[72]. Solar emergy provides a basis for calculating a measure of ecological efficiency that is adjusted for energy quality; solar transformity.

[70] It is interesting to note that Cleveland et al. (2000, p. 307) state that the work by Howard Odum helped to form the 'intellectual backbone' of ecological economics.

[71] Odum first developed a measure of energy quality called "embodied energy." Briefly, this concept of energy "attributed to the stored potential energy at each trophic level a quality computed according to the energy dissipated at each trophic step leading from solar energy to the trophic level in question" (Wiegert, 1988, p. 44). This redefinition of energy was useful, but misleading. This is, because "embodied energy" was not really a different form of energy at all, but a new quantity. Odum eventually changed the name to reflect this and coined the term "emergy" to replace "embodied energy".

[72] Defined as "the available solar energy used up directly and indirectly to make a service or product. Its unit is the solar emjoule (sej) (Odum, 1996, p. 8).

Solar transformity is defined as the ratio of a product's solar emergy to its energy (Odum, 1996, p. 10). The units of solar transformity are solar emjoules (sej) per joule (J). A couple of observations can be made about transformity. As solar transformity is specified as inputs (solar emjoules) per useful output (Joules), solar transformity is actually the reciprocal of efficiency (as Odum himself acknowledges). Also, the more energy transformations involved in producing a product or service, the higher the transformity. This is because at each transformation, available energy is used up to produce a smaller amount of energy of another form. However, degraded energy is not available to do work, and has no emergy. Thus, with more energy transformations, emergy increases as the energy decreases (Odum, 1996, p. 11).

The transformity concept is particularly relevant when considering the economy's use of ecosystem services. Consider a simplified diagram of wood production of one hectare of Swedish spruce forest (see Figure 4-11).

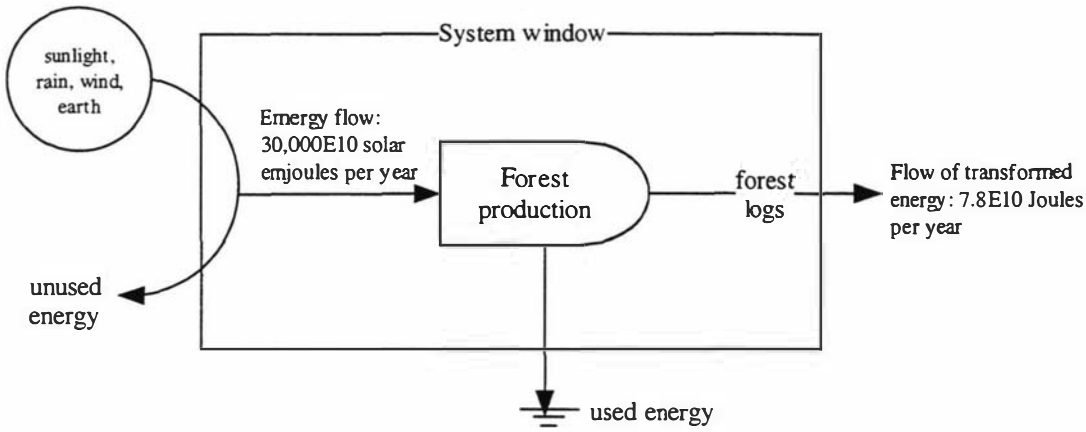


Figure 4-11: A simplified diagram of forest log production showing the flow of emergy and energy (Source: Odum, 1996, p. 8)

Figure 4-11 shows that the sum of environmental contributions to produce 7.8E10 J/year of spruce wood in Sweden is a solar emergy of 30,000E10 sej/year. In other words, the solar transformity of the logs is:

$$\frac{\text{solar emergy flow}}{\text{energy flow}} = \frac{30{,}000\text{E10 sej/year}}{7.8\text{E10 J/year}} = 3846 \text{ sej/J}$$ **Equation 4-26**

This approach has been used to calculate the transformity of many products. For example, Odum (1996) presents a table comparing transformities of plant products and fuels:

Table 4-5: Selected transformities for plant products and fuels (Source: Odum, 1996, p. 311)

Item	Transformity (sej/J)
Plantation pine wood	6.7×10^3
Lignite	37×10^3
Cornstalks	39×10^3
Rainforest logs	41×10^3

Natural gas	48×10^3
Corn	83×10^3
Electric power	200×10^3
Cotton	860×10^3

Emergy is a key variable for estimating transformity. As such, transformity offers a couple of useful insights into eco-efficiency. First, solar emjoules is a measure that attempts to commensurate different forms of energy. Any application of transformity necessarily involves an acknowledgement of the importance of accounting for energy quality.

Second, the emergy concept is a measure that "looks back upstream to record what energy went into the train of transformation processes" (Odum, 1996, p. 14). Similarly, transformity is proportional to the number of energy transformations involved in producing a product. In other words, emergy and transformity emphasise the importance of tracing indirect inputs to a product.

The maximum power principle

The concept of evolution has had a profound influence on ecology and on ecological views of efficiency. Starting from Lotka's (1925) work, many attempts have been made to find general laws for energy efficiency in evolutionary processes. Lotka (1925) suggested that natural selection tended to result in (i) increasing energy flow through biological systems and (ii) increasing energy efficiency of biological processes. His conjectures are often referred to as 'Lotka principles' (Buenstorf, 2000). In other words, Lotka argued that "those systems that survive in the competition among alternative choices are those that develop more power inflow and use it best to meet the needs of survival" (Peet, 1992, p. 11)[73]. Howard Odum developed Lotka's conjecture on increasing energy flows and referred to it as the 'maximum power principle' (MPP) (Odum & Pinkerton, 1955)[74].

The basic idea of the MPP is that physical or biotic systems tended to select in favour of processes that maximise the flow of energy (i.e. power). For example, an organism that maximises its power will grow faster than competitors that do not. Once it is larger than its competitors, it "will command greater resources, can use yet more power, and grow even faster" (Peet, 1992, p. 11).

In the context of understanding eco-efficiency, the MPP has an important implication. The MPP maintains that ecological or economic systems are selected to operate at an efficiency that

[73] Others have made contributions with regard to energy efficiency in evolutionary processes. For example Binswanger (1993), Schneider (1988) and Wicken (1998). It is beyond the scope of this thesis to discuss these other approaches in detail. For a useful summary refer to Buenstorf (2000).
[74] This is clearly closely aligned with finite time thermodynamic formulation outlined in section 4.2.2.

generates maximum power . Thus, this perspective accepts a certain determinism with respect to efficiency, in contrast to the discussion above.

4.4.3 Assumptions underlying ecological approaches to eco-efficiency

As with other approaches to eco-efficiency, the ecosystem ecology perspective is coloured by a number of underlying assumptions and ways of approaching reality. Of particular relevance to this thesis is the world view that follows from adopting an ecosystem approach, the implications that follow from evolutionary change perspective of the natural environment and adopting ecological energetics as a means to characterise efficiency concepts.

Ecosystem-based assumptions and implications for eco-efficiency

The ecosystem focus results in a world view, and consequent approach to eco-efficiency that:

- promotes a judicious mix of holistic and reductionistic analysis;
- emphasises the importance of boundaries;
- acknowledges complexity and questions an equilibrium view of systems;

Each of these is discussed in more detail below.

An holistic versus reductionistic approach

A major theme of ecological discourse is the argument between an holistic versus reductionistic approach (Hagen, 1992). Reductionism claims the nature of a phenomenon can be understood by reducing it to its parts. Holism takes another approach. It builds on a concept of unified structures (wholes), that include physical bodies, chemical compounds, organisms; a creative synthesis in which the whole is the synthesis of the parts (Smuts, 1926).

The debate between holistic versus reductionistic approaches is still unresolved in ecological literature. However, Golley (1993) points to a compromise solution. He suggests that what is needed is a judicious mix of analysis at both scales; the parts and the whole. The work of Koestler (1978) complements Golley's call. Koestler points out that neither end of the reductionism-holism 'spectrum' is sufficient on its own for scientific research. "Both reductionism and holism, if taken as sole guides, lead into a cul-de-sac" (Koestler, 1978, p. 26). Koestler offers an approach that attempts to account for the relations between wholes and parts through his concepts of 'holon' and 'holarchy.' A holon is "a stable, integrated structure, equipped with self-regulatory devices and enjoying a considerable degree of autonomy or self-government" (Koestler, 1978, p. 26). A holon is Janus-faced in that it can be both a part and a whole. Holarchy implies a hierarchy of holons.

The lessons from Golley and Koestler are pertinent to an ecological understanding of eco-efficiency. They suggest that an ecological approach to eco-efficiency would ideally promote a judicious mix of scales in analyses as well as a change of mind set that accepts that parts can be wholes and vice versa. From a pragmatic perspective, this suggests that examination of eco-efficiency at various levels, from the individual production process, to the firm, to the sector and the national level all provide an important part of the emerging eco-efficiency picture.

The importance of boundary definition

In ecosystem ecology, the definition of system boundaries is of fundamental importance. In fact, the need to clarify system boundaries is a direct implication of the ecosystem concept (Golley, 1993) and the application of thermodynamic laws to ecosystems (Ruth, 1993). However, ecology does not provide any direction on how to define boundaries. The common approach is to define them arbitrarily for the purpose at hand. As O'Neill et al.(1986, p. 4) state, "boundaries are abstract and precise definition is far from easy."

The definition of system boundaries is important for measuring eco-efficiency. This is because boundary placement influences the scope of the inputs and outputs included in eco-efficiency calculations (see section 2.4.3). Without a clear boundary definition, for example, the range of possible indirect inputs that could be traced back through the system would be essentially limitless. While ecology offers no prescription for where to place boundaries for economy-environment interactions, the work by Odum (1996), for example, suggests that an 'environmental window' as shown in Figure 4-12 is appropriate.

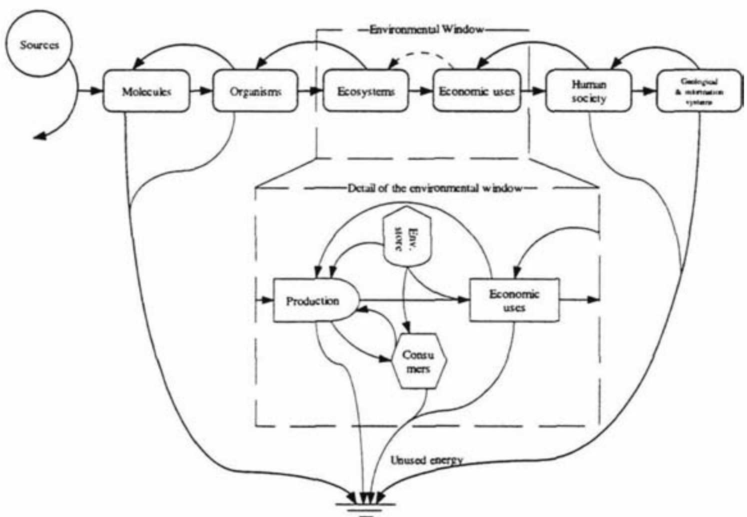


Figure 4-12: Odum's environmental window boundary (Source: Odum, 1996, pp. 3 & 6)

Complexity, dynamical behaviour and non-equilibrium assumptions

An ecosystem approach acknowledges the complexity of the interrelationships between system elements – in the case of eco-efficiency, between the environment and the economy. In the words of Malcolm Slesser (1989, p. 423) "the science of ecology entails an examination of nature in all its interconnected complexity."

Acknowledgement of complexity leads many ecologists to reject determinism. It is not true, Golley (1993) states, that the ecosystem approach requires ecosystems to function deterministically. Rather, it is likely that ecosystems evidence complex probabilistic behaviour over space and time.

Ecosystem ecology is also strongly grounded in a dynamical-system view of the world (Odum, 1983). Flows, cycles and feedbacks are all part of such an approach (see Chapter 2). Allied to this dynamical view is one that questions the existence of a stable equilibrium. While the concept of equilibrium has played an important role in the development of the ecosystem concept, (Golley, 1993; Hagen, 1992), there is still considerable debate over whether ecosystems tend towards equilibrium or not. Odum (1992) summarises current thinking when he states that ecosystems can be regarded as 'far-from-equilibrium systems' (Odum, 1992, p. 542). The modern approach to the existence of equilibrium is through the concepts of resistance[75] and resilience[76]. These describe how an ecosystem might respond to, or recover from, a disturbance (Golley, 1993).

The implication of these lessons for eco-efficiency is significant. From an ecological perspective, it appears that systems do not necessarily reach (or perhaps even tend to) a stable equilibrium. Therefore, predictive statements about an 'optimal' equilibrium goal for eco-efficiency are inappropriate (as stated in 4.3.3). Rather, ecologists use efficiency concepts as measures of the functioning of a dynamic system.

Evolutionary change and the maximum power principle

The many attempts (such as the MPP) to develop laws of evolution based on Lotka's thermodynamic conjectures must be treated with caution. While there is empirical evidence for energetic regularities in the development of ecosystems and in both biological and economic evolution, Buenstorf (2000, p. 125) argues that "the generality of the evidence is not sufficient to support the proposed laws of evolution as strict laws of nature."

---

[75] Resistance to disturbances describes how a system arranges itself to avoid or reduce change. According to Golley (1993) this is a function of a number of things, including the structural mass of the biota, the capacity to store the essential resources, the redundancy of essential components and a history of survival of past disturbances.

[76] The capacity of an ecosystem to respond after being disturbed is called resilience. Resilience is a function of several things, including the scale and intensity of the disturbance, the presence or absence of the biota, and efficiency. The resilience concept is central to many ecologist's notions of sustainability (see section 2.4.4).

Second, although the principle operates in some straightforward systems, its generality and applicability to more complex systems have not been fully demonstrated (Buenstorf, 2000; Hall, 1995). In response, Buenstorf (2000, p. 128) suggests Lotka's principles can be explained as emergent properties of the self-organisation of dissipative structures which arise in systems made up by a number of interdependent elements competing for energy resources.

Ecological efficiency concepts depend on an 'ecological energetics' approach

An ecological approach to eco-efficiency is firmly rooted in what Wiegert (1988) refers to as ecological energetics; a focus on energy flows through the ecosystem. O'Neill et al. (1986) call ecological energetics a functional approach to ecology because it focuses on the functions and processes between the biotic and abiotic components of the ecosystem.

The ecosystem ecologist's primary focus on energy and matter flows provides them with a unified framework within which to incorporate and measure concepts such as eco-efficiency. The application of thermodynamics to ecosystem ecology reinforces the need for attention to both first and second laws of thermodynamics (Ruth, 1993, p. 77). Both laws are important when considering eco-efficiency. By accepting the importance of the second law in particular, ecology maintains time irreversibility "with an emphasis on time as the axis of change, and on the incompleteness of systemic evolutions" (O'Connor, 1994, p. 66). Time, in this view, is "the Nemesis of any pretension to have determined the future, and connotes indeterminancy, ambivalence, and mutability of historical trajectories" (O'Connor, 1994, p. 66).

However, an ecological energetic approach to eco-efficiency is limited in three important ways. First, the functional analysis ignores some of the complex interrelationships (such as interspecies relationships or social and economic interdependencies). Whenever a functional analysis looks at fluxes of energy, materials and information through a system, it does so as though the fluxes existed independently of the species involved in the system. It is important to note that the functional approach cannot provide a comprehensive perspective of eco-efficiency.

Second, Holling (1973, p. 1) notes that the ecologist's traditional analysis in theoretical and empirical ecology is "largely inherited from developments in classical physics and its applied variants." This is particularly the case for ecological energetics. The application of classical science to ecology inevitably implies a tendency to emphasise the quantitative rather than the qualitative (and the related pars pro toto problem as discussed in section 4.3.3).

Finally ecological energetics implies an 'objective' view of ecological interactions. However, the concept of efficiency per se, and eco-efficiency in particular are anthropocentric concepts, which involve value judgments (such as assigning a positive 'value' to assimilation and a negative 'value' to waste) (Ruth, 1993, p. 76). In this context, ecology's putative objectivity is misleading. The mere focus on efficiency in ecological research belies a value judgment about the importance of efficiency.

4.4.4 Summary of ecosystem ecology interpretations of efficiency and insights into eco-efficiency

A focus on efficiency is a natural consequence of ecosystem ecology's focus on energy and material flows. Ecosystem ecology provides a theoretical foundation for a number of efficiency concepts. Ecological interpretations of efficiency derive primarily from three sources; Odum's (1959) ecological efficiencies 'between and within trophic levels', Howard Odum's transformity and the maximum power principle. The interrelationships between these concepts are shown in the diagram below.

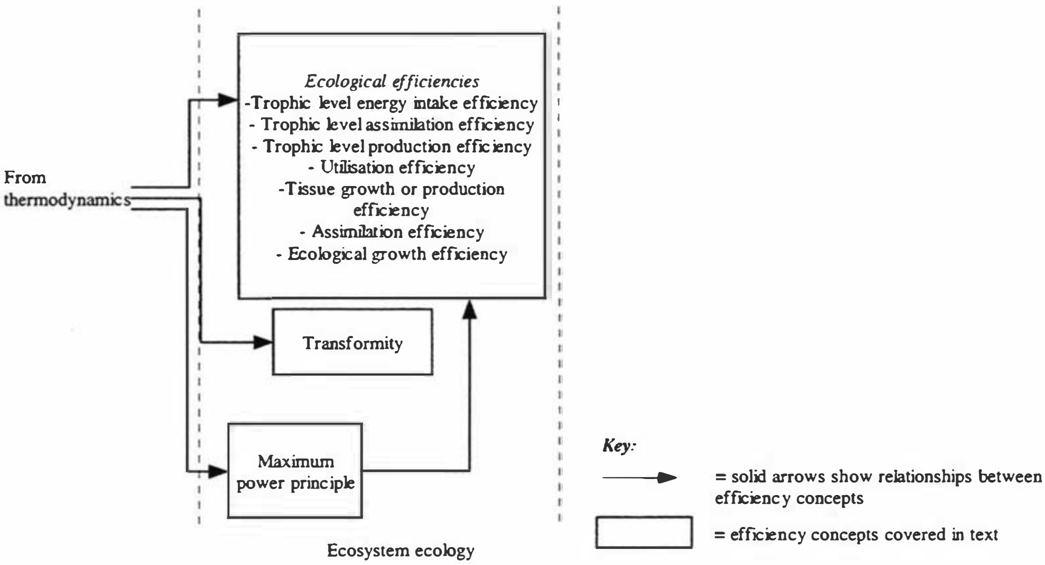


Figure 4-13: Interrelationships between ecosystem ecology efficiency concepts

An ecosystem ecology perspective provides several insights into eco-efficiency. These are summarised in the table below:

Table 4-6: Insights and lessons for eco-efficiency from an ecosystem ecology perspective

Efficiency concept	Insights and lessons for eco-efficiency
Ratios within and between trophic levels	Efficiency is defined in terms of energy and matter flows; Focuses on ecosystem service use by primary industry/biological sectors of the economy;
Transformity	It is important to account for energy quality in eco-efficiency; It is important to account for 'indirectness' in eco-efficiency;
Maximum power principle	The level of eco-efficiency is a function of evolution; Systems are selected to operate at the eco-efficiency that generates maximum power;
Assumptions	Eco-efficiency analyses require a judicious mix of scales; Boundary definition is important; Evolutionary change and eco-efficiency relationship is a conjecture only; The functionalist approach ignores some of the complex interactions in a system.

4.5 Conclusions

This chapter has attempted to illuminate the insights into eco-efficiency from the three core disciplines of ecological economics. It has done this by placing the discussion in a theoretical analysis. Such a theoretical discussion has hitherto been neglected in eco-efficiency related literature.

This chapter has established that eco-efficiency has a core, or 'timeless' meaning, i.e. a constancy of meaning that exists throughout the different contexts. This core meaning is overlaid and hidden by disciplinary accretions and must be uncovered through etymological and contextual analysis. The core meaning of eco-efficiency could be "a measure of the success (accounting for environmental impacts) of economic activities aimed at promoting sustainable development that is quantified as the ratio of useful outputs to ecological inputs".

From a context-specific perspective, the efficiency concept has multiple interrelated interpretations. These different interpretations depend critically on the academic discipline of the interpreter. The interrelationships are summarised by combining Figure 4-4, Figure 4-9, and Figure 4-13 together into Figure 4-14 below.

Each of these efficiency concepts potentially provides a unique perspective and insights into eco-efficiency. The range of insights into how each discipline would approach the eco-efficiency concept are many and varied. Also, all perspectives of eco-efficiency are coloured by the epistemological assumptions that underpin each academic discipline. These insights and assumptions are summarised in the table below.

Table 4-7: Summary of insights and lessons for eco-efficiency from classical thermodynamic, neoclassical economic and ecosystem ecology theories

Efficiency concept	Insights and lessons for eco-efficiency
Classical thermodynamic theory	
Thermal efficiency	Provides a formulation for eco-efficiency concepts as the ratio of useful energy output to inputs;
Efficiency measures based on ideal limits	Emphasises that there are limits to eco-efficiency; Useful for identifying the theoretical savings that can be achieved in eco-efficiency; Useful for identifying the proximity to eco-efficiency limits;
Finite-time efficiency	Emphasises the trade-off between efficiency and speed of transformation;
Efficiency measures adjusted for energy quality	Highlights the importance of energy quality; Emphasises that useful work should form the basis for an eco-efficiency that accounts for energy quality;
Assumptions	Nature is controllable therefore eco-efficiency is controllable; Eco-efficiency is focused on machines of work; Equilibrium implies the level of eco-efficiency is computable and unique; The motives for pursuing eco-efficiency are both limited resources and a decrease in entropy generation;
Neoclassical economic theory	
Neoclassical economic production theory	
Technical efficiency	Focuses on the efficiency of the production process; Focuses on those inputs and outputs that are commodified as part of the production function; Focuses on direct inputs and outputs; Emphasises on technology.;
Production efficiency	Emphasises the need to consider prices when allocating resources; Focuses on profit objective;
x-efficiency	Helps to identify why the firm is not on the outermost production possibility frontier (perhaps because of unnecessary waste that has not been eliminated); Helps to identify waste reduction that can be achieved;
Neoclassical welfare economics	
Allocative efficiency	Eco-efficiency should be focused on arranging resources to maximise welfare; Eco-efficiency would add emphasis to the importance of internalising externalities;
Intertemporal efficiency	Rational consumers do consider time in their decisions to use natural resources, and these decisions are influenced by interest rates;
Assumptions	Eco-efficiency achieved when the 'right context' is set; Predictive statements about eco-efficiency are appropriate in an equilibrium world; Atomistic focus implies that neoclassical economic approach to eco-efficiency ignores wider system interdependencies; Assumed reduced importance of the physical environment implies that eco-efficiency is less important than other efficiency concepts; Focus only on 'capital' inputs they can be commodified;

	Time and physical scale issues are not important.
Ecosystem ecology theory	
Ratios within and between trophic levels	Efficiency is defined in terms of energy and matter flows; Focus on ecosystems service use by primary industry/biological sectors of the economy;
Transformity	It is important to account for energy quality in eco-efficiency; It is important to account for 'indirectness' in eco-efficiency;
Maximum power principle	The level of eco-efficiency is a function of evolution; Systems are selected to operate at the eco-efficiency that generates maximum power;
Assumptions	Eco-efficiency analyses require a judicious mix of scales; Boundary definition is important; Evolutionary change and eco-efficiency relationship is a conjecture only; The functionalist approach ignores some of the complex interactions in a system.

Together, the many different potential perspectives of eco-efficiency provide a rich tapestry with which to address the efficiency of economic-environmental interactions. This multi-dimensional nature of eco-efficiency presents a challenge for those concerned with improving eco-efficiency. A conundrum now exists; what is the best way forward for improving our understanding of eco-efficiency? Should a single definition be pursued, or is a pluralistic approach to eco-efficiency most appropriate for understanding the concept? The next chapter addresses this issue and presents an ecological economic conceptual framework for understanding eco-efficiency in a broad context.

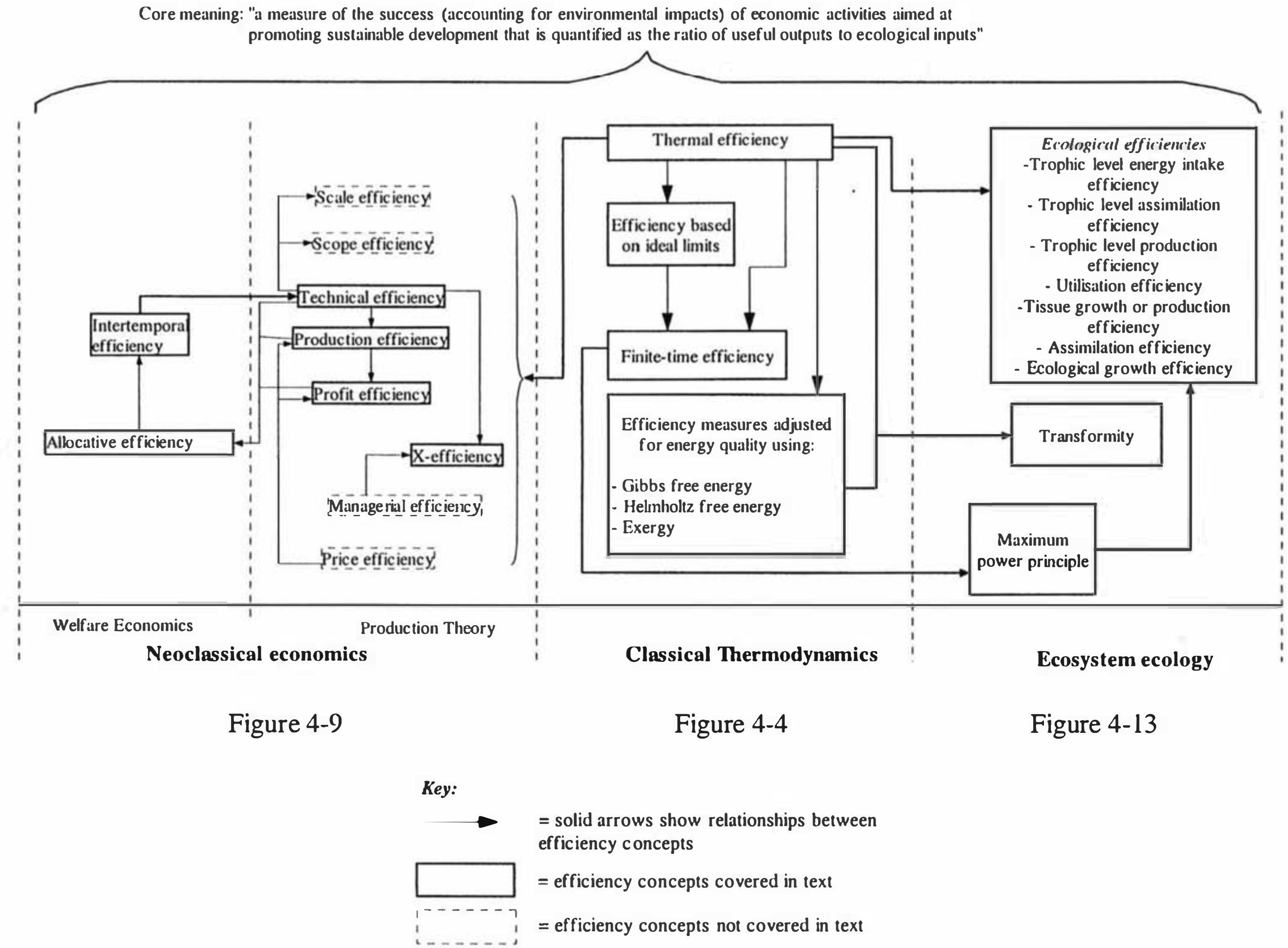


Figure 4-14: The interrelationships between the multiple efficiency concepts from classical thermodynamics, neoclassical economics and ecosystem ecology

5 Towards a pluralistic framework – an ecological economic approach to eco-efficiency

> *"The question is," said Alice, "whether you can make words mean so many different things." "The question is," said Humpty Dumpty, "which is to be master – that's all."*
>
> (Carroll, 1872)

Words cannot be used cavalierly, as Humpty Dumpty recommends, without reaping some crop of confusion. The previous chapter attempted to show that there is a broader range of approaches to eco-efficiency than the EIE interpretations outlined in Chapter 3. It is now clear that there are many potential theoretically-sound approaches to eco-efficiency. This chapter presents a perspective of eco-efficiency based on ecological economic theory.

The concept of eco-efficiency has received relatively little attention in contemporary ecological economic literature. Notable exceptions are the articles by Hukkinen (2001) and Jalas (2002). Hukkinen critiqued eco-efficiency from an institutional and governance perspective. In contrast, Jalas attempts to extend the notion of eco-efficiency to include a time-use perspective on the materials intensity of consumption. Neither of these authors attempt to define eco-efficiency, although Hukkinen (2001, p. 311) implies that eco-efficiency and 'ecological efficiency' are synonymous.

This chapter attempts to remedy the lack of attention paid to eco-efficiency as a potentially important concept in ecological economic theory. In doing so, this chapter will discuss the role of efficiency in general in ecological economic theory and identify a way forward for an ecological economic approach to eco-efficiency. The chapter attempts to present a theoretically robust ecological economic framework for understanding eco-efficiency.

5.1 The role of efficiency in ecological economic theory

The concept of efficiency has had a long history in ecological economic tradition. As early as the Physiocrats, the notion of the efficiency of resource use was alluded to (see section 4.5.1). Similarly, early classical economic thinking focused on natural resource constraints (Ricardo and Malthus). This naturally led them to consider the idea of efficiency of resource use. For example, Malthus (1826, Appendix 1) states

> *"The poorer of a country to increase its resources or defend its possessions must depend principally upon its efficient population, upon that part of the population which is of an age to be employed effectually in agriculture, commerce or war; but it appears with an evidence little short of demonstration, that in a country, the resources*

> *of which do not naturally call for a larger proportion of births, such an increase, so far from tending to increase this efficient population, would tend materially to diminish it."*

Likewise, Ricardo considered that the growth of capital and population led to an extension of cultivation to less fertile and accessible land, and decreasing returns (poorer 'production efficiency') to farming (Oser & Brue, 1988).

Efficiency concepts continue to play a vital role in contemporary ecological economic theory. The basic world view of ecological economics is that the world economy's energy and material resource base (what Daly refers to as "ultimate means") is limited (Costanza, Daly, & Bartholemew, 1991). Efficient use of low-entropy energy and material resources is a direct conclusion that flows from this biophysical perspective of ecological economics. In the light of limited availability of materials and low-entropy energy and a limited waste absorption capacity of the environment, there is a need to strive for efficient use of energy and materials in order to limit the deviation from sustainable levels (Ruth, 1993).

Ecological economics identifies efficiency of resource use as an important strategy for achieving sustainable development (Ayres & Nair, 1984; Harris & Kennedy, 1999; Templet, 1999; Templet, 2001). For example, Templet (1999, p. 223) states that "sustainability is enhanced by strategies which promote ... resource use efficiency in economic systems." Furthermore, the prominent ecological economist Herman Daly states that with respect to technology "the rule of sustainable development would be to emphasise... the amount of value extracted per unit of resource ... Improving end use efficiency of resources is desirable regardless of whether the resource is renewable or nonrenewable" (Daly, 1990, p. 5). Efficiency can be seen as a strategy for reducing energy and material throughput to achieve a 'steady state economy'[1].

> *"There are two classes of investment for reducing the need for throughput ... reducing population [and]... The second class of investment ... is increasing efficiency of throughput use. More generally, this means increasing the efficiency with which capital, both natural and man-made, is used to provide life-support and life-enhancing services" (Daly, 1996, p. 83).*

Therefore, efficiency is an important part of any approach to sustainability for ecological economists (as discussed by Harris & Kennedy, 1999). Ayres and Nair (1984) suggest that it is

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[1] Proops (1989) reminds us that Daly's 'steady-state economy' is a utopia. It gives a description of a world as it might be, under certain strong assumptions. "The expectation is that we are unlikely to achieve a steady-state economy by rational and beneficial policies. However, as a utopia it *does* offer a very useful yardstick for the policies that can be recommended, and for those that should be resisted" (Proops, 1989, p. 67, italics in original).

important to increase the thermodynamic efficiencies of processes to offset the catastrophic rise in entropy associated with our present system.

Daly builds on this view of the importance of efficiency in his development of 'Steady State Economics.' In Daly's steady-state world, growth is limited, and all improvements must come from efficiency improvement (Daly, 1996, p. 85). "Since by definition growth is ruled out in the steady state, all progress must take the form of qualitative development or increases in maintenance efficiency ... and in service efficiency" (Daly, 1992b, p. 77).

However, ecological economic literature is clear that efficiency should not be considered the sine qua non of sustainable development (Callens & Tyteca, 1999; Woodward & Bishop, 1995)[2] for two related reasons. First, efficiency faces physical limits. Section 4.4.2 clearly established that "efficiency is subject to thermodynamic limits" (Daly, 1992b, p. 24). As Huesemann (2001, p. 285) states, "at some point, eco-efficiency improvements are no longer possible because they become cost-prohibitive due to the law of diminishing returns characteristic of technological innovations or because of thermodynamic constraints (i.e. second law)."

Second, efficiency faces 'social limits.' Efficiency is wholly inadequate to address issues of scale and distribution, which depend on ecological realities and social, political and ethical principles respectively. Ecological economic literature is clear that efficiency should not be considered in isolation (Daly, 1992b; Norgaard & Howarth, 1992). Daly (1996, p. 219) argues that efficiency (coupled with sufficiency, equity and sustainability) needs to become part of a new 'central organising principle' to replace 'growth mania.' Two slightly different approaches to addressing the scale, social goal setting and efficiency tradeoffs are found in ecological economic literature (see section 5.3.1 below).

Ecological economic theory saves an important place at the sustainable development table for efficiency-enhancing strategies. However, efficiency in itself is not regarded as sufficient for achieving sustainability goals.

5.2 The concept of efficiency in ecological economics

Despite the important role of efficiency in ecological economic theory, little work has been done to develop an ecological economic approach to efficiency. The rhetoric of ecological economics (see Chapter 2) suggests that a theory of efficiency should:

- focus on integrating ecological and economic theory;

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[2] See also Chapter 2.

- be based on a biophysical perspective of economic-environment interactions;
- take a systems perspective;
- link efficiency concepts with sustainable development;
- be inter/transdisciplinary.

5.2.1 Current usage of the efficiency concept in ecological economics

Regardless of the rhetoric of ecological economics, "ecological economics will, in the end, be what ecological economists do" (Costanza, 1989, p. 2). A review of 91 articles in the journal *Ecological Economics* (volumes 1 through 42) that discuss efficiency[3] provides useful insights in this regard. The analysis of these papers indicates that there is a divergence between ecological economic theory and revealed practice.

Taken together, the 91 papers cover an appropriately eclectic range of efficiency concepts, from allocative and x-efficiency to ecological and food-conversion efficiency. However, this aggregate view is misleading. Ecological economic literature is dominated by applications of economic efficiency concepts (70 percent of the 91 articles reviewed), and allocative efficiency in particular (51 percent of all 91 articles) (see Figure 5-1). In fact, 33 of all of the articles applied the allocative efficiency concept in isolation of other efficiency concepts or wider social, ecological or thermodynamic considerations. These articles present research that is essentially indistinguishable from neoclassical economic analyses.

[3] That is, those articles that mention efficiency in the keywords or abstract.

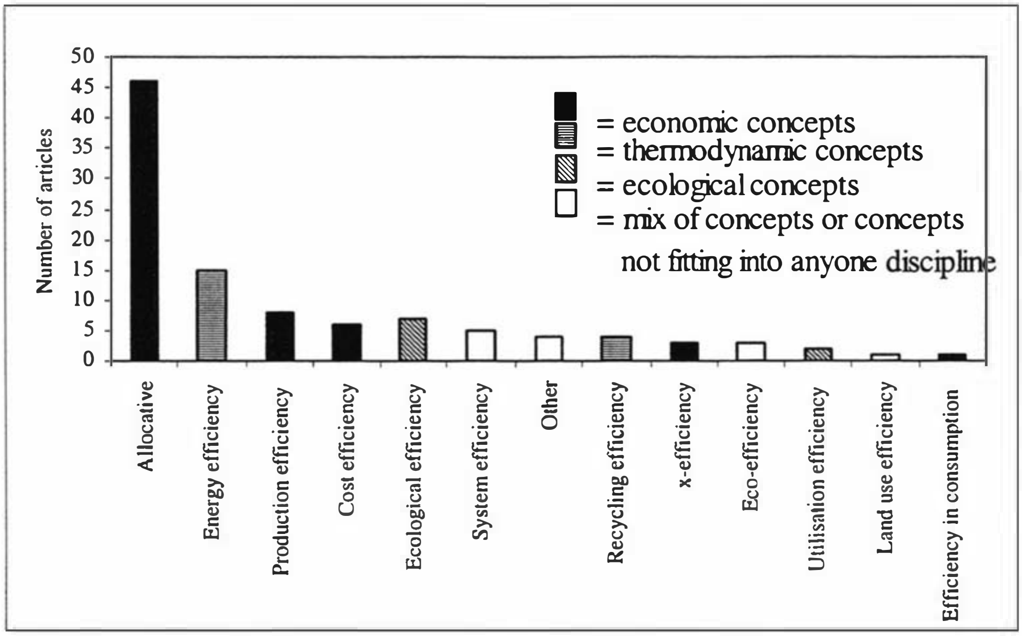

Figure 5-1: Number of efficiency-related articles in the journal *Ecological Economics* (volumes 1 through 42) by type of efficiency concept[4] and discipline[5]

Thermodynamic-related efficiency concepts (energy efficiency and recycling efficiency categories in Figure 5-1 above) were applied in approximately 20 percent of the articles. However, most of these articles addressed issues of energy efficiency from a thermal-efficiency perspective. Only three articles actually attempted to draw energy quality considerations into the ecological economic literature (Amir, 1994; Azar, Holmberg, & Lindgren, 1996; Matutinovic, 2002).

Few articles (10 percent) drew on ecological theory of efficiency. This is surprising given ecological economics' putative attempt to integrate ecological and economic theory. Of specific interest to this thesis is that only three papers (3 percent) dealt with eco-efficiency explicitly (Huesemann, 2001; Hukkinen, 2001; Jalas, 2002).

Another interesting finding is that, despite ecological economics' call for pluralism, only 11 articles attempted to use more than one efficiency concept in their analysis. Of these articles, five papers used only economic concepts (Aldy, Hrubovcak, & Vasavada, 1998; Felder & Schleiniger, 2002; Khanna & Zilberman, 1997; Regev, Gutierrez, Schreiber, & Zilberman,

[4] The 'other' category contains 'overall efficiency', 'absolute efficiency of cars and buses', 'efficiency of monitoring systems' and 'efficient attribute combination.'
[5] Note that the number of efficiency concepts presented in Figure 5-1 add to more than the number of articles, because several articles mention more than one efficiency concept.

1998; Ricker, 1997). The remaining six papers draw on efficiency concepts from more than one discipline and could be regarded as 'interdisciplinary.' It is in these latter six articles that we find at least one useful advance in ecological economic theory of efficiency. The work by Hannon (2001; 1998) presents an accounting framework that integrates ecological and economic theory and allows estimation of 'technical system efficiency' (see below). Unfortunately, neither Hannon's, nor the other four papers, appear to have received much attention[6] in ecological economic literature.

Another concerning finding from the review is the lack of attention to defining efficiency in the reviewed papers. Only 31 percent of the papers proffered a definition of the efficiency concept they used. Those that did not offer a definition implicitly assumed the reader would understand the specific efficiency concept under consideration. This absence of efficiency definitions is concerning because the range of efficiency concepts that are available to ecological economists is potentially far greater than in mono-disciplinary research (see for example Figure 4-14). Without explicit definitions there is considerable room for confusion over what is actually meant by the specific efficiency concept used.

Finally, a clear finding of the review of articles is the lack of development of a uniquely ecological economic approach to efficiency. Hannon (2001) presents one of the few attempts to develop a system-wide efficiency concept. In his work on attempting to combine ecological and economic systems in an input-output framework, he proposes what he calls "technical system efficiency." This efficiency is defined as "the ratio of the monetised value of the combined net input to the monetised value of the net outputs" (Hannon, 2001, p. 23-24). Hannon calculates this measure by considering what he calls flows of "irrecoverable stock or capital loss." These include flows like soil loss, diffusion of chemicals and metals and the radiation of high temperature energy to low-concentration energy that is lost from the economy. These unrecovered flows are classified as part of the total economic output, but not a part of net output. Thus, in the words of Hannon (2001, p. 23):

> *If we were able to cast the entire set of net inputs of the combined system into monetary terms, the economic value of the net output of the combined system could be calculated. We could then value the lost net outputs of the economic system and categorise such lost flows in the total system output measure, but not the net output of the system. Thus, the monetised value of the combined system net output would be less than the monetised value of the net inputs.*

Using this approach Hannon claims to have developed a technical efficiency concept that is;

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[6] That is, they have not been cited.

- useful for measuring and the effectiveness of reducing waste and the environmental impact of economic activity;
- consistent without double counting.

However, Hannon's approach is limited in several important ways. First, Hannon (2001, p. 19) comments that "no single measure of the system... efficiency can be given for the combined system,... until the ecosystem metabolism is converted into economic terms." This statement is limiting. Efficiency measures commonly do include different units for the denominator and numerator (see for example Patterson, 1996). Also, if Hannon is referring to the need to commensurate ecological and economic components, the need for monetary units is not a given. Many other commensurating numeraires are available (such as Odum's emjoules) and maybe more appropriate, depending on purpose.

Hannon's reliance on monetary measures of ecosystem inputs and outputs is also concerning from two other perspectives. Peet (1992) argues compellingly that some things may not be capable of valuation in terms of cash, or that they maybe priceless (ie have infinite value). Also, Hannon's confidence in contingent valuation seems ill placed (see Blamey & Common, 1994).

Hannon's approach is also methodologically complex and data hungry. Even if his approach was ideal, this complexity would likely limit the wider adoption of his efficiency concept. Finally, Hannon's approach appears relatively narrowly focused on waste and consequent environmental impacts.

In conclusion, it appears from this review of articles in *Ecological Economics* that what ecological economists 'do' with respect to efficiency leaves much to be desired. To find another potentially more methodologically rich ecological economic approach to efficiency, we must leave the journal articles and draw on Daly's worked on the steady-state economy.

5.2.2 Daly's "overall ecological economic efficiency" concept

One of the few 'ecological economic' approaches to efficiency is that developed by the prominent ecological economist, Herman Daly (1992b; 1996). In his work on the steady-state economy concept, Daly attempted to meld ecological and economic theory and in doing so provided a unique insight into efficiency.

Daly paints a simplified picture of economy-environment interaction as summarised in Figure 5-2 below. Daly's picture is based on the biophysical perspective of the economy-environment interactions that form the bedrock of ecological economics (see Chapter 2).

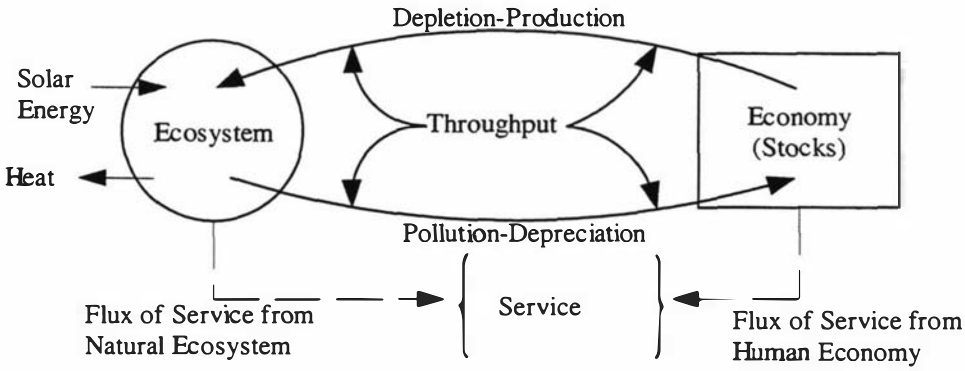

Figure 5-2: The concept of a steady-state economy (based on Daly, 1992)

Daly's work on efficiency arises out of his critique of neoclassical economic conceptions of efficiency. Daly (1992b, p. 94) states that

> *"Our current notions of efficiency are grossly confused. We usually measure only the efficiency of the fund factors, labor and capital (excluding consumer goods). GNP divided by number of laborers or by value of the stock of producer's goods are the usual measures. GNP is a flow, reflecting mainly the flow of throughput, an index expressed in value units, but measuring change in a flow of physical quantities. Thus the greater the flow of throughput (the faster the depletion ...) the higher is "efficiency." In other words, this notion of efficiency measures the efficiency with which we destroy what is valuable!"*

Daly draws on the 'core' efficiency ratio of useful outputs to inputs to define efficiency in a general sense as the ratio of services gained (useful output) to services sacrificed[7] (inputs). More specifically, when applied to the interaction of the economy and the environment he draws on both ecological and economic theory and defines efficiency as:

$$\eta_{Daly} = \frac{MK \text{ services gained}}{NK \text{ services sacrificed}}$$ **Equation 5-1**

Where MK is manufactured capital[8] and NK is natural capital. Daly (1996, p. 84) refers to this ratio as "overall ecological economic efficiency."

By means of an expanded identity, Daly breaks Equation 5-1 into four dimensions of efficiency.

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[7] That is, input is considered an opportunity cost or the 'sacrificed benefit of the best alternative foregone.'

[8] Daly (1996) refers to this as man-made capital (MMK). In order to avoid Daly's gender-specific term, MMK will be replaced by 'manufactured capital' (MK).

$$\frac{\text{MK services gained}}{\text{NK services sacrificed}} = \frac{\text{MK services gained}}{\text{MK stock}} \times \frac{\text{MK stock}}{\text{throughput}} \times \frac{\text{throughput}}{\text{NK stock}} \times \frac{\text{NK stock}}{\text{NK services sacrificed}}$$

(1) (2) (3) (4)

Equation 5-2

In other words, Daly presents efficiency as a concept with several interrelated dimensions. Each ratio on the right-hand side of Equation 5-2 represents a different dimension of efficiency. These ratios are described as:

(1) *Service efficiency*[9]. This ratio measures the service efficiency of manufactured capital stock. According to Daly (1996, p. 84) this ratio depends on the technical efficiency of the product itself, on the allocative efficiency among different product uses in conformity with individual preferences and ability to pay and distributive efficiency among individuals. The first two concepts are straightforward and conform to standard welfare and production economic theories (see Chapter 4). Daly introduces the issue of distribution across society as another aspect of this ratio.

An increase in the services gained from *MK*, would, ceteris paribus, lead to an improvement in this service efficiency ratio. It is this ratio that has received most attention from neoclassical economists.

(2) *Maintenance efficiency*[10]. This ratio reflects the durability of the manufactured capital stock. "While Ratio 1 measures the service intensity per unit of time of the man-made stock, Ratio 2 measures the number of units of time over which the stock yields that service" (Daly, 1996, p. 85). This ratio essentially measures the turnover or renewal period of the manufactured stock. The more durable the stock, the less maintenance and replacement (or throughput) it needs. Maintenance efficiency is increased if the quantity of manufactured capital increases while throughput is held constant. Similarly, this ratio is increased if throughput decreases, ceteris paribus. This ratio could be considered analogous to Odum's (1983) trophic-level production efficiency, ecological growth efficiency and assimilation efficiency ratios (see Table 4-4), because these measure stock growth per unit of energy input.

(3) *Growth efficiency*[11]. This "reflects the degree to which the ecosystem can maintain a supply of throughput on a sustainable basis" (Daly, 1992b, p. 79). In other words, this ratio measures

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[9] Originally referred to by Daly (1992b) as 'Artifact service efficiency.'
[10] Originally referred to by Daly (1992b) as 'Artifact maintenance efficiency.'
[11] Originally referred to by Daly (1992b) as 'Ecosystem maintenance efficiency.'

the efficiency of natural capital in yielding an increment available for offtake as throughput. This ratio is determined by the "intrinsic biological growth rate of the exploited population in its supporting ecosystem" (Daly, 1996, p. 85). For example, pine trees grow faster than mahogany, so in uses where either will do, pine is more 'growth efficient.' Daly's growth efficiency ratio could potentially accommodate Odum's transformity if throughput was measured in emjoules and NK stock was measured in joules.

(4) *Ecosystem service efficiency*. This ratio "measures the amount of natural capital stock that can be exploited for throughput (either as source or sink) per unit of other natural services sacrificed" (Daly, 1996, p. 86). This ratio addresses the question "is the loss of ecosystem stocks allocated among parts of the ecosystem in such a way as to minimise the total loss of ecosystem services"? (Daly, 1992b, p. 79). Ratio 4 is called ecosystem service efficiency to reflect the minimisation of loss of other ecosystem services when a population or ecosystem is exploited primarily for throughput.

A strength of Daly's efficiency formulation is that it captures several dimensions of the efficiency concept. Taken together, these dimensions paint a richer picture of efficiency than Hannon's 'technical system efficiency.' Furthermore, Daly's approach extends beyond considering simply natural 'resources' or 'capital' in an attempt to account for natural capital services (ratio 4).

Daly also notes that all of these ratios meet constraints. For example, he suggests technology can increase all four ratios, "but it confronts limits." Ratios 2 and 3 are limited by second-law constraints. Ratio 1 is limited by diminishing marginal utility and ratio 4 is limited by increasing marginal costs.

Despite Daly's leading work in this area, ecological economists have done little work to apply his concepts or develop his ideas further. Perhaps this is because, while Daly's (1992b) exposition of efficiency is appealing, it has several limitations. Daly's work on efficiency is influenced by ecological economics' preanalytic vision. This has already been outlined in section 2.5. This world view may not be a limitation as such. Rather, the point here is that it is important to be reminded of the assumptions that underly and 'bound' Daly's approach.

Daly's apparent attempt to provide a definitive interpretation of efficiency raises a conceptual tension with ecological economic theory. On one hand, ecological economic theory promotes 'pluralism' (see Chapter 2). On the other, Daly's approach could be construed as a prescriptive ecological economic definition of efficiency. To be fair to Daly, he does not present his efficiency concepts as such a fait accompli. He acknowledges that "the world is complex, and no single identity can capture everything" (Daly, 1996, p. 86). This caveat is important in the context of pluralism because although Daly's formulation is extensive in its coverage, there are several efficiency concepts outlined in Chapter 4 that it does not accommodate. These include:

- from the ecologist's palette input efficiency;
- from the economist's palette, profit efficiency and x-efficiency;
- from the thermodynamicist's gallery, energy-quality adjusted efficiency[12].

As a result, Daly's work cannot be considered sufficient in the context of ecological economic's pursuit of pluralism.

Another potential criticism of the Daly efficiency model could be targeted at his use of terminology. In addition to his inappropriate 'gender-specific' term "man-made capital", in his more recent book *Beyond Growth* (Daly, 1996) he also uses the term 'natural capital.' This is interesting given that his earlier work on the subject (Daly, 1992b) had a stronger ecosystem service focus. For example, his overall efficiency ratio was initially defined as the ratio of "artifact services gained to ecosystem services sacrificed." It is difficult to understand why Daly changed his terminology – perhaps it belies the author's economics background, or perhaps it was an attempt to make his work more accessible to an economics audience?

As with the term 'resource', 'natural capital' connotes natural goods with direct utilitarian benefits to people. In the place of natural capital, ecological economic theory has promoted the use of the ecosystem-service concept (see section 7.2.3). Daly (1996) still refers to ecosystem services in his ratio 4, but he has diluted the ecosystem service dimension. A more appropriate formulation of is efficiency model would see *NK* replaced by 'ecosystem services.'

From a production function perspective, Daly's approach usefully extends the standard production function, which subsumes natural capital (NK) within the economy along with labour (L) and manufactured capital (K) as in Figure 5-3(a).

[12] Although, perhaps Daly could argue that, if his ratios were measured in exergy terms, they could account for energy quality.

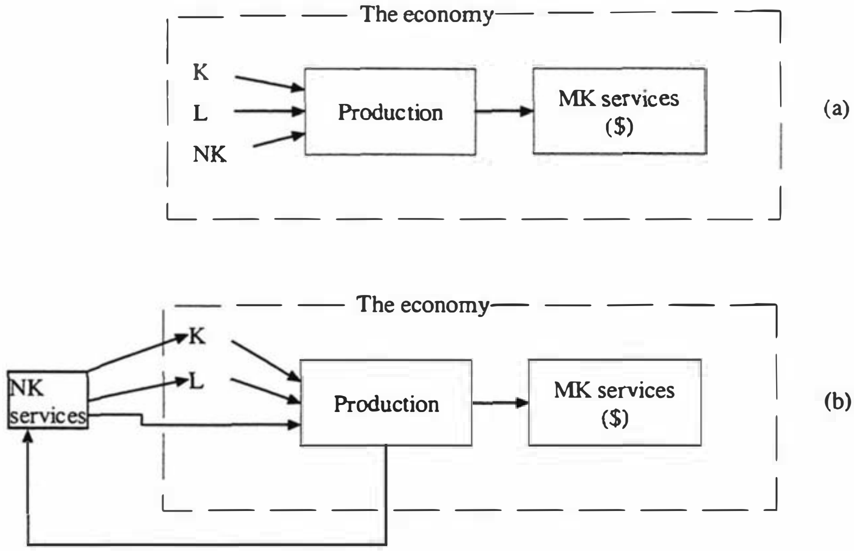

Figure 5-3: Diagrammatic representation of (a) the standard economic production function and (b) Daly's implicitly redrawn production function including NK services

Daly emphasises the importance of natural capital *services* and the economy's dependence on these services. Consequently, he implicitly redraws the production function to resemble something like Figure 5-3(b). However, Daly's ratios do not explicitly account for labour inputs. In the context of *eco*-efficiency, this may not be a concern since the focus is on the efficiency of use of ecosystem services in the economy; labour and capital inputs are of interest, but peripheral.

A further difficulty arises with Daly's ratios; how to address the tradeoffs that will inevitably arise between the various efficiency dimensions? For example, the durability of UPVC weatherboard homes may be greater than wooden cladding for houses (and, therefore, greater maintenance efficiency than wooden cladding). But UPVC is made from non-renewable resources and has poorer maintenance efficiency than wooden cladding. Daly's 'overall ecological efficiency' formulation provides no guidance on how to decide between these tradeoffs.

Finally, the measurement of some of Daly's ratios is problematic. For example, Daly is unclear how 'services' would be quantified or how the various '*NK* stocks' would be commensurated.

To conclude this discussion, Daly has presented one of the few attempts to refine an ecological economic perspective of efficiency, but it is limited in several important ways. Daly's formulation of efficiency is not necessarily the ecological economic interpretation. Given ecological economics' aim to move towards pluralism, it would seem that uniquely defining efficiency using Daly's approach is inappropriate, despite the merits of his particular method. Thus, because of ecological economics' pluralistic tendencies, it is inappropriate to define an 'overarching' theory of efficiency in ecological economics. Rather, ecological economic notions of efficiency are appropriately drawn from the core disciplines of ecology, thermodynamics and economics and would emphasise:

- drawing together ecological and economic theory;
- a biophysical perspective of economic-environment interactions;
- a systems perspective;
- linking efficiency concepts with sustainable development;
- an interdisciplinary approach.

5.3 Proposed ecological economic framework for interpreting eco-efficiency

Daly's approach could be considered a definition of eco-efficiency, but it has limitations. Of particular importance in ecological economics is the tension between presenting such a 'prescribed definition' and the idea of pluralism. As was discussed in Chapter 2, an ecological economic approach to eco-efficiency should promote pluralism and interdisciplinarity while at times being nourished by trandsciplinary insights.

Therefore, the framework presented below adopts a multidimensional approach that is essentially interdisciplinary in nature. The framework explicitly focuses on the three core disciplines of ecology, economics and thermodynamics.

The implications of interdisciplinarity for the framework presented below are important. The framework does not aim to show where economists' interpretations of eco-efficiency are right and ecologists and thermodynamicists are wrong or vice versa. Each discipline takes the core meaning of eco-efficiency, surrounds it with different assumptions and applies it to different areas of interest. Ecology, economics and thermodynamics address objects in the real world from different angles, make different assumptions and apply different methodologies on the 'same' phenomena. Instead of seeing this as a problem, this framework views diversity as an asset. Vedeld (1994, p. 3) states:

> *"it is possible to live with different approaches being applied to the same problems. When we get accustomed to it we will be able to translate and use such knowledge within our own perspectives and ways of thinking and doing research."*

It is precisely in the spirit of the semiotics philosopher Grice (1968) that this thesis has sought to illustrate the concept of eco-efficiency in economic, thermodynamic and ecological terms, rather than seeking a definition of eco-efficiency in a closed analytical way.

Despite the richness of approaches to eco-efficiency derived from the different theoretical bases, to date there has been no attempt to reconcile them in ecological economic literature. The lack of a framework that can accommodate this multi-dimensionality without losing either the core meaning of the term or the richness of the approaches through simplifying assumptions remains a significant lacuna in our ability to understand and improve eco-efficiency. The ecological economic framework presented below attempts to address this shortcoming. The framework consists of three tiers: scale considerations, goal setting and eco-efficiency.

5.3.1 A three-tiered framework

Eco-efficiency is a necessary but not sufficient condition for improving sustainability (Templet, 2001, p. 459). That is, progress towards sustainable development will inevitably require an improvement in the efficiency of ecosystem service use. However, improving eco-efficiency alone will not achieve the sustainable nirvana. Using eco-efficiency concepts alone cannot help distinguish between sustainable and unsustainable resource allocations. This is because there are an infinite number of eco-efficient states, some of which will be more sustainable, many others of which will use resources in a manner that will adversely affect later generations' welfare.

Because of the limits to eco-efficiency's ability to contribute to sustainable development, it is important to embed eco-efficiency within broader considerations. In particular, it is suggested that the goals of sustainable scale (Daly, 1992a) and social goals[13] such as equitable distribution (Daly, 1992a; Norgaard & Howarth, 1992) need to be considered before eco-efficiency. Two slightly different approaches to dealing with the scale, social goal setting and eco-efficiency tradeoffs are found in ecological economics literature.

Daly (1992a) suggests that it is not so much a trade-off but rather a hierarchy of issues that need to be considered. He suggests efficiency concepts are a third-order objective, subordinate to issues of scale and equity. Daly uses a tradable pollution permits scheme as an example to demonstrate the relation between the three goals of scale, distribution and allocation (Figure 5-4).

[13] It was noted earlier that this thesis was not considering socio-cultural implications for eco-efficiency interpretations. This does not preclude the importance of placing of the multiple disciplinary interpretations within broader social and political perspectives.

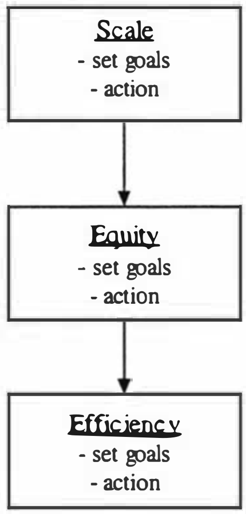

Figure 5-4: Daly's scale, equity and efficiency hierarchy

First, society must decide about an 'optimal' or 'sustainable' scale of operation. Scale "refers to the physical volume of the throughput, the flow of matter-energy from the environment as low-entropy raw materials and back to the environment as high entropy wastes" (Daly, 1992a, p. 186). In the pollution example, this would involve establishing the number of rights to pollute. Second, society must consider what is an 'optimal distribution' (i.e. equity). In the pollution example, this would involve deciding on the optimal distribution and then allocating the pollution rights accordingly. As noted by Norgaard & Howarth (1992), if questions of equity are not included, then although efficiency of resource allocation may improve, we may still only be moving from one less sustainable point to another. Only "in third place, after having made social decisions regarding an ecologically sustainable scale and an ethically just distribution, are we in a position to allow reallocation among individuals through markets in the interests of efficiency" (Daly, 1992a, p. 188). Essentially Daly's model involves both a goal setting and decision/action component in each of the three tiers.

It is dangerous to generalise this 'step by step' process as a model widely applicable for economic policy-making (Stewen, 1998). In particular, Stewen (1998, p. 122) states that "the great danger is to overlook the complexity of the problems and to ignore important interdependencies." A hierarchy and sequence order 'scale-distribution-efficiency' is not realistic in a complex world where economic policies are politically determined through coevolutionary incremental processes (Etzioni, 1967; Lindblom, 1959; Stewen, 1998). All three goals are inseparably connected.

A less linear model is proposed by Norton et al. (1998). They suggest a two-tiered interactive decision process (Norton et al., 1998, p. 195).

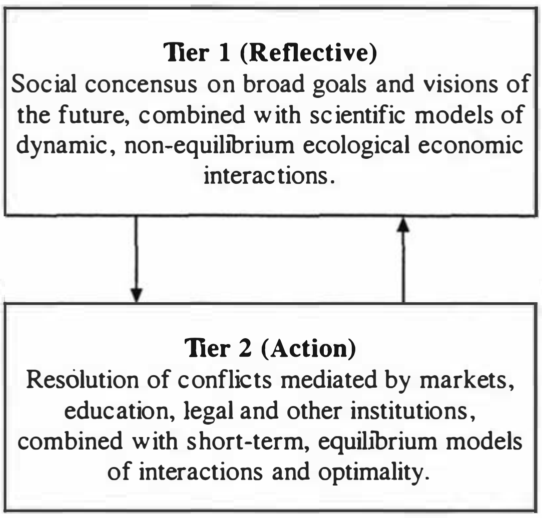

Figure 5-5: The two-tiered interactive decision process (based on Norton et al. (1998, p. 195))

The objective of the first tier is "to identify measurable physical processes that are relevant to locally-defined goals for environmental management" (Norton et al., 1998, p. 195). That is, it attempts to incorporate social goals into the resource management process. The second 'action' tier generates policy guidance by applying certain decision criteria (e.g. eco-efficiency). The two-tier process is described as interactive. It allows movement back and forth between an examination of social values and goals and the likely impact of acting on those values. Unlike most models for evaluating eco-efficiency, the two-tier system embeds both economic and ecological models in a larger social process. The first step in that process, however, is political, not scientific.

> *"A two-tier system of analysis therefore sorts possible environmental problems and risks according to the likely temporal and spatial scale of the impacts in the first tier, and applies an appropriate action criterion, such as cost-benefit criterion or a safe minimum standard criterion, given the scope and scale of possible risks of a policy in the second tier"* (Norton et al., 1998, p. 207).

Norton et al.'s (1998) model does accommodate Stewen's concerns about goal interdependence. However, while it acknowledges the importance of physical processes, it runs the risk of obscuring issues of scale and physical limits by combining them with other social issues in tier 1.

The issue of scale[14] is fundamentally different to other social issues in tier 1. While decisions about scale are decided by social processes, they must reflect physical limits (Daly, 1992a). Scale effects are inescapable (Costanza et al., 1991; Daly, 1996; Hardin, 1991). Daly illustrates

[14] 'Scale' is essentially shorthand for "the physical scale or size of the human presence in the ecosystem" (Daly, 1991, p. 35).

the fundamental nature of scale effects with a nautical plimsoll line analogy. The plimsoll line indicates how well weight has been arranged on board ship to keep the level. Even if you load the boat so that it keeps perfectly level it still sinks if you simply load it with too much cargo. Similarly, the economy may be succeeding with respect to social goals, but it can still 'sink' because it has exhausted the limited physical resources from the environment on which it depends. Other issues such as the type of governmental structure, or the mode of health-care provision within the first tier of Norton et al's (1998) model are less dependent on ecological limits. This leads to Costanza's (1989, p. 5) comment that "issues of sustainability are ultimately issues about scale."

This is not to say that decisions on the level of biophysical limits are not influenced by politics, etc. Rather, the point is that scale issues are a fundamentally different question than other issues. Scale issues must be addressed distinctly and "be settled at the beginning" (Daly, 1992a, p. 188).

> *"We must acknowledge that the human system is a subsystem within the larger ecological system. This implies not only a relationship of interdependence, but ultimately a relation of dependence of the subsystem on the larger parent system. The **first** questions to ask about a subsystem are: how big is it relative to the total system, how big can it be, and how big should it be?" (Costanza et al., 1991, p. 6 – emphasis added).*

Lumping scale considerations in with other social decisions can lead to scale issues being swamped by more immediate concerns.

In order to develop a workable framework for eco-efficiency, it is useful to combine the insights from both models (see Figure 5-6). Following Norton et al.(1998), reflective goal setting overlays the decision criteria and action tier. Furthermore, the model is interactive and acknowledges the movement back and forth between an examination of scale, social values and the likely impact of acting on those values. Consistent with Daly's model, the first tier necessarily involves a consideration of biophysical scale. This is superior to, but interacting with other goal setting that considers social issues such as equity and visions of the future. Efficiency concepts (and other decision criteria) are regarded as a third-tier consideration.

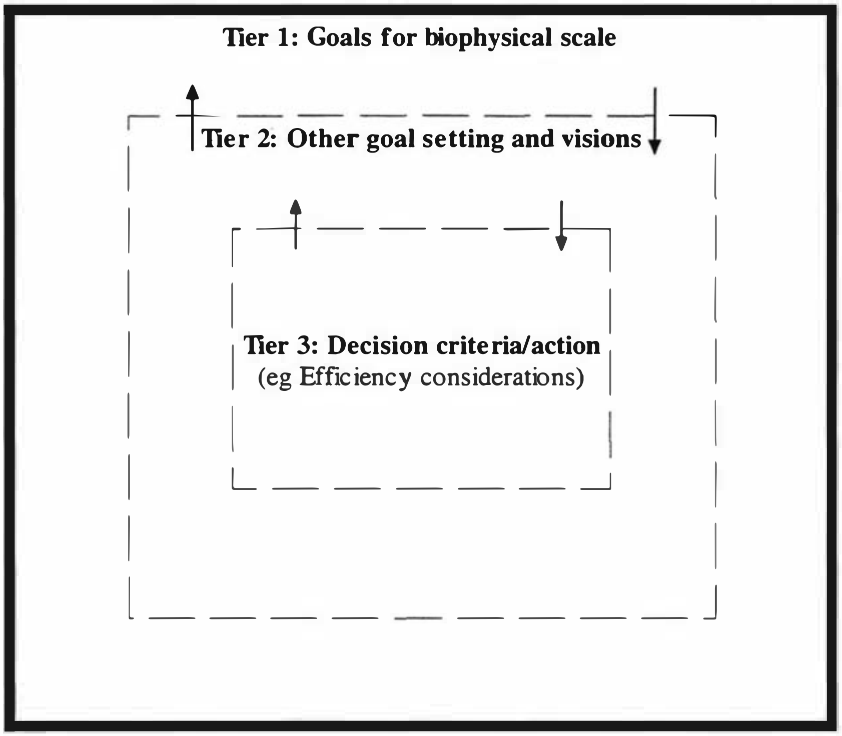

Figure 5-6: A proposed three-tier ecological economic framework for locating eco-efficiency within wider social and biophysical scale issues

5.3.2 Describing the third tier: the eco-efficiency space

The third tier deals with decision criteria and action in general terms. In this thesis, the focus of the third tier is on eco-efficiency concepts. This eco-efficiency tier can be understood by describing the role of eco-efficiency as a decision tool, the context-dependent nature of eco-efficiency and the plurality that must be embodied in the eco-efficiency tier.

Within the third tier, eco-efficiency concepts are used to generate guidance on how to pursue the goals set in tiers 1 and 2. Whether it be for a simple machine, or a more complex system, understanding eco-efficiency can help decision-makers to identify where changes to the system of interest should occur, if at all. However, eco-efficiency cannot be used as a decision criterion in isolation, nor will it be appropriate to use the eco-efficiency criterion in all circumstances. The eco-efficiency tier is subordinate to tiers 1 and 2 and must constantly interact with the higher tiers. There needs to be a constant movement back and forth between the higher-order goals and the impacts of acting on these goals using the eco-efficiency criteria. In some situations, goals from tiers 1 and 2 may not require input from an eco-efficiency perspective (such as a goal of achieving a more equitable wealth distribution). In other situations, eco-efficiency will provide fundamental information for decision-makers (for example, in the case of a goal to halve total material requirements – the popular "Factor 4" (Weizsäcker, Lovins, &

Lovins, 1997)). In the context of constant interactions between tiers, locating eco-efficiency within the third tier is useful because it highlights the limitations of eco-efficiency as a decision tool, as well as the tradeoffs, the necessary hierarchy and the complexity of decision-making involving economy-environment interactions.

Efficiency concepts (including eco-efficiency) are context dependent (Stein, 2001). That is, eco-efficiency is dependent not only on the goals set in tiers 1 and 2 as discussed above, but also on the disciplinary perspective (and the preanalytic vision this implies) and the nature of the system under consideration. For example, Chapter 4 identified that there are many approaches to the eco-efficiency concept stemming from thermodynamic, economic and ecological theory. Chapter 4 also highlighted that it appears that the place and role of efficiency differs between systems in equilibrium and those systems far-from-equilibrium (see section 4.4.3). The eco-efficiency concept that is chosen to assist decision-making is also dependent on the analytical purpose. For example, if the purpose of the analysis is to provide information on the eco-efficiency of a thermal electricity generation plant, then a thermal efficiency may suffice. If, however, the purpose is to inform on the appropriate allocation of resources within a factory, production efficiency would be more appropriate.

Because of the context-dependent nature of eco-efficiency, tier 3 is not tied to one eco-efficiency concept. Rather, it can be described as interdisciplinary and pluralistic (Figure 5-7 attempts to capture this idea). This interdisciplinary and pluralistic description is appropriate given that the contexts within which eco-efficiency can be applied can vary so dramatically. It is also appropriate given ecological economics' pursuit of pluralism. As a consequence, rather than defining eco-efficiency in the singular, tier 3 can be considered a multi-dimensional space that accommodates a pantheon of interrelated perspectives of eco-efficiency. In this way, tier 3 manifests a core conclusion of this thesis: that a combined application of the eco-efficiency concepts from thermodynamic, economic and ecology disciplines can describe eco-efficiency more richly than is possible with methods borrowed from a single discipline. Such a perspective is motivated by ecological economics' pursuit of new insights into the relationship between economic processes and environmental repercussions.

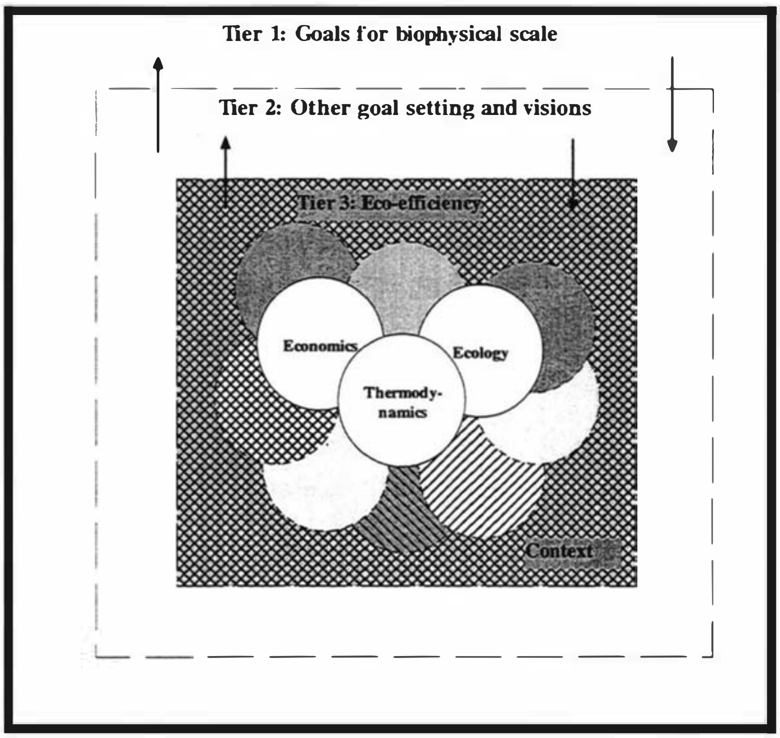

Figure 5-7: A depiction of the third, eco-efficiency tier showing different interrelated perspectives (spheres) embedded in context

The plurality embodied in tier 3 is important for two reasons. First, it encourages a view that different perspectives of eco-efficiency are intertwined and interdependent. That this is the case was established in Chapter 4, which commented that the thermal efficiency ratio developed in the physical sciences now pervades all efficiency concepts.

Second, the idea of pluralism promotes tolerance and an acceptance that all different perspectives offer important insights into eco-efficiency. Whereas neoclassical allocative efficiency can inform about the welfare maximising level of efficiency, an ecologist's approach to efficiency is required to understand the efficiency of nutrient assimilation in agricultural crops. No single eco-efficiency concept applies in all contexts. By accommodating multiple perspectives of eco-efficiency, tier 3 avoids losing the richness that would be lost by attempting to coalesce interpretations into a single definition and allows ecological economists to select the appropriate eco-efficiency concept for the task at hand.

In sum, a multi-dimensional, interdisciplinary third tier helps to encourage ecological economics move towards Norgaard's 'methodological pluralism', and a more pluralistic appreciation of the eco-efficiency concept.

5.4 Conclusion

This chapter has attempted to remedy the lack of attention to eco-efficiency as a potentially important concept in ecological economic theory. The chapter discussed the role of efficiency in ecological economic theory and revealed practice. Efficiency concepts play a vital role in ecological economic theory. Yet, despite the rhetoric, revealed practice suggests ecological economic analyses are dominated by neoclassical economic efficiency concepts. Little effort has been devoted to developing a uniquely ecological economic approach. Two potential approaches to efficiency in ecological economic literature include the work by Hannon (2001) and Daly (1996). Neither of these models were regarded as sufficient in their own right to be considered the definitive ecological economic approach to efficiency.

This chapter proposed a three-tiered framework that embeds decision criteria such as eco-efficiency within scale and other social issues. The eco-efficiency tier is sub-ordinate to scale and equity concerns. As such it usefully highlights the limitations of eco-efficiency as a decision tool as well as the tradeoffs, the necessary hierarchy and the complexity of decision-making involving economy-environment interactions.

Because of the context-dependent nature of eco-efficiency, tier 3 is appropriately interdisciplinary and pluralistic. The plurality in tier 3 encourages a view that perspectives of eco-efficiency are intertwined and promotes tolerance and an acceptance that all perspectives provide important insights into eco-efficiency. In this way, the hope is that the proposed framework can help to assist ecological economics take a step towards a more pluralistic appreciation of eco-efficiency, and efficiency in general.

Part II – Empirical applications

From concepts to empirical applications

If the eco-efficiency concept is to assist with mitigating the increasing global environmental crises, there is a need to move beyond the conceptual realm (as discussed in Part I). Part II shifts attention to empirical methods that can improve our understanding of the levels and changes in eco-efficiency. In this way, the thesis attempts to assist with the implementation of eco-efficiency as a means of addressing New Zealand's burgeoning material and energy throughput.

New Zealand case studies

The focus of Part II of this thesis is on eco-efficiency at the economy-wide level in New Zealand. Until now, little analytical work has been conducted on trying to understand the level and trends of eco-efficiency in New Zealand as a whole. To date, most attention to eco-efficiency has occurred at the level of the individual firm or business (see for example, New Zealand Business Council for Sustainable Development, 2002). A limited amount of effort has focused on eco-efficiency at the regional level with the *Eco*Link database work calculating eco-efficiency indicators for three regions of New Zealand (McDonald & Patterson, 1999). The lack of information on economy-wide eco-efficiency in New Zealand is a significant gap in New Zealand's eco-efficiency policymakers' arsenal.

In order to address this lack of information, Part II draws on the ecological economic framework in Chapter 5. It will be evident that it would be inappropriate to restrict Part II to presenting an analysis using just one tool, for at least one reason. Since the potential perspectives of eco-efficiency are so diverse, one tool cannot hope to capture the richness of the eco-efficiency concept. Therefore, Part II applies three selected analytical techniques. These techniques have clear links to an ecological economic research agenda.

In attempting to develop empirical applications of eco-efficiency Part II draws on the 'core' interpretation of eco-efficiency identified in Chapter 4:

> *Eco-efficiency could be generically described as "a measure of the success (accounting for wider environmental impacts) of economic activities aimed at promoting sustainable development that is quantified as the ratio of useful outputs to ecological inputs."*

This core meaning is broad enough to capture the many different perspectives of eco-efficiency but also provides the necessary ingredients to focus empirical analysis.

Chapter 6 investigates a mathematical economic approach to decomposing aggregate eco-efficiency indices into component parts. In other words, the chapter attempts to quantify the effect that key factors have on changes in aggregate eco-efficiency indices. This decomposition method is useful for helping analysts more fully understand the complex driving forces behind eco-efficiency in New Zealand.

Chapter 7 addresses the issue of system-wide eco-efficiency. Specifically, Chapter 7 estimates a matrix of eco-efficiency multipliers. These quantify the direct, indirect and total system-wide eco-efficiency of the New Zealand economy.

Chapter 8 addresses an important methodological issue related to eco-efficiency indicators; the need to aggregate eco-efficiency information for decision-makers. Chapter 8 investigates a promising statistical technique for achieving parsimony in the indicators matrix while attempting to minimise information loss.

6 Decomposition of eco-efficiency indicators: a case study using New Zealand's energy:GDP ratio

"In fact, the decomposition technique offers virtually the only way forward in identifying retrospectively the relative contribution of different factors to changes in energy demand."

(Ang & Skea, 1994, p. 13)

This chapter attempts to develop and apply a method for quantifying the effect key factors have on changes in aggregate eco-efficiency indices[1]. Aggregate eco-efficiency indices combine several aspects of eco-efficiency into a single number. As such, it can be difficult to identify the underlying factors that influence changes in the indices. This chapter applies a refined Divisia decomposition approach derived from economic theory to a selected aggregate that could be considered an eco-efficiency index[2]; the energy:GDP ratio[3]. The approach allows the analyst to delve behind the apparent simplicity of the aggregate index in an attempt to reveal the next layer of complexity; those factors, such as technical change and economic structure that affect an aggregate eco-efficiency index.

6.1 Rationale

The work of this chapter is consistent with several themes within ecological economics:

- policy relevance and the need for accurate and valid information on eco-efficiency;
- the role of technology;
- the importance of the role of energy in the economy and issues of 'energy quality';
- the emergence of decomposition techniques as a tool in ecological economics.

6.1.1 Policy relevance

A common theme to emerge from the literature is that ecological economics aims to be policy relevant. For example, Costanza (1991, p. 7) states that ecological economic "research should not be divorced from the policy ... process, but rather integrated with it." In other words, ecological economics is focused on the integration of economic and ecological theory specifically to aid decision-making (Edwards-Jones, Davies, & Hussain, 2000; Proops, 1989; Ruben & van Ruijen, 2001). In the words of van den Bergh (1999, p. 84) "the ultimate goal of

[1] In this thesis, the terms 'index' and 'indices' (used to refer to the aggregates formed by combining two or more indicators) are distinguished from the terms 'indicator' and 'sub-index' (used to refer to the components of the aggregate indices).
[2] That is, a measure of the efficiency of economic (GDP) and environment (energy) interactions.
[3] Although the approach could be applied to any aggregate eco-efficiency index.

economic-ecological analysis is aimed at formulating and implementing environmental management and policy instruments... for solving objectives such as... sustainability."

Consequently, it is not surprising that much of the ecological economic literature focuses on policy prescriptions. Two notable examples include Faucheux and O'Connor's (1998) "*Valuation for Sustainable Development: Methods and Policy Indicators*" and van den Bergh's (1999) "*Ecological Economics and Sustainable Development.*"

In the context of eco-efficiency, one way ecological economics can assist policy makers is by providing accurate and valid measures of eco-efficiency (Meadows, 1998). The aggregate energy:GDP ratio, as one eco-efficiency index, has been widely criticised because it is not necessarily a valid measure of changes in energy efficiency per se (Brookes, 1995). For example, it has been shown that several underlying components affect changes in the aggregate ratio. These factors include economic structure (Ang, 1994; Bending, Cattell, & Eden, 1987; Gardner, 1993; Jenne & Cattell, 1983; Marlay, 1984; Stern, 2002), factor substitution (Patterson, 1993b), fuel mix (Liu, Ang, & Ong, 1992b; Stern, 2002), energy quality (Jollands, Lermit, & Patterson, 1997; Jollands, Lermit, & Patterson, 2003), and actual technical efficiency (Schipper, Myers, Howarth, & Steiner, 1992). A method is required that can identify these factors in order to increase the validity and information value of the energy:GDP index for policy makers. The decomposition method below is presented as one tool that is particularly useful in this regard.

6.1.2 Understanding the role of technology

Understanding the actual role of technological improvement in eco-efficiency is particularly important from an ecological economic theory perspective. This is because there is considerable concern among ecological economists about the tendency by some (for example the EIE, see Chapter 3) to take an optimistic view of technology's ability to avert Ricardian scarcity (Costanza, 1989; Costanza, 2000; Harris & Kennedy, 1999; Norgaard, 1988; Regev, Gutierrez, Schreiber, & Zilberman, 1998)[4] [5]. In contrast to the EIE, ecological economics takes a prudently sceptical view of the role of technological improvement in addressing environmental problems.

Given the fundamental uncertainty about whether technology will help to solve present or future environmental problems, Costanza (1989, p. 3) asks "what should we do?" One strategy must be to develop methods to measure the actual role that technology is playing in reducing

[4] Chapter 3 (section 3.5.2) has already highlighted the debate over the role of technology in addressing environmental issues.

[5] Although this position does not appear to be unanimously held by ecological economists. See for example the article in Ecological Economics by Aldy et al., (1998).

ecosystem service throughput/use. In other words, there is a need for methods that separate technical efficiency changes in eco-efficiency measures from changes in economic structure and other factors. The hope is that such methods will counter the temptation to misinterpret aggregate eco-efficiency indices such as the energy:GDP ratio as simply aggregate measures of the technical efficiency of the economy. In isolating the 'technical effect', such methods will provide:

- a reality check on the relative contribution of technology to changes in eco-efficiency;
- a touchstone for policy development aimed at improving eco-efficiency. Properly applied, these methods provide policy makers with information on the appropriate focus (i.e. technology development, structural shifts etc) for policies aimed at enhancing eco-efficiency.

Decomposition analysis in general, and the Divisia decomposition specifically, is one approach to improving our understanding of the role of technical efficiency relative to other factors. Wier and Hasler (1999) use a decomposition analysis for just this purpose. They find that the technical effect "compensates the effect of economic growth and structural change, thereby providing evidence for the ability of cleaner technology to offset economic growth" (Wier & Hasler, 1999, p. 329). Other applications of decomposition analysis find that the structural shifts in the economy far outweigh technological changes (see for example, Bending et al., 1987; Gardner, 1993; Jenne & Cattell, 1983; Marlay, 1984; Motamen & Schaller, 1985).

6.1.3 The role of energy in the economy and energy quality

This chapter focuses on one aggregate eco-efficiency index that has received significant attention in the literature; the energy:GDP ratio. This focus on energy is entirely concordant with ecological economics' biophysical view of the economy. Indeed, there is a consensus in ecological economics that energy plays a fundamental role in the economy (Ayres, 1998; Cleveland, 1999; Cleveland, Costanza, Hall, & Kaufmann, 1984; Daly, 1992b; O'Connor, 1991; Odum, 1971; Peet, 1992; Stern, 1999; van den Bergh, 1996). According to Peet (1992, p. 84) "it is vital to recognise the key role of energy in the physical world; otherwise, it is fatally easy to fall into the trap of thinking that all processes of importance to human decision-making are internal to the economy." Ecological economics focuses on energy for three good reasons (Peet, 1992, p. 223). First, the interaction of energy with matter is fundamental to a biophysical perspective. Second, energy is a convenient indicator of flows in the economy since all production activities expend energy. Third, energy is directly and indirectly associated with significant quantities of pollution and waste that accompanies economic activity.

Analysis of energy-related eco-efficiency necessarily involves a consideration of energy quality[6] [7]. However, energy quality is nearly always overlooked in standard energy analyses (Cleveland, 1992). In contrast to standard approaches to energy analysis, the issue of energy quality, or usefulness, has received significant attention in ecological economic literature (Cleveland, 1992; Cleveland, Kaufmann, & Stern, 2000; Funtowicz & O'Connor, 1999; Patterson, 1998; Patterson, 2002a). As Funtowicz and O'Connor (1999, p. 266) state "while scientifically all Energy conversions are equal, anthropocentrically some are more equal – that is, useful – than others." Following Cleveland et al (2000, p. 302) this chapter defines energy quality as the relative economic usefulness per unit of different fuels and electricity[8].

Energy quality is an important aspect of energy analysis. Investigations of the role of energy in the economy often involve aggregating different energy flows. The usual approach is to measure the energy in the energy:GDP ratio in thermal equivalent terms[9]. This approach has a couple of important limitations. It suggests perfect substitutability among energy resources—an assumption which rarely holds (Zarnikau, 1999). The approach also ignores form-value attributes of different energy sources (Cleveland et al., 2000, p. 304). Different delivered energy inputs do exhibit different energy qualities. High quality energy sources such as electricity can be more efficiently converted to energy end-uses (leading to more economic output), so a shift to such energy sources will lead to an apparent decrease in the energy:GDP ratio (see section 4.4.2).

Econometric studies by Cleveland et al. (1984; 2000) have demonstrated that energy inputs such as electricity and petroleum have higher marginal products than coal, meaning in relative terms that one input of electricity / petroleum will result in more output ($) than one input of coal. Consequently, adding different energy qualities together using thermal equivalent terms is akin to adding apples and oranges; they are not commensurate and should not, theoretically, be summed. Furthermore, if adjustments are not made for energy quality, misleading empirical

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[6] Note that the issue of 'quality' is also relevant to some other ecosystem services. For example, land and water.
[7] The implications of energy quality for thermodynamic interpretations of eco-efficiency have been covered in section 4.4.2.
[8] It is important to distinguish between 'energy quality' and the term 'resource quality' as used by Stern (1999) and Hall et al (1992). Petroleum or coal deposits may be identified as having very high 'resource quality' because they provide a very high energy surplus relative to the amount of energy required to extract the fuel. On the other hand, electricity generated from solar energy may be characterised as a low 'resource quality' source because they have a lower energy return on investment (EROI). However, the electricity energy vector may have higher 'energy quality' because it is more useful economically than one unit of petroleum or coal.
[9] Sometimes crude adjustments for energy quality are made using the OECD equivalents, where the 'quality' of a primary input is equivalenced in terms of its conversion efficiency to electricity. The OECD abandoned this approach in 1991. Patterson (1993a) provides a critique of the OECD approach.

results from applying the decomposition methods may eventuate (Cleveland et al., 2000, p. 301).

The ecological economics literature canvasses a variety of methods for accounting for energy quality that could be incorporated into decomposition analyses. However, as with the commensuration issue in general "none has received universal acceptance" (Cleveland et al., 2000, p. 301). These energy quality numeraires can be broadly classified as being *systems-based* (as proposed by Patterson (1983) and Odum (1996)), *thermodynamic* (such as exergy) or *economic* (used by Berndt (1978), Turvey and Norbay (1965) and Zarnikau (1999)) measurements.

6.1.4 Decomposition as a tool in ecological economics

A final point to be made regarding the links between the research in this chapter and ecological economics relates to the use of the decomposition tool. Analysts have developed several methods to decompose aggregate eco-efficiency indices into their component parts (Ang & Zhang, 2000). However, decomposition analysis is not used extensively in ecological economic research. Only three articles utilising decomposition approaches were found in the issues of the *Ecological Economics* journal. Färe et al. (1996) use an index-decomposition type approach to decompose overall factor productivity into a pollution index and input-output efficiency index. Wier and Hasler (1999) use an input-output decomposition technique to break down changes in agricultural and industrial nitrogen loading in Denmark. Stern (2002) uses stochastic decomposition to analyse sulphur emissions from 64 countries. From his analysis he concludes that increasing scale and countervailing technical change explained most of the observed global change in sulphur emissions. Also, prominent ecological economist van den Bergh includes a section on structural decomposition analysis in his *Handbook of environmental and resource economics* (van den Bergh, 1999). Despite this recent interest, there is a notable lack of use of index-decomposition[10] techniques in ecological economic literature.

Despite the lack of attention in ecological economics, decomposition analysis can offer useful insights into the environment-economy interactions. As Ang and Skea (1994, p. 13) state, "in fact, the decomposition technique offers virtually the only way forward in identifying retrospectively the relative contribution of different factors to changes in energy demand."

6.2 Methodological considerations in decomposition analysis

Developing a method for decomposing aggregate eco-efficiency indices such as the energy:GDP ratio involves a number of critical choices including choosing the decomposition

[10] The differences between the various decomposition methods is discussed below.

factors, the decomposition method, the level of disaggregation and whether components will be additive or multiplicative. In past studies, often these choices were made arbitrarily, with no reason given (Ang & Zhang, 2000, p. 1169). These choices are shown in Figure 6-1 below and are outlined in more detail below.

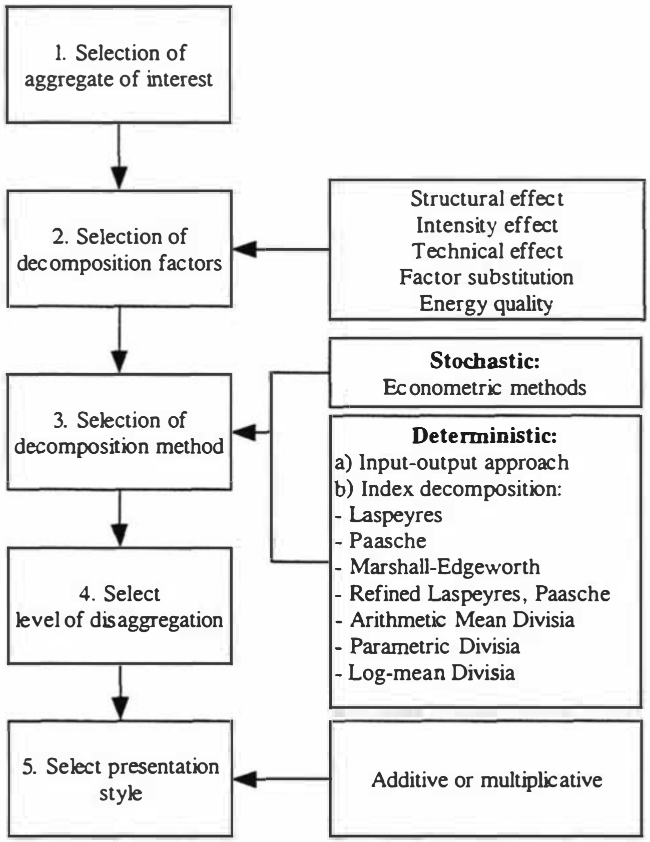

Figure 6-1: A schematic presentation of the methodological process for decomposition analysis

6.2.1 Selection of aggregate of interest and decomposition factors

The first step in a decomposition analysis is to select the aggregate of interest. The aggregate index chosen should be policy relevant, measurable and have time series data available. In this thesis, the focus is on eco-efficiency. There are many potential eco-efficiency indices of interest such as the total land area or water use per unit of economic output. One prominent eco-efficiency index that is commonly used for policy purposes is the energy:GDP ratio. This ratio is the focus of analysis in this chapter.

The next step in a decomposition analysis is to select the decomposition factors. Several factors can explain the movement of aggregate eco-efficiency indices, including changes in economic structure, factor substitution, resource quality and technical efficiency.

With respect to the energy:GDP ratio, most past studies have decomposed the ratio into a *structural effect* and an *intensity effect*, with the primary focus often being the structural effect (Bending et al., 1987; Gardner, 1993; Marlay, 1984). As a result of the focus on the structure of the economy, a precise definition of the intensity effect is often overlooked. Some studies make the assumption that the intensity effect and actual thermal energy efficiency changes are synonymous. For example, Ang and Skea (1994) conclude that, because the intensity effect caused a drop in total electricity consumption, thermal 'energy efficiency' has improved. This is not necessarily the case. Patterson (1996) argues this is a dangerous assumption, as changes in the intensity effect may be entirely due to changes in the energy-input mix. For example, switching from coal (low-quality input) to electricity (high-quality input) will, ceteris paribus, decrease the intensity effect simply because the economy has moved from a low quality to a high-quality energy input. This need to account for 'quality' is important in energy analyses, but can also be relevant when decomposing eco-efficiency indices other than the energy:GDP ratio. For example, the 'quality' of land invariably affects production levels and therefore land-efficiency indices such as economic output per hectare. Similarly, water 'quality' may have an effect on water-efficiency measures such as economic output per m^3 of water take. Therefore, when issues of quality are relevant it is important to include a quality effect in the decomposition factors.

There appear to be two reasons why past studies of the energy:GDP ratio tend not to delve any deeper into the intensity effect. First, there is the problem of data scarcity: the more factors that are investigated, the more data that are required. Often these data are simply not available. The second reason is that each extra factor analysed adds another level of methodological complexity. Separating out extra factors increases both the algebraic and computational complexity of the procedure. A notable exception to the majority of studies is Liu et al.'s (1992b) investigation of the effect of impacts of fuel substitution on the energy:GDP ratio. While Liu et al.'s study does succeed in extending the bounds of decomposition methodology, it fails to rigorously take account of the energy quality of the energy types.

6.2.2 The decomposition method

Broadly speaking, two approaches are available for decomposition analysis; deterministic and stochastic.

Deterministic decomposition

Deterministic decomposition analysis can be carried out using input-output decomposition (IOD) or index numbers decomposition (ID). The IOD technique is designed to quantify sources of changes of variables based on economic input-output (IO) tables (see for example Wier & Hasler, 1999). The formulation of IOD uses matrices (see Chapter 7) rather than summations used in ID (Ang & Zhang, 2000, p. 1160). Using standard IO algebra, IOD is able to account for both direct and indirect effects. Further, IO tables offer the possibility of significant disaggregation, allowing more factors to be studied. However, IOD studies are dictated by the availability of IO tables, which in theory, in New Zealand, are only updated every five years (Department of Statistics, 1991). This is not useful if year-to-year changes are of interest. As a consequence, Ang and Zhang (2000) found IOD is not often used. Another problem with IOD is that, methodologically, it is often simply an extended version of the Laspeyres index decomposition approach, which itself incurs a significant error term.

Index number decomposition (ID) techniques have become the most widely used decomposition approach. Ang and Zhang's (2000) review of 124 decomposition studies carried out between the mid 1980s and 2000 showed that over 80% used ID. Because of this popularity, it is worth providing some detail on the approach.

All ID methods begin by defining a mathematical identity and relating it to component indices. For example, the energy:GDP ratio is expanded to at least two component indices:

$$\frac{E_t}{Y_t} = \sum_j \frac{E_{jt}}{Y_{jt}} \frac{Y_{jt}}{Y_t}$$

Equation 6-1

Where:

E_t = total consumer energy in period t

Y_t = gross domestic product in period t

E_{jt} = energy consumed in sector j in period t
Y_{jt} = value added of sector j in period t.

A salient feature of ID analysis is the availability of a number of methods for decomposition (Sun & Ang, 2000). Indeed, the results of decomposition analysis depend upon the index number method used (Liu et al., 1992b). This is because every method incorporates a specific set of assumptions about how to weight energy and GDP in different time periods. The discussion below briefly describes several index number methods that can be used in ID analysis[11] and outlines their relative strengths and weaknesses.

The Laspeyres, Paasche and Marshall-Edgeworth Index methods

The most basic ID methods are given in the Laspeyres, Paasche and Marshall-Edgeworth index number approaches (Liu, Ang, & Ong, 1992a). The Laspeyres method weights all temporal changes in index components with initial-year values. The Paasche method weights all changes with the value of the index in the final year. The derived factors from both the Laspeyres and Paasche methods are calculated in terms of their initial year or final-year equivalents respectively. The Marshall-Edgeworth method assumes that observations of the index are

[11] For further discussion and a survey of index number methods as applied to energy analysis, see the excellent paper by Ang and Zhang (2000).

available for both the beginning and end years, and the arithmetic averages of the ratios of both years are used in the calculations.

The advantage of the Laspeyres, Paasche and Marshall-Edgeworth methods is that the decomposed factors are easily interpreted (Howarth, Schipper, Duerr, & Strom, 1991). These methods give clear weights to the interactions between, for example, changes in economic structure and energy intensity.

The disadvantages of these approaches include the fact that the weights are held constant overtime. Therefore, there is a risk that the calculation error can be substantial (as demonstrated by Ang & Lee, 1994). Also, a common characteristic of the Laspeyres, Paasche and Marshall-Edgeworth methods is the presence of a residual. A residual is undesirable because a part of the observed change in the energy:GDP ratio is left unexplained, thus defeating the objective of decomposition analysis.

Sun (1998) and Sun and Ang (2000) recently proposed methods that refine the Laspeyres, Paasche and Marshall-Edgeworth models to give exact decomposition. Sun and Ang (2000, p. 1185) showed that these three refined decomposition models "give exactly the same decomposition results."

The Divisia method

The Divisia index is an integral index number introduced by Divisia[12] (Ang & Zhang, 2000). In the Divisia (ID) method, the rate of change in the aggregate ratio is expressed as the sum of the rates of change in the component indices. The decomposition is carried out by multiplying the rates of change by the aggregate ratio and then integrating with respect to time.

The use of the Divisia index in the decomposition of changes in industrial energy use was introduced by Boyd et al. (1987; 1988). Liu et al. (1992a) generalised the decomposition method for industrial energy demand and transformed the Divisia integral-path problem in the Divisia index approach into a parametric estimation problem. In doing so, they presented two general parametric methods and showed "that many methods proposed earlier,... are special cases of their two general parametric methods" (Ang & Zhang, 2000, p. 1156). In a further development, Ang and Choi (1997) presented a refined Divisia method, based on logarithmic mean weights, that provides exact decomposition (i.e. without a residual).

[12] More details about this index number can be found in Diewert (1976; 1980).

The refined Divisia approach has many desirable properties. In particular, Sun and Ang (2000) show that the refined Divisia method satisfies three tests for identifying desirable properties of index numbers (time-reversal, circular and factor-reversal tests[13]).

However, the Divisia method of decomposition is not as intuitively easy to understand as the Laspeyres and Paasche approaches. Also, the general Divisia approach incurs an error term – although Ang and Choi (1997) have removed this problem with their refined approach. Finally, computational difficulties limit the Divisia approach when zero values appear in the data set. The study by Ang and Choi (1997) show that by using the refined Divisia method, converging results are achieved by replacing zero values in the data set with a small positive number.

Compared with IOD, ID methods, in general, require less detailed structural data, and can also accommodate timeseries discontinuities. According to Stern (2002), ID approaches are appropriate for charting the experience of individual countries. However, for an analysis of cross-country similarity and differences, Stern suggests the econometric approach (below) is more appropriate. The ID approach has also been criticised because it does not factor out technical change. However, this is not entirely correct. The ID approach is flexible and with adequate data could isolate a technical change component. Finally, in the case of energy, the ID approaches requires both energy and economic data to be available to a consistent level of sectoral disaggregation. This certainly could limit analysis, but in the case of New Zealand, this has not proved to be too significant a constraint.

Stochastic decomposition

Another approach to decomposition analysis is to use stochastic methods. As an example, Stern (2002) explains changes in global sulphur emissions using an econometric model. Such an econometric model requires estimation of a decomposition model. Stern himself notes that such an approach to decomposition is particularly relevant when analysts "are interested in the common features shared by countries..." (Stern, 2002, p. 204). Stochastic decomposition analyses have not been used extensively in energy:GDP ratio decomposition.

Stochastic approaches, it is claimed, require less data than ID. However, this may not be the case. Stern identifies several significant data availability problems with his analysis. Furthermore, a reasonable sample size is required in stochastic studies to ensure the robustness of results. ID approaches do not face this constraint.

[13] The time-reversal test requires that the index number reckoned forward to be the reciprocal of that reckoned backwards. The circular test requires that the index number does not depend on how the indicator developed over time between time 0 and T. The factor-reversal test requires that all decomposed components give the observed ratio of the aggregate when multiplied together.

One advantage stochastic decomposition has over ID is that the properties of the stochastic model can be statistically tested. In this way, stochastic models can determine the statistical significance of decomposition factors. The ID methods do not have the ability to provide such statistical information.

When conducting stochastic decomposition, often the Laspeyres (ID) approach is implicitly applied (which uses base year weights). As is discussed below, the Laspeyres approach incurs a large interaction (error) term. Finally, stochastic decomposition will invariably incur a random error term. In contrast, several ID approaches have been developed that eliminate the error term.

6.2.3 Other choices

Another choice to be made when selecting a decomposition approach is the level of sectoral disaggregation. Several authors have established that decomposition results are affected by the level of sectoral disaggregation (Ang & Skea, 1994; Liu et al., 1992a; Liu et al., 1992b). For example, Ang and Skea (1994) investigated the effect of sectoral disaggregation on decomposition of the changes in electricity in the UK. They clearly demonstrated that "the estimated structural or intensity effects can be significantly influenced by sector disaggregation" (Ang & Skea, 1994, p. 12). They concluded that "a larger number of sectors gives more refined and accurate results in analysing the past" (Ang & Skea, 1994, p. 12).

A choice to be made when using ID is whether the results will be expressed in terms of either the sum or the product of the resulting decomposition components. Ang (1994) demonstrated that the differences between the multiplicative and the additive forms are small. The choice is, therefore, left to the analyst to decide which form is preferable in terms of ease of interpretation of the results (Ang & Zhang, 2000, p. 1169).

6.2.4 Final selection of decomposition approach used in this paper

The decomposition approach used in this paper is applied to the energy:GDP ratio. The decomposition factors that are analysed are shown schematically in Figure 6-2. Most past studies tend to decompose changes in the energy:GDP ratio to level one. This study extends past analyses by separating the intensity effect to a second level. The final three decomposition components are the:

Energy quality effect, which measures the decrease in the energy:GDP ratio due to the relative increase in high-quality energy inputs that provide energy services. Conversely, it measures the increase in the energy:GDP ratio due to the relative increase in low-quality energy inputs. For example, an increase in the proportion of drying that was met by infrared electrical devices as opposed to gas-fired dryers would contribute to a negative 'quality effect' and a drop in the overall energy:GDP ratio.

Technical effect, which reflects the contribution of changing energy efficiency of machinery through replacement of old technology and retrofitting existing technology. The technical effect also accounts for energy efficiency changes resulting from different levels of energy management.

Structural effect, which measures the change in the energy:GDP ratio due to change in the relative size of energy intensive sectors. For example, an increase in the proportion of GDP derived from an energy intensive sector would cause a positive structural effect.

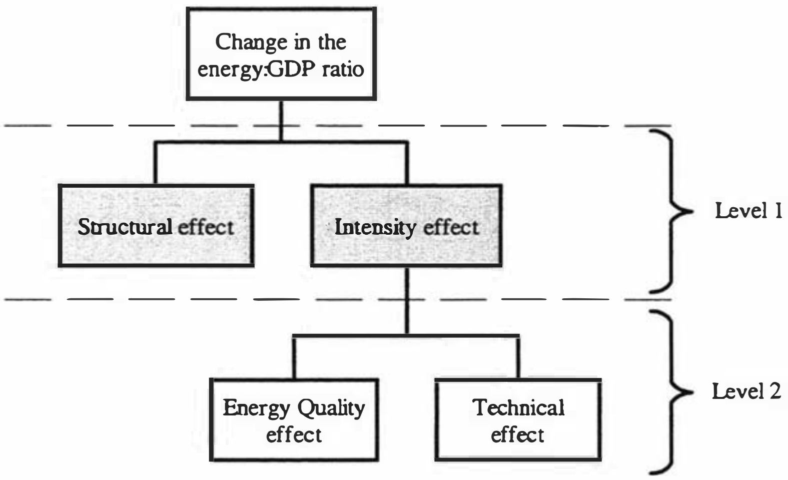

Figure 6-2: Decomposition framework

This chapter aims to decompose annual changes in the energy:GDP ratio in New Zealand as accurately as possible, given available data constraints. In this context, the analysis in this chapter adopts an extension of Ang and Choi's (1997) refined Divisia method, which belongs to the ID family. This method was chosen principally because of its ability to provide decomposition without an error term, its ability to cope with zero values and the need to track annual changes in the energy:GDP ratio to monitor New Zealand's energy efficiency targets[14]. The decision to adopt this approach is consistent with Ang and Zhang's assessment. In their exhaustive review of decomposition models, Ang and Zhang (2000, p. 1170) stated "the logarithmic mean Divisia method as a whole has an edge over the refined Laspeyres method." Given that the refined Laspeyres method gives the same results as the refined Paasche and Marshall-Edgeworth models, one can conclude the Divisia model maintains an edge over the other two models as well.

[14] Which essentially rules out IOD because accurate IO tables are not available on an annual basis.

Finally, the analysis is made at the national and sectoral levels because this is where the political goals for energy efficiency are set (for example, New Zealand's National Energy Efficiency and Conservation Strategy). Sectoral disaggregation in this context is dictated by available energy data. Economic production figures are available for a very detailed sectoral breakdown. However, the level of sectoral disaggregation for energy data is limited by the Ministry of Economic Development's Energy Supply and Demand Balances – that is, thirteen sectors (see Appendix 2).

6.3 A decomposition methodology to quantify the effects of key factors on changes in the energy:GDP ratio

This section describes in more detail the method used to quantify the effect of the key factors identified above on changes in the energy:GDP ratio[15].

6.3.1 Notation

The economy is divided into j sectors, which are each taken as homogeneous. The economic value added and energy use are measured for each sector over time. Similarly, different energy types (i) are used, and the mix may change over time. The aim of this decomposition technique is to separate the effects of structural change from those of technical efficiency and energy quality effects in individual sectors. The notation is shown below:

E	Total consumer energy (measured in joules)
E_{ij}	Energy use measured in joules for the ith energy type in sector j
E_j	Energy (measured in joules) used in the jth sector ($= \Sigma_i E_{ij}$)
$E_{ij}^{\bullet}$	Use of the ith energy type in sector j, measured in emjoules[16]
C_i	The inverse of the energy quality coefficient of the ith energy type. It is used for converting from thermal equivalent measures of energy use to emjoules ($C_i=E_{ij}/E_{ij}^{*}$) (assumed to be the same for all economic sectors)
Y	Total economic output, in constant dollars
Y_j	Value added from the sector j
y_j	Production share of the jth sector ($=Y_j/Y$)
I	Energy:GDP ratio of the whole economy ($=E/Y$) where E is measured in joules
I_j	Energy intensity[17] of the jth sector ($=E_j/Y_j$) where E is measured in joules
I_{ij}	Emjoule intensity of use of the ith energy type in the jth sector ($=E_{ij}^{*}/Y_i$)
w_{ij}	Energy share of the ith energy type in the jth sector ($=E_{ij}/E$)

All variables are continuous, but are typically observed only at certain points of time, usually aggregated annually. Let $t=0$ and $t=T$ be two such times over which changes in energy use

[15] While decomposition can also be conducted on energy consumption or energy coefficients (the average rate of change in energy consumption, divided by the average rate of change of gross domestic product), the interest of this thesis is with trends in the energy:GDP ratio. Furthermore, the difference between decomposing energy or the energy:GDP ratio in algebraically trivial. Decomposition of the energy coefficient is not recommended because it has been found that the indicator is unstable (Hull, 1981).

[16] See Chapter 4 and section 6.3.5 below.

[17] That is, energy to value-added ratio.

and value added are measured. These variables are intended to capture the three main factors affecting changes in the intensity of energy consumption; the energy quality, technical, and structural effects.

6.3.2 The static description of the energy:GDP components

The energy intensity of the economy can be broken down into the energy intensity for individual sectors, weighted by the production share of each sector:

$$I = \frac{E}{Y} = \sum_j \frac{Y_j}{Y}\frac{E_j}{Y_j}$$ **Equation 6-2**

The energy used in each sector can be further broken down into individual energy types (electricity, gas, coal, oil, renewables, etc.). The quality of use of each type can also be accounted for:

$$E_j = \sum_i E_{ij} = \sum_i \frac{E_{ij}}{E^*_{ij}} E^*_{ij}$$ **Equation 6-3**

The simplifying assumption is made that the emjoule conversion efficiency of each energy type is the same for all sectors.

$$C_i = \frac{E_{ij}}{E^*_{ij}}, \quad \text{for all } j$$ **Equation 6-4**

The intensity of the whole economy can therefore be expressed as:

$$I = \sum_j \left(\sum_i \frac{E_{ij}}{E^*_{ij}} \frac{E^*_{ij}}{Y_j} \right) \frac{Y_j}{Y}$$ **Equation 6-5**

6.3.3 The dynamic description of the energy:GDP components.

The aim is to calculate the changes in energy intensity due to:

- Changes in energy quality (C_i);
- Changes in technical intensity (I_{ij});
- Changes in economic structure (y_j).

First, consider the rate of change of the logarithm of intensity. The reason for choosing the logarithm is that $d\ln(I) = dI/I$, so that the derivative represents the *relative* change in the growth rate of intensity.

$$\frac{d\ln(I)}{dt}=\frac{1}{I}\frac{dI}{dt}$$ **Equation 6-6**

$$\frac{d\ln(I)}{dt}=\frac{1}{I}\frac{d}{dt}\sum_j\left(\sum_i\frac{E_{ij}}{E^*_{ij}}\frac{E^*_{ij}}{Y_j}\right)\frac{Y_j}{Y}$$

Simplify using notation:

$$=\frac{1}{I}\frac{d}{dt}\sum_j\left(\sum_i C_i I_{ij}\right)y_j$$ **Equation 6-7**

Expand Equation 6-7 using the chain rule:

$$=\frac{1}{I}\left[\sum_i\left(\sum_j I_{ij}y_j\right)\frac{dC_i}{dt}+\sum_j\sum_i C_i y_j\frac{dI_{ij}}{dt}+\sum_j\left(\sum_i C_i I_{ij}\right)\frac{dy_j}{dt}\right]$$ **Equation 6-8**

Apply the general rule of $d\ln(a_i)=(1/a_i)da_i$, and therefore that $a_i d\ln(a_i)=da_i$:

$$=\frac{1}{I}\left[\sum_i\left(\sum_j I_{ij}y_j\right)C_i\frac{d\ln(C_i)}{dt}+\sum_j\sum_i C_i y_j I_{ij}\frac{d\ln(I_{ij})}{dt}\right.$$ **Equation 6-9**

$$\left.+\sum_j\left(\sum_i C_i I_{ij}\right)y_j\frac{d\ln(y_j)}{dt}\right].$$

However,

$$\frac{C_i I_{ij} y_j}{I}=\frac{E_{ij}}{E^*_{ij}}\frac{E^*_{ij}}{Y_j}\frac{Y_j}{Y}\Big/\frac{E}{Y}=\frac{E_{ij}}{E}=w_{ij}$$ **Equation 6-10**

so that the rate of change in the logarithm of the intensity (at any instant) can be expressed as the weighted sum for each sector and energy type of the rate of change of the logarithm of the three change components: energy quality, technical, and structural effects:

$$\frac{d\ln(I)}{dt}=\sum_i\sum_j w_{ij}\left[\frac{d\ln(C_i)}{dt}+\frac{d\ln(I_{ij})}{dt}+\frac{d\ln(y_j)}{dt}\right]$$ **Equation 6-11**

Integrating Equation 6-11 over the interval 0 to T yields the following breakdown in intensity change:

$$\ln(I_T/I_0)=\underbrace{\int_0^T\sum_i\left(\sum_j w_{ij}\right)\frac{d\ln(C_i)}{dt}dt}_{\text{quality effect}}$$

$$+\underbrace{\int_0^T\sum_i\sum_j w_{ij}\frac{d\ln(I_{ij})}{dt}dt}_{\text{technical effect}}$$ **Equation 6-12**

$$+\underbrace{\int_0^T \sum_j \left(\sum_i w_{ij}\right)\frac{d\ln(y_j)}{dt}dt.}_{\text{structural effect}}$$

Taking the exponential, this change may be expressed in multiplicative form:

$$I_T/I_0 = D_{tot} = D_{qual}D_{tech}D_{str}$$ **Equation 6-13**

Where:

$$D_{qual} = \exp\left[\int_0^T \sum_i \left(\sum_j w_{ij}\right)\frac{d\ln(C_i)}{dt}dt\right]$$

$$D_{tech} = \exp\left[\int_0^T \sum_i \sum_j w_{ij}\frac{d\ln(I_{ij})}{dt}dt\right]$$

$$D_{str} = \exp\left[\int_0^T \sum_j \left(\sum_i w_{ij}\right)\frac{d\ln(y_j)}{dt}dt\right]$$

These integrals cannot be evaluated precisely, since data are available only at the end points 0 and T. It is therefore necessary to use the approximate formulae for the components of change in intensity D_{qual}, D_{tech}, and D_{str} defined by:

$$D_{qual} = \exp\left[\sum_i \left(\sum_j w_{ij}^*\right)\ln\left(C_{i,T}/C_{i,0}\right)\right]$$

$$D_{tech} = \exp\left[\sum_i \sum_j w_{ij}^* \ln\left(I_{ij,T}/I_{ij,0}\right)\right]$$

$$D_{str} = \exp\left[\sum_j \left(\sum_i w_{ij}^*\right)\ln\left(y_{j,T}/y_{j,0}\right)\right]$$

The weights (w_{ij}^*) are chosen to give zero residual between D_{tot} and ($D_{qual}+D_{tech}+D_{str}$) and are based on the energy shares (w_{ij}) evaluated at the end points. These are derived below in section 6.3.4.

Converting Equation 6-13 to a form that decomposes the difference between I_T and I_0 is relatively straight forward. By multiplying by $L(I_T,I_0)$[18], which is the logarithmic mean of I_T and I_0, the *ratio* $\ln(I_T/I_0)$ can be converted to a *difference*. That is:

$\Delta I = I_T - I_0$

$= L(I_T,I_0)\times\ln(I_T/I_0)$

$= L(I_T,I_0)\times\ln(D_{qual}D_{tech}D_{str})$ **Equation 6-14**

[18] Where $L(I_T I_0) = \dfrac{I_T I_0}{\ln(I_T/I_0)}$

$= L(I_T, I_0)\times(\ln D_{qual}+\ln D_{tech}+\ln D_{str})$

$$= \underbrace{L(I_T, I_0)\ln D_{qual}}_{\text{quality effect}} + \underbrace{L(I_T, I_0)\ln D_{tech}}_{\text{technical effect}} + \underbrace{L(I_T, I_0)\ln D_{str}}_{\text{structural effect}}$$

6.3.4 Derivation of the weighting function for the extended refined Divisia decomposition method

In general, the energy shares w_{ij} change over time. However, since the integrals cannot be evaluated because only the values at the endpoints are known, estimation using only known data is required. The method of Ang and Choi (1997) can be used to derive an error-free weighting of end point data. First note that if the w_{ij} were constant over time:

$$D_{qual} = \int_0^T \sum_i \left(\sum_j w_{ij}\right)\frac{d\ln(C_i)}{dt}dt = \sum_i \left(\sum_j w_{ij}\right)\ln\left(C_{i,T}/C_{i,0}\right), \quad \textbf{Equation 6-15}$$

And

$$D_{str} = \int_0^T \sum_j \left(\sum_i w_{ij}\right)\frac{d\ln(y_j)}{dt}dt = \sum_j \left(\sum_i w_{ij}\right)\ln\left(y_{j,T}/y_{j,0}\right) \quad \textbf{Equation 6-16}$$

These involve only the end values at $t = 0$ and $t = T$. A convenient method is therefore to use a set of weights w_{ij}^*, and define the components of change D_{qual}, D_{tech}, and D_{str}, by:

$$D_{qual} = \sum_i \left(\sum_j w_{ij}^*\right)\ln\left(C_{i,T}/C_{i,0}\right), \quad \textbf{Equation 6-17}$$

$$D_{tech} = \sum_i \sum_j w_{ij}^* \ln\left(I_{ij,T}/I_{ij,0}\right), \quad \textbf{Equation 6-18}$$

and

$$D_{str} = \sum_j \left(\sum_i w_{ij}^*\right)\ln\left(y_{j,T}/y_{j,0}\right), \quad \textbf{Equation 6-19}$$

where the w_{ij}^* are currently undefined, but $\sum_i \sum_j w_{ij}^* = 1$. The w_{ij}^* are, in effect, *average* values of the w_{ij}^* over the interval 0:T. This is defined more formally later.

From Equation 6-7, we know that $I=\Sigma_j(\Sigma_i C_i I_{ij})y_j$. Thus:

$$D_{tot} = \ln\left(I_T/I_0\right) = \ln\frac{\sum_i \sum_j C_{i,T} I_{ij,T} y_{j,T}}{\sum_i \sum_j C_{i,0} I_{ij,0} y_{j,0}}, \quad \textbf{Equation 6-20}$$

and

$$D_{qual} + D_{tech} + D_{str} = \sum_i \sum_j w_{ij}^* \ln \frac{C_{i,T} I_{ij,T} y_{j,T}}{C_{i,0} I_{ij,0} y_{j,0}}.$$ **Equation 6-21**

These two must be identically equal. Let Δ be the difference between them:

$$\Delta = \sum_i \sum_j w_{ij}^{\bullet} \ln \left[\frac{C_{i,T} I_{ij,T} y_{j,T}}{C_{i,0} I_{ij,0} y_{j,0}} \right] - \ln\left(\sum_k \sum_l C_{k,T} I_{kl,T} y_{l,T} \Big/ \sum_k \sum_l C_{k,0} I_{kl,0} y_{l,0} \right)$$ **Equation 6-22**

Since $C_i = E_{ij} \big/ E_{ij}^*$, $I_{ij} = E_{ij}^* \big/ Y_j$ and $y_j = Y_j \big/ Y$, evaluated at either $t = 0$ or $t = T$:

$$\sum_i \sum_j w_{ij}^* \ln\left(C_i I_{ij} y_j\right)$$

$$= \sum_i \sum_j w_{ij}^* \ln\left(\frac{E_{ij}}{E_{ij}^*} \frac{E_{ij}^*}{Y_j} \frac{Y_j}{Y} \right)$$

$$= \sum_i \sum_j w_{ij}^* \ln\left(\frac{E_{ij}}{Y} \right)$$

$$= \sum_i \sum_j w_{ij}^* \ln E_{ij} - \ln Y.$$ **Equation 6-23**

Substituting Equation 6-23 into Equation 6-22 and evaluating this expression at $t = 0$ and $t = T$, the value of Δ becomes (noting that the $\ln Y$ cancel):

$$\sum_i \sum_j w_{ij}^* \ln \frac{E_{ij,T}}{E_{ij,0}} - \ln \frac{\sum_k \sum_l E_{kl,T}}{\sum_k \sum_l E_{ki,0}}$$ **Equation 6-24**

and (since $\sum_i \sum_j w_{ij}^* = 1$),

$$\Delta = \sum_i \sum_j w_{ij}^* \ln \frac{E_{ij,T}}{E_{ij,0}} - \sum_i \sum_j w_{ij}^* \ln \frac{\sum_k \sum_l E_{kl,T}}{\sum_k \sum_l E_{kl,0}}$$

$$= \sum_i \sum_j w_{ij}^* \left[\ln \frac{E_{ij,T}}{\sum_k \sum_l E_{kl,T}} - \ln \frac{E_{ij,0}}{\sum_k \sum_l E_{kl,0}} \right]$$

$$= \sum_i \sum_j w_{ij}^* \ln\left(w_{ij,T} \big/ w_{ij,0} \right).$$ **Equation 6-25**

A choice of weights (w_{ij}^*) must be made so that this expression is identically zero. First define the logarithmic mean:

$$L(x, y) = \frac{y - x}{\ln(y/x)}.$$ **Equation 6-26**

This has the desirable property that $L(x,y) = L(y,x)$. Note that as $y \to x$, $L(x,y) \to x$, we therefore define $L(x,x) = x$. Thus:

$$L(w_{ij,0}, w_{ij,T}) = \frac{w_{ij,T} - w_{ij,0}}{\ln(w_{ij,T}/w_{ij,0})}.$$ **Equation 6-27**

Define the weights (w_{ij}^*) by:

$$w_{ij}^* = L(w_{ij,0}, w_{ij,T}) / \sum_l \sum_k L(w_{kl,0}, w_{kl,T})$$ **Equation 6-28**

The denominator simply ensures that $\sum_i \sum_j w_{ij}^* = 1$. Substituting Equation 6-28 into Equation 6-25, Δ becomes:

$$\Delta = \sum_i \sum_j \frac{L(w_{ij,0}, w_{ij,T}) \ln(w_{ij,T}/w_{ij,0})}{\sum_k \sum_l L(w_{kl,0}, w_{kl,T})}$$

$$= \sum_i \sum_j \frac{w_{ij,T} - w_{ij,0}}{\sum_k \sum_l L(w_{kl,0}, w_{kl,T})}$$

$$= 0$$ **Equation 6-29**

Since $\sum_i \sum_j w_{ij,0} = \sum_i \sum_j w_{ij,T} = 1$.

Thus no remainder term is generated, regardless of the changes in energy quality, technology, or economic structure. This means that no error term is present in splitting the energy:GDP ratio changes into these various effects.

6.3.5 Quality equivalent methodology

Most energy analyses tend to aggregate energy using thermal equivalents (for example see Ministry of Economic Development, 2000). However, despite the importance of accounting for energy quality (see section 6.1.3) few attempts (with the exception of Liu et al., 1992b; Patterson, 1993b) have been made to incorporate energy quality effects into decomposition of the energy:GDP ratio. The quality equivalent method[19] (QEM) provides a useful technique for accounting for energy quality.

The QEM enables energy quality coefficients to be determined in complex systems of energy flows (Patterson, 1993a; Patterson, 1996) where there are many interdependent energy

[19] Application of the QEM approach to issues of energy quality is gaining acceptance as an important contribution to energy analysis. For example, prominent ecologist Howard Odum adopts the QEM for estimating *em*ergy and transformity (Collins & Odum, 2000).

conversion processes, sources and end-uses (Patterson, 1983). The QEM appears to provide a rigorous basis for incorporating energy quality into the Divisia decomposition method.

Mathematics of the quality equivalent method

The QEM involves solving a system of simultaneous linear equations that describe the energy flow (measured in joules) in the economy. The solution of these equations leads directly to the determination of quality coefficients for each of the energy types in the system.

Consider the complexity of energy flows through the economy. Energy is converted into different forms (mechanical work, heat, etc.) to provide energy services. Often, there are several ways of converting delivered energy to an end use, and sometimes energy conversion processes have multiple outputs (for example, cogeneration). Also, each energy conversion process requires indirect energy for its operation. All of these factors make it very difficult to measure relative energy quality based on conversion efficiencies, when considering energy flows in economic systems.

The QEM deals with this complex system of energy flows by way of a system of simultaneous linear equations. These equations can be solved to determine the quality coefficients (β)[20] for each energy type and residuals (e) for each process. This system of simultaneous equations can be solved for minimum sums of squares of the residuals and expressed in terms of multiples of any of the energy forms (Patterson, 1983). These multiples represent the quality coefficient for each energy forms. It is important to note that the same relativities exist between the quality coefficients, irrespective of which particular energy form is used as the numeraire (i.e. irrespective of which form is set to unity).

The system of simultaneous linear equations can be expressed compactly in matrix notation:

$$\mathbf{X\beta} + \mathbf{e} = \mathbf{0} \qquad \textbf{Equation 6-30}$$

Where:

$\mathbf{X}$ = matrix (m×n) of m processes describing the conversion of energy between n types of energy. The energy flows are measured in joules, with inputs entered as negative entries and outputs as positive entries.

$\boldsymbol{\beta}$ = Column vector ($n \times 1$) of quality coefficients of each energy type. The quality coefficients are measured in terms of quality equivalents or emjoules (E^*) per joule (i.e. E^*/E). The quality equivalents are determined by solving the simultaneous equations.

[20] Equivalent to Howard Odum's 'transformity' concept.

e = residual vector ($m \times 1$). The residual is expressed in quality equivalents (E^*) for each process. For a process with an efficiency equalling the system's average $e = 0$, for a process with efficiency less than the system's average $e > 0$ and for a process efficiency greater than the system's average $e \leq 0$.

Quality coefficients for New Zealand, 1987-2000

Quality coefficients for the New Zealand economy were calculated using the QEM outlined above (the results are shown in Table 6-1). The changes in the coefficients are the result of a set of assumptions about the relative improvements in the efficiency of different processes, and the changes in qualities and types of energy used to provide each service. These assumptions are outlined in Appendix 3. The coefficients show the quality of the different energy types between each other and over time (relative to liquid fuels in 1987); the higher the coefficient, the higher the energy quality.

Table 6-1: Estimated energy quality coefficients (in oil emjoules/joules) for New Zealand, 1987 to 2000, relative to liquid fuels in 1987

	Electricity	Gas	Geothermal[21]	Solid Fuel	Liquid Fuel
1987	1.46	0.91	1.19	0.58	1.00[22]
1988	1.47	0.92	1.20	0.55	1.01
1989	1.47	0.93	1.21	0.54	1.02
1990	1.48	0.93	1.22	0.53	1.03
1991	1.49	0.93	1.23	0.52	1.04
1992	1.49	0.93	1.25	0.52	1.05
1993	1.51	0.93	1.26	0.52	1.06
1994	1.41	0.92	1.27	0.52	1.13
1995	1.41	0.93	1.29	0.52	1.14
1996	1.42	0.93	1.30	0.53	1.15
1997	1.42	0.93	1.31	0.53	1.17
1988	1.42	0.93	1.33	0.53	1.18
1999	1.42	0.93	1.34	0.53	1.19
2000	1.41	0.93	1.35	0.53	1.20

Interestingly, these quality coefficients present a ranking of energy types that is consistent with *a priori* expectations (for example, that electricity is a higher quality energy type than other energy types) and previous research (Cleveland et al., 2000; Schurr & Netschert, 1960).

[21] Note that the geothermal quality coefficients are relatively high. This may appear counterintuitive since the efficiency of use of primary geothermal energy (for example in electricity generation) is generally low. However, the quality coefficients for geothermal energy are calculated based on the quantity of geothermal energy delivered to end use, not on primary geothermal energy extraction.
[22] 1987 liquid fuel is used as the numeraire.

6.4 Results of the decomposition of New Zealand's energy:GDP ratio, 1987 – 2000

6.4.1 Changes in New Zealand's energy:GDP ratio, 1987-2000

Energy data used in this analysis were drawn from the energy supply and demand balances contained in various Ministry of Economic Development Energy Data File reports (see for example Ministry of Economic Development, 2000) and the Energy Efficiency and Conservation Authority's (1996) Energy Use Database. GDP data were obtained from Statistics New Zealand's (2000a) INFOS database and aggregated to conform with the Ministry of Economic Development's sectoral definitions. GDP data are measured in constant 1991/92 dollars. The residential sector was excluded from the analysis because there is no effective measure of output (GDP contribution) from the household sector (most household work is unpaid, and therefore excluded from the GDP calculation).

New Zealand's energy:GDP ratio has increased from 1987 to 1993 (see Figure 6-3). Since 1993, New Zealand's energy:GDP ratio has tended to decline. It is now slightly higher than it was in 1987, and lower than it was in the mid 1970s.

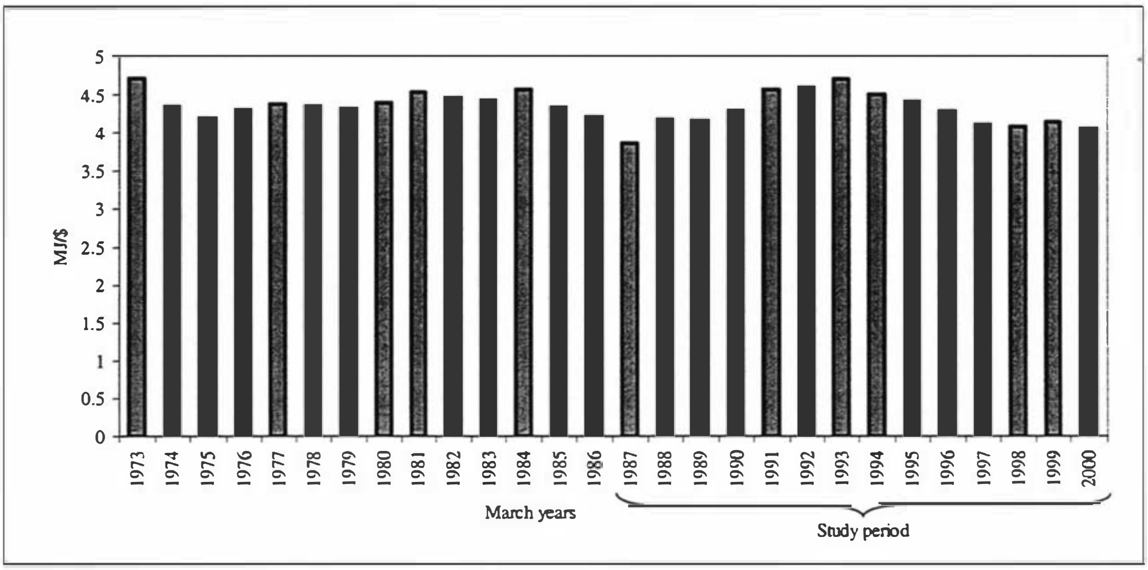

Figure 6-3: New Zealand's energy:GDP ratio, 1973-2000 (MJ/$)[22]

[22] Note that the total energy:GDP ratio is presented here in joules/$ terms (rather than emjoules/$) because this is the aggregate of interest that will be factorised into various effects, including energy quality.

6.4.2 Summary of the effect of the key factors on changes in New Zealand's energy:GDP ratio, 1987-2000

Figure 6-4 summarises the effect of each factor on changes in the energy:GDP ratio over the 1987-2000 period.

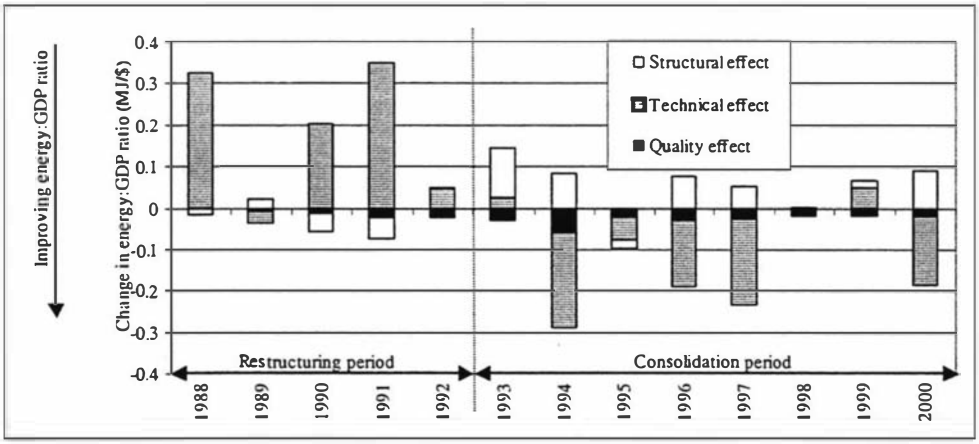

Figure 6-4: Decomposition of New Zealand's energy:GDP, 1987-2000

Over the period 1987 to 2000, New Zealand's energy:GDP ratio increased on average by about 0.34% per annum (or about 13kJ/$ per annum). The Divisia decomposition analysis reveals that the energy quality, technical and structural effects all influenced the aggregate energy:GDP ratio (Figure 6-4). Interestingly, the technical effect dominates changes in the energy:GDP ratio. This finding is consistent with the results of other industrialised countries (Ang & Zhang, 2000).

The years 1987 to 2000 were a time of immense economic change in New Zealand. Therefore, it is instructive to break this time into two periods. The first was a period of significant economic restructuring from 1987 to 1992 ('the restructuring period'); the second was a period of consolidation and economic recovery from 1993 to 2000 ('the consolidation period').

Analysing these two periods separately gives useful insights into changes in New Zealand's energy:GDP ratio. The restructuring period is characterised by an average annual increase in the energy:GDP ratio of around 145kJ/$ (or 3.5% per annum). This period was characterised by a period of stagnation of the New Zealand economy (GDP declined on average by about 0.2% per annum during this period). Figure 6-4 shows that the main factor contributing to the increases in the energy:GDP ratio in this period was the poor performance in New Zealand's overall technical efficiency (shown by the positive technical effect[23]).

The technical effect is counteracted by a concurrent shift away from manufacturing, and towards less energy intensive sectors of the economy (the average structural effect for this

[23] That is, the technical effect contributed to an increase in the energy:GDP ratio.

period contributed to a decrease in the energy:GDP ratio of approximately 17 kJ/$). The energy quality effect consistently added to a decrease in energy intensity during restructuring, mainly as a result of improvements in the quality of the liquid fuels (see the energy quality effect section below).

The period of consolidation, on the other hand, showed an average decline in the energy:GDP ratio of 68kJ/$ (or 2.1% per annum decline). This reflects the fact that New Zealand's economy grew on average by 3.5% per annum over this period. The relatively high growth rate was dominated by the transport sector. This sector showed a growth in value added of around 7.3% per annum. The strong growth of the transport sector helps to explain the technical and structural factors for this period. Strong economic performance of the transport sector tends to lead to greater investment in new and efficient vehicles and equipment (hence the negative technical effect). The growth in the transport sector also saw it increase as a proportion of total GDP (from 5.6% in 1993 to 7.2% in 2000). A shift of the economy into this relatively energy intensive sector results in a positive structural effect.

The following discussion analyses each of the three effects in more detail for the restructuring and consolidation periods.

6.4.3 The technical effect

This effect can be analysed either by sector or by energy type. The sector with the most significant influence on the technical effect is transport. Figure 6-5 below shows how transport's role in the technical effect has changed over the two time periods. Liquid fuels are the predominant energy source fuel used in this sector. From 1987 to 1995, total transport fuel use grew significantly (by 41%[24]), as restructuring took place and imports replaced local production.

[24] In emjoule terms.

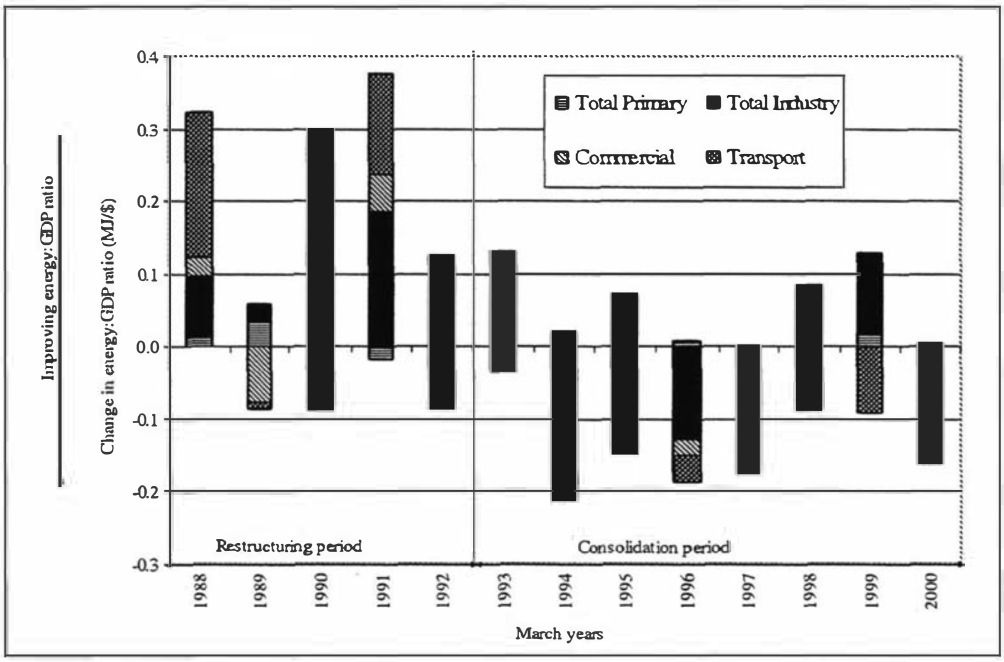

Figure 6-5: Technical effect by major sector groups in New Zealand, 1987-2000[25]

For the restructuring period, the manufacturing sectors consistently contributed to an increase in the technical effect (around 8 kJ/$ per annum) and therefore, an increase in the aggregate energy:GDP ratio. This was a direct result of the downturn in the industrial/manufacturing sectors and reflects the slow down in investment in new energy-efficient technology over this period. This is corroborated by data on the expected level of investment approvals on new plant and machinery over that period (Figure 6-6) from Statistics New Zealand (2000a).

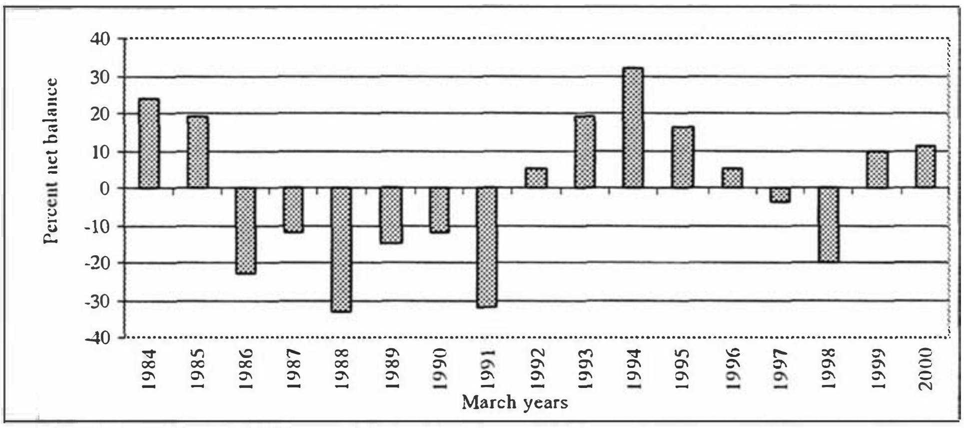

Figure 6-6: Expected level of investment approvals on new plant and machinery[26]

[25] Note that prior to 1990, only aggregate energy data were available from the Ministry of Commerce. Therefore, 1987 to 1990 show only total primary, total industrial, commercial and transport sectors. After this period, a 13-sector breakdown is possible.

[26] The negative 'percent net balance' scores indicate the percent of businesses that expected a decline in investment for the next 12 months. The positive 'percent net balance' indicates the percent expecting an increase in investment.

A similar story is shown by statistics on the capacity utilisation of plant and equipment. These statistics show that manufacturing capacity utilisation decreased from 88% in 1987 to 85% in 1992 – the lowest level in the 14 year period (Statistics New Zealand, 2000a) (Figure 6-7).

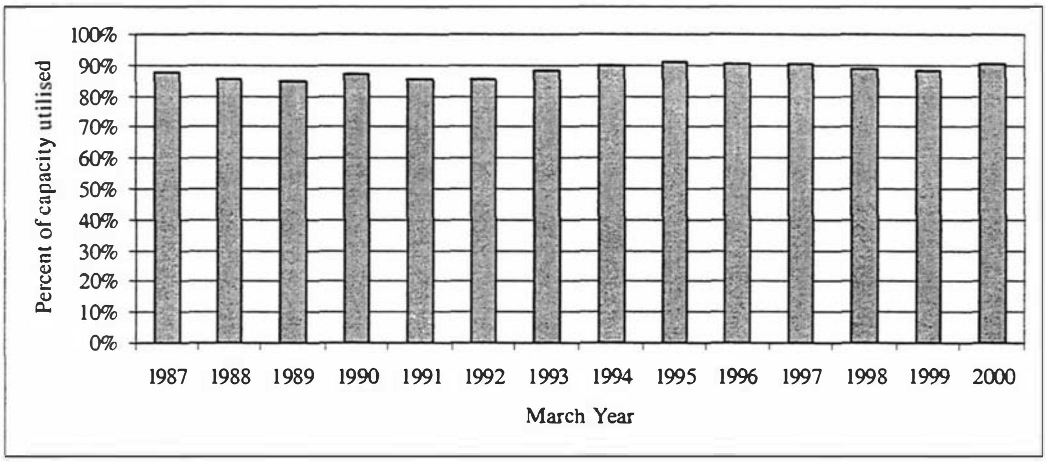

Figure 6-7: Capacity utilisation of manufacturing plant and equipment in New Zealand, 1987-2000

For the period from 1993 to 2000 the story changed. The technical energy efficiency of the industrial sector tended to improve – this is shown in the negative technical effect (on average about –9 kJ/$ per annum). This is consistent with our expectation that as the industrial sector – and the New Zealand economy as a whole – expands, so will investment in new efficient capital and plant. This in turn leads to an improvement in energy efficiency in the manufacturing sectors.

The energy efficiency of the primary sector tended to decline over both periods (on average around 12kJ/$ per annum). During both periods the technical effect of this sector worsened and added to an increase in the energy:GDP ratio. The reason for the decline is possibly due to New Zealand's terms of trade. New Zealand's agricultural sector has had to face an increasingly competitive international market, often with reducing real commodity prices. For example, the average wool price at auction declined from the late 1980s to 2000, and on average is projected to remain relatively low in the foreseeable future (see Figure 6-8) (Ministry of Agriculture and Forestry, 2002).

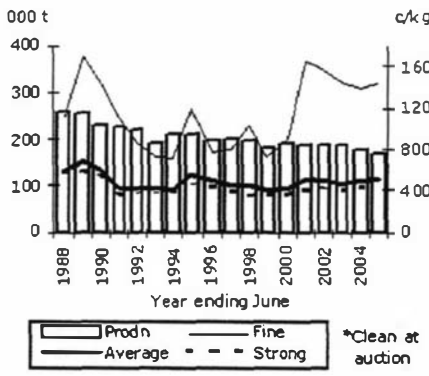

Figure 6-8: Auction prices for wool categories, 1988-2005

The agricultural sector, as a proportion of total GDP, contracted in New Zealand over the period 1987-2000 (see Figure 6-10).

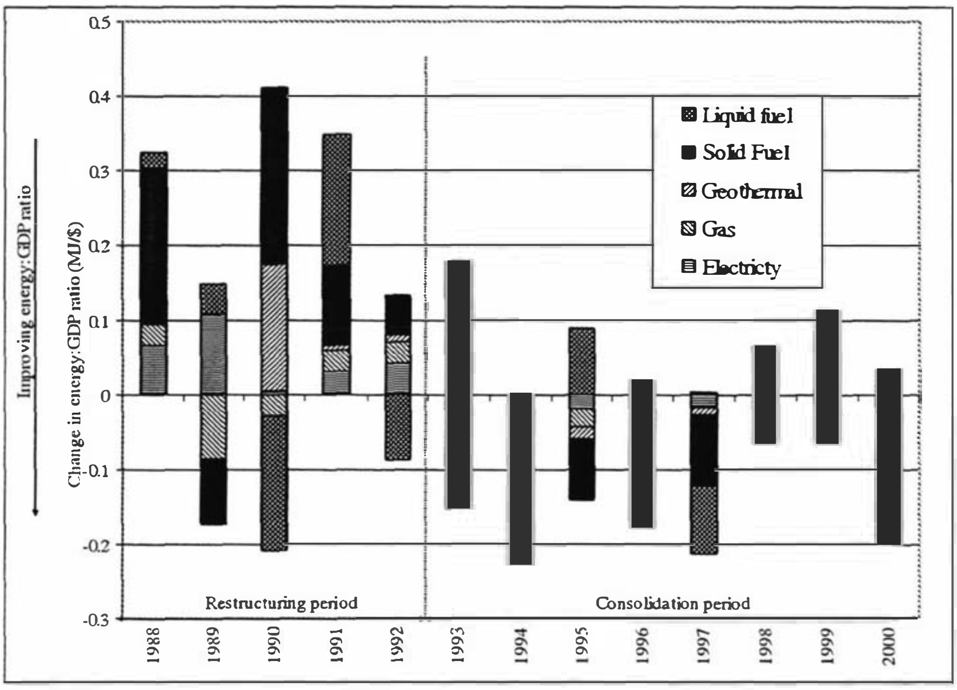

Figure 6-9: Technical effect by energy type in New Zealand, 1987-2000

Analysing the technical effect by energy type (Figure 6-9) gives the same picture: increased pressure from the technical effect on the energy:GDP ratio in the restructuring period, followed by a reduction in the latter period. Of particular note is the dominance of liquid fuel use. Interestingly, the results suggest an increase in the efficiency of liquid fuel use over the latter period. This is expected since the major user of liquid fuels is transport, and transport has shown an increase in its technical energy efficiency.

6.4.4 Structural effects

The structural effect measures the change in the energy:GDP ratio due to relative changes in the proportion of output from energy intensive sectors. On average, over the restructuring period (1987 to 1992), the structural effect tended to decrease the aggregate energy:GDP ratio (by around 16 kJ/$ per annum). This reflects a trend away from relatively energy-intensive sectors (such as basic metals), and into those that are less so (such as service sectors). This trend can be explained to a large extent by the reduction in the proportion of total GDP produced by the industrial sector (see Figure 6-11).

During the first period, the tendency for the total structural effect to exert a negative influence on the energy:GDP ratio was, to some degree, counteracted by the transport sector. Transport's upward pressure on the energy:GDP ratio through the structural effect, is an indication that the relatively energy intensive transport sector grew as a proportion of GDP over this period. Indeed this is the case. In 1987, the transport sector contributed 4.8% of New Zealand's GDP. By 2000 this proportion had increased consistently to 7.2% of GDP (Figure 6-10).

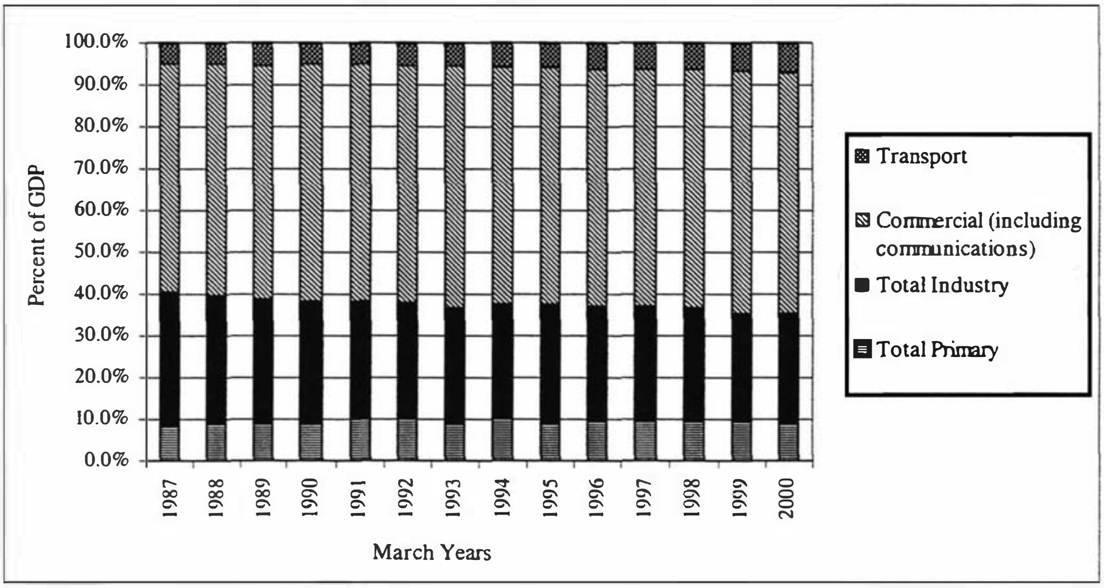

Figure 6-10: GDP contributions from sectoral groups in New Zealand, 1987-2000

During the decade 1990 to 2000, the transport sector's value added grew by no less than 79%. This high level of growth in transport is to be expected in a time of economic expansion because of transport's important role in the economy.

The role of manufacturing in the economy has diminished. From a high of 32% of GDP in 1987, it has shrunk to only 26% of GDP in 2000. Consequently, manufacturing sectors tended to contribute to a decreased structural effect in the latter period.

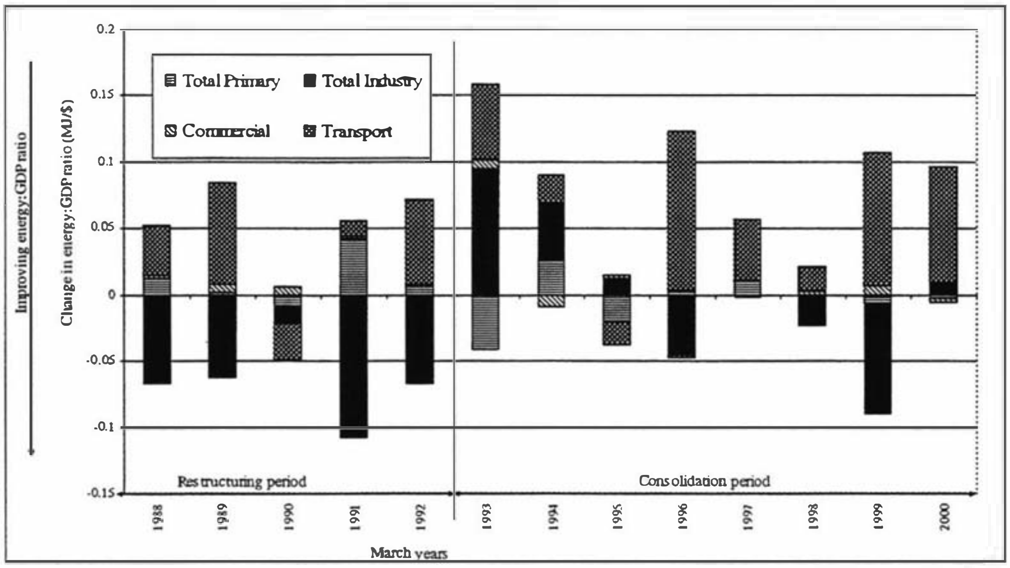

Figure 6-11: Structural effect by major sector groups of the New Zealand economy, 1987-2000

Over the period 1987 to 2000, the proportions of agriculture and commercial sector-derived GDP have been reasonably steady. Agriculture contributed 8.5% of GDP in 1987. This increased to 10.5% in 1992, then dropped back to 9.3% in 2000. The proportion of GDP derived from the commercial sector grew relatively steadily from 55% in 1987 to 57.6% in 2000.

6.4.5 The energy quality effect

The energy quality effect measures the change in the energy:GDP ratio due to the changes in the quality of energy inputs that provide energy services. Over both the restructuring and consolidation periods, energy quality tended to have a net downward effect on the aggregate energy:GDP ratio (see Figure 6-12).

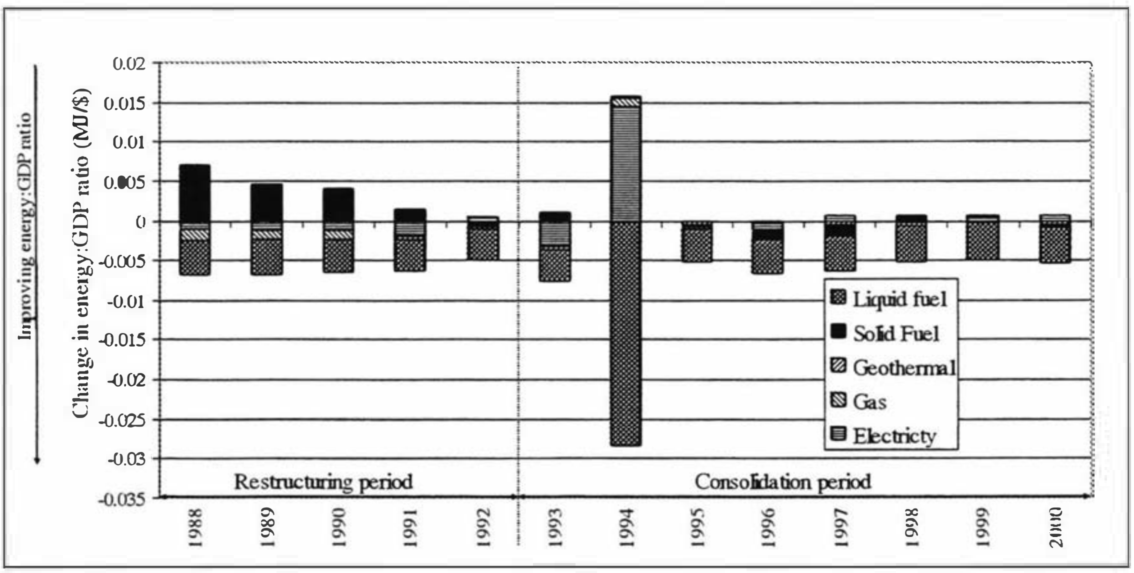

Figure 6-12: The energy quality effect by energy type for New Zealand, 1987-2000

During the restructuring period, the energy quality effect was dominated by two changes. First, there were improvements in the energy quality of liquid fuels, and to a lesser extent, electricity. That is, the energy quality of liquid fuel and electricity contributed to a decline in the energy:GDP ratio. Second, the energy quality of solid fuels declined (or contributed to an increase in the energy:GDP ratio). The downward pressure on the energy:GDP ratio from liquid fuels remained a consistent feature throughout the following consolidation period. This downward effect reflects the combined influence of improvements in the efficiency of motor vehicles (see Appendix 3), and the increasing dominance of liquid fuels in the economy (see Figure 6-13). In 1990, liquid fuels made up 40% of New Zealand's consumer energy. In 2000, liquid fuels made up 49%.

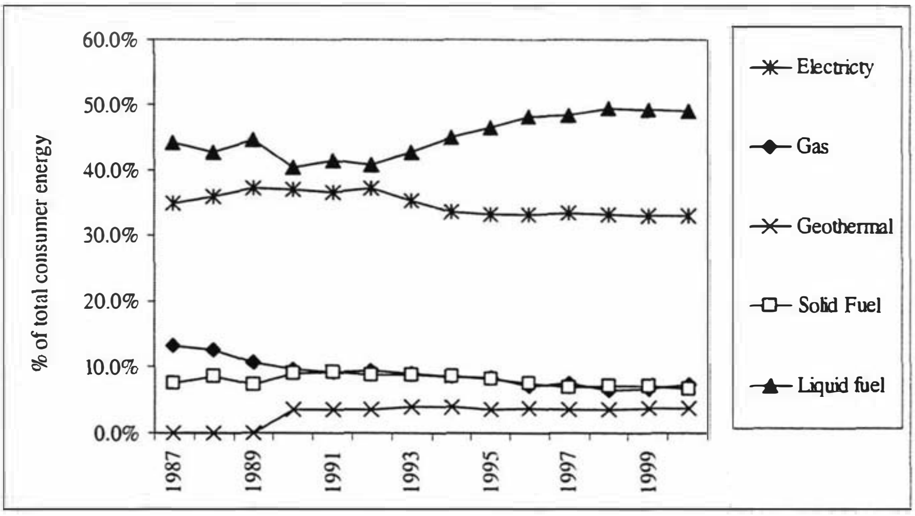

Figure 6-13: Energy shares in New Zealand (as a percent of total consumer energy in emjoules), 1987-2000

The downward pressure on the energy:GDP ratio exerted by electricity is likely to be a result of the assumptions about improvements in the efficiency of electro-technology. The pressure to decrease the energy:GDP ratio associated with liquid fuels and electricity during the restructuring period appears to be offset by the positive effect of solid fuels. This is a direct result of the growth in energy share of solid fuels over this period. From 1987 to 1992, solid fuels increased as a proportion of total energy from 7.6% to around 9%. This growth in solid fuel use occurred mainly in the industrial sector, and may be a reflection of substituting cheaper solid fuels for liquid fuels over the period of economic stagnation.

The patterns exhibited by the energy quality effect by fuel type in the restructuring period persisted through the later period (1993 to 2000). The main difference between the two periods is that solid fuels began to contribute to a decrease in the energy quality effect. Again, this can be related to the energy share of solid fuels dropping from 8.9% in 1993 to 6.8% in 2000.

It is important to note that a shift, or substitution, of higher quality energy types for lower quality energy types has tended to decrease the energy:GDP ratio. However, Cleveland et al. (2000, p. 316) caution that “if the substitution process cannot continue, further reductions in the energy:GDP ratio would slow.” They identify three factors that might limit substitution to higher quality energy. First, there are limits to the substitution process. Eventually, for example, all energy used would be of the highest quality (say electricity) and no further substitution would be possible. Second, as different energy sources are not perfect substitutes, the substitution process could have economic limits. Third, it is likely that supplies of petroleum will begin to decline in the near-to-mid term.

The other prominent point to note in the quality effect during the early part of the consolidation period, is the apparent outlier in the year ended March 1994 (see Figure 6-12). The *net* quality effect in this year is similar to other years. However, the large liquid fuels and electricity components point to a shift from liquid fuels to electricity. This is probably a result of the economy readjusting following the countrywide electricity shortage to the year ended March 1993.

Gas and geothermal energy use in both periods tended to slightly decrease the energy quality effect. This was a result both of relatively stable energy shares and marginal improvements in the quality coefficients.

6.5 Conclusions

This chapter has demonstrated that an index-decomposition technique can be useful for quantifying the underlying factors that influence changes in aggregate eco-efficiency indicators. Specifically, this chapter shows how the refined Divisia method proposed by Ang and Choi (1997) can be applied to decompose changes in the energy:GDP ratio into several factors; technical, structural and energy quality effects. The extension of the analysis to include quality considerations could also be useful for other environmental goods and services where quality issues affect economic production.

The results of the analysis conducted on the energy:GDP ratio show that changes in technology are a significant influence on the aggregate energy:GDP ratio. This effect is partially offset by structural and quality effects. This appears to support the claim of technology’s ability to offset economic growth. However, this analysis provides an historical view of changes – constant monitoring of the role of technology is required to avoid falling into the ‘techno fix’ trap.

The results of the analysis also clearly show that energy quality has an effect on changes in the energy:GDP ratio. This result is similar to that found by Liu et al. (1992b) and suggests that ignoring the issue of energy quality would have implications for the accuracy of the overall results of the decomposition.

This analysis has attempted to further refine the interpretation of the technical and quality effects. However, further work still remains to fully understand the components of these effects. Furthermore, more work is needed to extend the sectoral breakdown of official energy statistics – an issue highlighted in the 1996 energy statistics review (Statistics New Zealand, 1996).

Finally, the energy:GDP ratio is often criticised as a measure of a nation's energy efficiency. The analysis in this chapter has shown the ratio is influenced by a number of factors. The use of the decomposition technique "offers virtually the only way forward in identifying retrospectively the relative contribution of different factors to changes in energy demand" (Ang & Skea, 1994, p. 13). Thus, despite the limitations of the aggregate energy:GDP ratio (Brookes, 1995), use of decomposition analysis can help to increase the information value of the index and afford some insight into an aspect of a nation's eco-efficiency: the changing efficiency of energy use.

7 Measuring system-wide eco-efficiency in New Zealand

> *"It seems that most humans tend to think of, deal with, matters that are local, immediate, and relatively direct in their causation. Many environmental problems, however,... have indirect causation" (Herendeen, 1998, p. 148).*

The overall aim of this chapter is to measure system-wide eco-efficiency in New Zealand for national-policy purposes. Specifically, this chapter aims to expand the consideration of eco-efficiency in New Zealand to encompass both direct and indirect effects as well as a range of different environmental media. It will apply these considerations to estimate and analyse direct, indirect and system-wide eco-efficiency multipliers for New Zealand.

7.1 Rationale – the importance of system-wide eco-efficiency assessment in an ecological economic context

The work presented in this chapter follows several emergent themes in ecological economic literature that are important in the measurement of eco-efficiency. These themes include the need:

- for a focus on 'indirectness' and system-wide effects;
- to account for environment-economy interactions;
- to consider the appropriate scale, or resolution, for analysis.

7.1.1 System focus and 'indirectness'

A leitmotif of ecological economic theory is its attempt to take a whole-of-system perspective (see Chapter 2). As Costanza et al. (1991, p. 12) state, ecological economics has "the goal of attempting to quantify ecological economic interdependencies and arriving at overall system measures of health and performance."

A systems approach to eco-efficiency involves, inter alia, a consideration of both direct and indirect inputs[1] into the production process. Extending analysis beyond a consideration of direct inputs and effects to consider 'indirectness' is important in ecological economic analyses. Evidence of this importance is found in the significant body of ecological economic literature that has addressed indirect effects (see for example Farmer, Kahn, McDonald, & O'Neill, 2001; Grigalunas, Opaluch, & Luo, 2001; Guo, Xiao, Gan, & Zheng, 2001; Jalas, 2002; Jayadevappa & Chhatre, 2000; Konyar, 2001; Lohr, Park, & Higley, 1999; Subak, 1999).

[1] As was noted in Chapter 4 (section 4.6.2) eco-efficiency can be considered a ratio of ecosystems service inputs to useful outputs. Hence the imperative to consider the 'indirectness' of inputs.

Direct inputs can be defined as the actual inputs that the production process, or sector, consumes. However, economic activities indirectly require the use of other ecosystem service inputs, because industries draw on many kinds of inputs from a multitude of other sectors in order to generate their output. Indirect inputs, therefore, represent the system flows that were necessary to produce the direct inputs (Hannon, 1973). These indirect requirements arising out of inter-industrial dependencies must be taken into account in order to gain a full system-wide understanding of eco-efficiency (Di Pascoli, Femia, & Luzzati, 2001; Guo et al., 2001). Taken together, direct and indirect inputs represent the total, or system-wide inputs to a sector or process.

An example given by Herendeen (1998, p. 147) serves to illustrate the distinction between direct and indirect inputs. Herendeen (1998) asks how much energy is required to drive a car one kilometre? The possible answers are:

1. The fuel burned
2. Plus the energy to extract, refine and transport the fuel
3. Plus the energy to manufacture the car (prorated to 1 km's use)
4. Plus the energy to produce tyres, replacement parts, etc
5. Plus the energy to build and maintain roads
6. Plus the energy to maintain auto repair shops, government regulation and registration services, etc
7. Plus the energy to produce and maintain that portion of the health system used to care for the consequences of auto accidents and auto-related health problems.

The first input can be regarded as the direct input, while inputs 2 – 7 are indirect requirements to drive the car.

Most efficiency-related analyses consider only the direct inputs to a production process. However, ignoring indirect requirements is analytically myopic. Economic systems are highly interrelated and commodity production is dependent on both direct and indirect inputs. Further, indirect inputs can be a significant component of total inputs. For example, Patterson and McDonald (forthcoming) calculate the total (direct plus indirect) emissions of carbon dioxide from the New Zealand tourism sector in 1997/98. Total CO_2 emissions from the tourism sector are estimated to be 6.8 million tonnes. Of this, 26% of the emissions are from 'indirect' emissions, and 74% directly from the tourism sector. This is summarised in Figure 7-1 below.

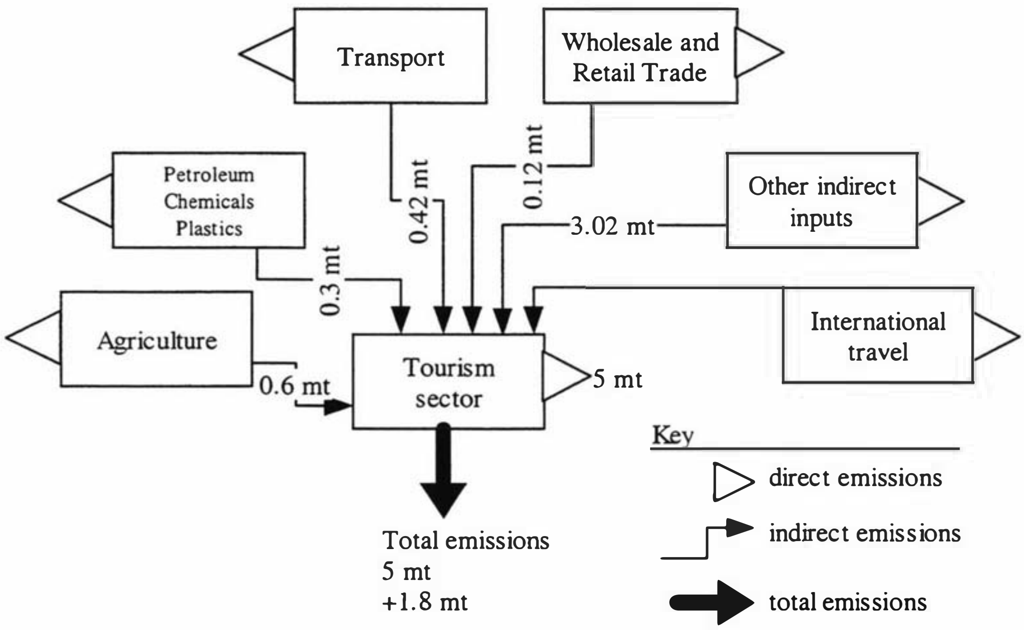

Figure 7-1: A simplified depiction of the results of Patterson and McDonald's (forthcoming) work estimating total (direct and indirect) CO_2 emissions in the New Zealand tourism sector for 1997/98 (million tonnes)

Unfortunately, when it comes to a systems perspective, eco-efficiency interpretations and measurement are often incongruous. While many advocates of eco-efficiency subscribe to a definition that emphasises life cycle assessment and a 'systemic' perspective, many of the indicators used to measure eco-efficiency neglect the system-wide effects of resource use and focus only on direct (or immediate) effects. For example, DeSimone and Popoff et al. (2000) who promote the WBCSD definition of eco-efficiency, hold up several eco-efficiency measures as best practice including Novo Nordisk's Eco-Productivity Index and Roche's EER (see section 6.1). Both of these indicators only measure direct inputs. Similarly, the indicators suggested by Hilson (1999) for measuring the eco-efficiency of the non-ferrous mining sector ignore system-wide effects. From an ecological economic perspective, there is an urgent need to move beyond the 'systemic' rhetoric and develop methods that can account for the systemic and interconnected aspects of eco-efficiency.

One approach to incorporating system-wide effects into an analysis of eco-efficiency is input-output (IO) analysis (see Table 5-2). This framework "brings out clearly the fact that changes in the composition of inputs in one sector will affect the [ecosystem service] requirements of all sectors of the economy" (Ryan, Méral, Schembri, & Zyla, 1998, p. 235. Comments in brackets added). Or in the words of Daly (1991, p. 42) input-output analysis "has been important in elucidating total (direct and indirect) requirements of materials and especially energy that must be extracted from the environment." Consequently, input-output analysis is used extensively in ecological economic practice (see for example Bicknell, Ball, Cullen, & Bigsby, 1998; Dellink, Bennis, & Verbruggen, 1999; Ferng, 2001; Ferrer & Ayres, 2000; Herendeen, 1978; Konyar, 2001; Lenzen & Murray, 2001; Loomis, 1995; Midmore & Whittaker, 2000; Nakamura, 1999).

7.1.2 Accounting for environment-economy interactions

Another feature of ecological economic theory is the importance of environment-economy interactions (see Chapter 2). As Costanza (1991, p. 3) explains "ecological economics differs from both conventional economics and conventional ecology in terms of the ... importance it attaches to environment-economy interactions." That is, ecological economics' "domain is the entire web of interactions between economic and ecological sectors" (Costanza et al., 1991, p. 3).

The importance of environment-economy interactions stems from a biophysical view where "the macro economy is an open subsystem of the ecosystem and is totally dependent upon it, both as a source for inputs of low-entropy matter-energy and as a sink for outputs of high-entropy matter-energy" (Daly, 1991, p. 35).

Given the importance of these interactions, an ecological economic analysis of eco-efficiency would necessarily need to consider the contribution of the environment to economic activity (El Serafy, 1991, p. 168). This contribution from the environment comes in the form of ecosystem services (Daily, 1997b; de Groot, 1987; Costanza et al., 1997). In other words, an ecological economic perspective of eco-efficiency sees economic activities "materially grounded in bundles of ecosystem services" (Hukkinen, 2001, p. 313).

There is a need to develop and apply models to account for the environment-economy interaction and ecosystem service contributions. Several ecological economists have outlined a range of techniques that currently in the ecological economist's tool box (Common, 1995; Faucheux. S. & O'Connor, 1998; Herendeen, 1998; van den Bergh, 1996). These tools range from system dynamics to scenario analysis, input-output matrices and multi-criteria evaluation.

7.1.3 Policy relevance in ecological economics

Chapter 6 has already discussed the importance of policy relevance in ecological economic theory. To date, most attention to eco-efficiency has occurred at the level of the individual firm or business unit (see for example DeSimone et al., 2000). A limited amount of effort has focused at eco-efficiency at the regional level with the *Eco*Link database calculating eco-efficiency indicators for three regions of New Zealand (McDonald & Patterson, 1999).

In contrast, little attention has been devoted to measuring levels and trends of eco-efficiency in New Zealand as a whole for national policy purposes. Central government has an important role in establishing overall policy settings and guidance for eco-efficiency in New Zealand. For example, the New Zealand government has set a target of 20% improvement in energy efficiency by 2012 (Energy Efficiency and Conservation Authority, 2001). In order to make appropriate decisions about eco-efficiency type policies such as the 20% energy efficiency target, policymakers need good information. The lack of information on economy-wide eco-efficiency in New Zealand is a significant gap in the New Zealand eco-efficiency policymakers' arsenal.

In summary, what is required from an ecological economic perspective is a methodology for measuring eco-efficiency in New Zealand for national policy purposes that explicitly embeds the flows of energy and materials to and from the environment into the complex web of the economic system. One approach that achieves this goal is input-output analysis.

7.2 Ecological multipliers as measures of system-wide eco-efficiency

Standard input-output IO matrices can be used to calculate economic multipliers (such as output, income and employment multipliers). In general terms, multipliers measure the direct and indirect repercussions of economic activity. For example, the output multiplier[2] of sector *j* measures the sum of direct and indirect (or system-wide) requirements from all sectors needed to deliver one additional dollar of output of *j* to final demand[3]. Calculating multipliers involves deriving the inverse Leontief matrix (the elements of which are used for calculating multipliers).

Several authors have attempted to incorporate ecological considerations into IO multiplier analysis and met with some success with respect to analysis of structure and indirect effects. These analyses have led to what are referred to as ecological multipliers. In general terms an ecological multiplier is a measure of the direct and indirect 'resources' (measured in physical terms) required to produce $1 of output. Ecological multipliers are useful in this research because they can be used as measures of system-wide eco-efficiency that account for both direct and indirect environmental inputs into the economy.

7.2.1 Approaches to calculating ecological multipliers

There are several approaches to calculating ecological multipliers. These approaches include those developed by ecologists and those that combine economic and ecological data such as that developed by Victor (1971) and an approach based on the inverse Leontief matrix[4].

[2] The output multiplier is a measure of the degree of structural interdependence between a sector and the rest of the economy.
[3] The rudiments of input-output matrices and mathematics are explained in Appendix 5.
[4] This research provides an overview of these approaches. For more detail see Richardson (1972), Hite and Laurent (1971), Hannon (1973) and Patten (1982).

Ecological models

In ecology, IO-type methods have been used to track flows and indirect effects in ecological systems. For example, Hannon (1973) uses an IO-type approach to trace the direct and indirect energy flow dependence (or structure) in the Silver Springs ecosystem in Florida. His models use matrix algebra techniques and can be regarded as descended from economic IO analysis. Patten (1982) has also used network models based on matrix algebra methods, which have some similarity with Hannon's input-output work.

The main limitation of these models is that they do not include economic variables. Therefore, they do not capture the interaction between economic activity and the environment, as is required by the core focus of eco-efficiency. A further difficulty with ecology-derived multiplier approaches is that they require significant amounts of detailed ecological data. This data is simply not available for New Zealand. This effectively renders these approaches unusable for this analysis.

Victor Model

The Victor model is more pragmatic than the purely ecological models when it comes to data requirements. Victor uses an industry-by-commodity framework for his model. In the Victor model all entries, except those for ecologic commodities[5] are in dollar terms. The ecologic commodities are measured in the appropriate physical units (Victor, 1971, p. 53).

For pragmatic reasons, Victor excludes the ecological sector that shows the interactions within the environment itself on the grounds that data shortages make it impossible to operationalise (Richardson, 1972, p. 224). Victor's attempt extends beyond a theoretical accounting model since he attempted to apply his model empirically on data assembled for Canada in 1961. Consequently, he was able to develop a set of ecological impact tables (with and without leakages) and in doing so, was one of the first to, inter alia, calculate system-wide measures of eco-efficiency (though he did not call them that). His ecological impact tables (Victor, 1971, p. 339) showed the direct and indirect effects on individual ecological inputs and outputs attributable to the production of one dollar's worth of each commodity delivered to final demand.

Victor's approach is able to accommodate multiple outputs (i.e. a relaxation of the homogeneity assumption). While this is a better approximation of reality than standard Leontief IO analysis,

[5] Economic commodities "are the output of industries or the material and supplies used by industries or goods bought by consumers" (Victor, 1971 p. 51). In contrast, an ecologic commodity "only passes from one economic unit to another by going through a part of the environment that is not held as private property" (Victor, 1971 p. 51).

it does pose a problem for application to New Zealand. Data are not readily available in New Zealand to support a multiple-output analysis.

An approach based on the inverse Leontief matrix

Hite and Laurent (1971) were one of the first[6] to develop an approach that focused specifically on calculating ecological multipliers. Hite and Laurent (1971) used an input-output framework to estimate the environmental repercussions of changes in the economic structure of Charleston, South Carolina, USA. They showed that it is not necessary to construct a full Victor-style model in order to calculate multipliers. Their approach essentially 'appended' an environmental matrix to the standard inverse Leontief matrix that is readily calculated from available data in New Zealand. This environmental matrix contains data on resource use or residual emissions per dollar of gross output for each sector in the input-output matrix. This approach incurs the same limitations and strengths as the standard Leontief IO table (see section 7.2.4).

This formulation of ecological multipliers based on the inverse Leontief matrix (ILM) is directly analogous to eco-efficiency multipliers that account for environment-economy interactions. This is because these multipliers measure the ratio of ecological inputs to economic outputs as per the 'core' definition of eco-efficiency. As a result of this, and the fact that the approach is based on relatively available information, the ILM approach is considered most appropriate for this study's calculation of system-wide eco-efficiency indicators for New Zealand.

7.2.2 Approach used in this thesis to calculate system-wide eco-efficiency

The two essential elements of the approach used by Hite and Laurent are (1) the inverse Leontief matrix of the IO matrix of the New Zealand economy, and (2) a matrix showing the flow of environmental inputs from and outputs to the economy.

Algebraically, the approach is outlined as follows. Consider the following equation:

$$e_{kj} = \frac{q_{kj}}{X_j}$$

Equation 7-1

[6] Several others were working on similar approaches at the same time – for example, Hirst and Herendeen (1973) and Leontief (1970). Hite and Laurent acknowledge the links between their work and the others.

Where e_{kj} is the output (or direct) ecological multiplier[7] of resource inputs or pollution outputs k in sector j, q_{kj} is the physical quantity of resource inputs or pollution outputs k used by sector j and X_j is the total output of sector j in \$.

Rearranging Equation 7-1

$$q_{kj} = e_{kj} X_j$$ **Equation 7-2**

Consider a situation of m resource inputs to, or pollution outputs from, n economic sectors. The set of all e_{kj} arranged in a matrix of order $m \times n$ is called **E**. In matrix notation:

$$\mathbf{q}=\mathbf{Ex}$$ **Equation 7-3**

Where **q** is a vector of order $m \times 1$ resource inputs or pollution outputs and **x** is a vector of gross economic output of order $n \times 1$. It can be shown that (see Appendix 4):

$$\mathbf{x}=(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}$$ **Equation 7-4**

Where:

$(\mathbf{I}-\mathbf{A})^{-1}$ is the inverse Leontief matrix of order $n \times n$

y is an $n \times 1$ vector of final demand.

Now substitute Equation 7-4 into Equation 7-3 above.

$$\mathbf{q}=\mathbf{E}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{y}$$ **Equation 7-5**

And substituting **F** for $\mathbf{E}(\mathbf{I}-\mathbf{A})^{-1}$ gives

$$\mathbf{q}=\mathbf{Fy}$$ **Equation 7-6**

Where **F** is a matrix of order $m \times n$ of the system-wide eco-efficiency (direct and indirect) multipliers of final demand expressed in terms of physical units per dollar.

7.2.3 Methodological issues associated with calculating ecological multipliers as measures of system-wide eco-efficiency

There are several methodological issues associated with applying the inverse Leontief matrix based approach to calculating system-wide eco-efficiency multipliers. These include double

[7] Sometimes this ratio is referred to as eco-intensity. Eco-intensity is the reciprocal of eco-efficiency and the difference between the two terms is mathematically trivial. The main difference from an interpretation point of view is that eco-intensity is an increasing scale indicator, whereas eco-efficiency is a decreasing scale indicator. This difference affects the appropriate aggregation function (see Chapter 8). Eco-intensity can be accommodated within the definition of an eco-efficiency indicator tendered in Appendix 1.

counting, treatment of household sector, imports and using 'ecosystem function, services and goods' concepts.

Double counting

Double counting can arise when physical resource flows in the **E** matrix are attached to the economic IO table. This is because economic IO tables already include monetary measures of some physical flows. In other words, physical resource flows in the economy are potentially counted twice, in both the **E** matrix and the interindustry transactions matrix.

Removing double counting is important for accuracy reasons, but can be difficult. Identifying and removing double counting is complicated by the fact that economic tables can be inconsistent in their coverage of resource flows within the economy. For some resources, the economic tables ignore direct resource extraction and only trace resource distribution. For example, in the case of water resources economic accounts only account for water distribution. Thus, attaching physical water abstraction data to the economic accounts does not incur a double-counting error. In other instances (such as energy) both extraction and distribution are included in the interindustry transactions matrix. In this situation care must be taken to remove double counting by ensuring that resource flows are counted only once.

Treatment of the household sector

There is no fixed rule for including (or excluding) any specific economic activity in the final demand sector. For some purposes it might be desirable to 'close' the system with respect to one or more of the activities in the final demand sector. Households, for example, can be shifted into Quadrant 1[8] of the IO matrix, and the same is true of any other activity in final demand (Miernyk, 1965, p. 16).

In conducting eco-efficiency analysis using IO tables, it is important to include in Quadrant 1 all economic activities that use environmental services to produce outputs. These activities are called *endogenous*, since their behaviour is determined *within* the economic system (Schaffer, 1976, p. 9). Other activities, such as government expenditure or household consumption can be considered to be based on decisions made *outside* the economic system and so are called *exogenous* activities. Sometimes it is not easy to classify activities as either endogenous or exogenous.

The household sector is a case in point. Household consumption is conventionally classified as final-demand. Labour and profits are regarded as primary inputs in the IO matrix and are not

[8] See Appendix 5

normally included in the inter-industry transactions matrix (Wright, 1975, p. 35). However, there is much debate as to whether this is conceptually appropriate or not.

Some analyses treat household consumption as part of Quadrant 1 (for example, Costanza & Herendeen, 1984; Schaffer, 1976). In other words, the model is 'closed with respect to households.' There appear to be two related arguments for including the household sector in Quadrant 1. First, it is argued that households are a critical part of an economy and should, therefore, be regarded as producing as well as consuming sectors (and included in Quadrant 1). Households sell labour, managerial skills and privately owned resources. And to produce these resources they buy food, clothing, cars etc. Some authors also argue that it is important to account for these labour inputs into the economy (see Costanza & Herendeen, 1984). In the context of calculating energy costs, (Costanza & Herendeen, 1984, p. 132) suggest that keeping households exogenous, "can lead to major distortions of energy cost calculations since labor ... provide services to the economy whose energy costs would be ignored."

There appear to be two arguments for excluding household consumption from Quadrant 1. The first argument focuses on boundary definition. If household consumption is included in Quadrant 1, then why not include the other final demand sectors? Taken to the logical extreme this essentially leads to a closed system. Second, the inclusion of the household sector in Quadrant 1 produces an 'homogenising' effect on the ecological multipliers. That is, the inclusion of household labour in Quadrant 1 swamps other inputs because labour is a large fraction of the expenditure for all inputs (around 15% of total expenditure in New Zealand in 1994/95 (Statistics New Zealand, 1997, p. 132)). While Costanza and Herendeen (1984) attempt to refute this empirically, the debate as to whether to endogenise households is still not resolved.

Imports

Attention must also be paid to imports. Ideally, they should be removed from the system in order to calculate the multipliers for the domestic economy, and then reintroduced to estimate eco-multipliers for all goods and services (domestic and imported) consumed in New Zealand. However, quantifying environmental inputs in imports is complicated by the existence of two kinds of imports in the economic system (Herendeen, 1978). First, competitive imports that have domestic counterparts, such as steel in New Zealand's case. Second, non-competitive imports which do not have domestic counterparts, such as bananas. For both of these import types, data are not readily available on the environmental inputs and pollution produced by other countries in their production of these imported goods.

One solution is to assume that the environmental inputs and outputs for competitive imports are the same as in New Zealand. This approach has two limitations. First, this approach may be easy to accept for steel commodities, but for many other commodities it could introduce significant distortions (for example, the land required to produce a litre of milk in New Zealand will be quite different from the land required to produce a litre of milk in the Netherlands). No such assumptions are appropriate for non-competitive imports. Second, this approach implies that New Zealand and the country of origin of the imported goods have the same intermediate demand structure. This is an unreasonable assumption. Given the complexity and diversity of intermediate demand structures in Western economies, it is unlikely that any two countries will have the same demand structures.

Because of the difficulties associated with quantifying environmental inputs into imports, some studies avoid including imports. Excluding imports would tend to underestimate eco-efficiency multipliers[9]. Needless to say, it would be desirable to include imports in an analysis if that was possible.

The use of ecosystem function, goods and services concepts

Eco-efficiency multipliers need to be formulated as a ratio of useful outputs and environmental inputs. However, the inverse Leontief matrix based approach used by Hite and Laurent looked at both environmental inputs and residual (or pollutant) output multipliers. From first impressions it could appear that the group of 'residual' output multipliers are not eco-efficiency ratios because they measure the ratio of useful output to waste output. This apparently breaks the efficiency convention of 'outputs to inputs.' But this view is misleading.

There is a need to reconceptualise Hite and Laurent's 'resource inputs' and 'residual outputs' in terms of the emerging concepts of ecosystem functions, goods and services (Bolund & Hunhammar, 1999; Costanza et al., 1997; Daily, 1997a; de Groot, 1987; Norberg, 1999). Ecosystem functions are defined as "the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly" (de Groot, Wilson, & Boumans, 2002, p. 394). Using this definition, ecosystem functions are seen as a subset of ecological processes and ecosystem structures. When human values are implied, ecosystem functions are conceptualised as ecosystem goods and services. That is, ecosystem goods and services represent the benefits human populations derive from ecosystem functions (Costanza et al., 1997). For simplicity, this thesis will refer to ecosystem goods and services together as ecosystem services[10].

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[9] However, this underestimation might not be too significant. Bullard and Herendeen (1975, p. 274) estimated that "the true effect of neglecting energy embodied in imports is less than 5% (on the average) for the relatively closed economy of the USA."
[10] This follows the approach by Costanza et al. (1997, p. 253).

Ecosystem functions provide services that are important *inputs* into the economy as most economic production processes depend heavily on them (de Groot, 1987). For example, these functions provide regulation processes (which provide services such as clean water, storm protection and decomposition of waste), habitat functions (which provide services such as the maintenance of biodiversity and maintenance of commercially harvested species), production functions (which provide food, raw materials, energy etc) and information functions (which provide for the enjoyment of scenery etc). From this perspective, all ecosystem services (including waste purification services) can be regarded as an input to the economic process.

de Groot et al. (2002) identify 23 major categories of ecosystem services. These ecosystem services are shown diagrammatically in Figure 7-2.

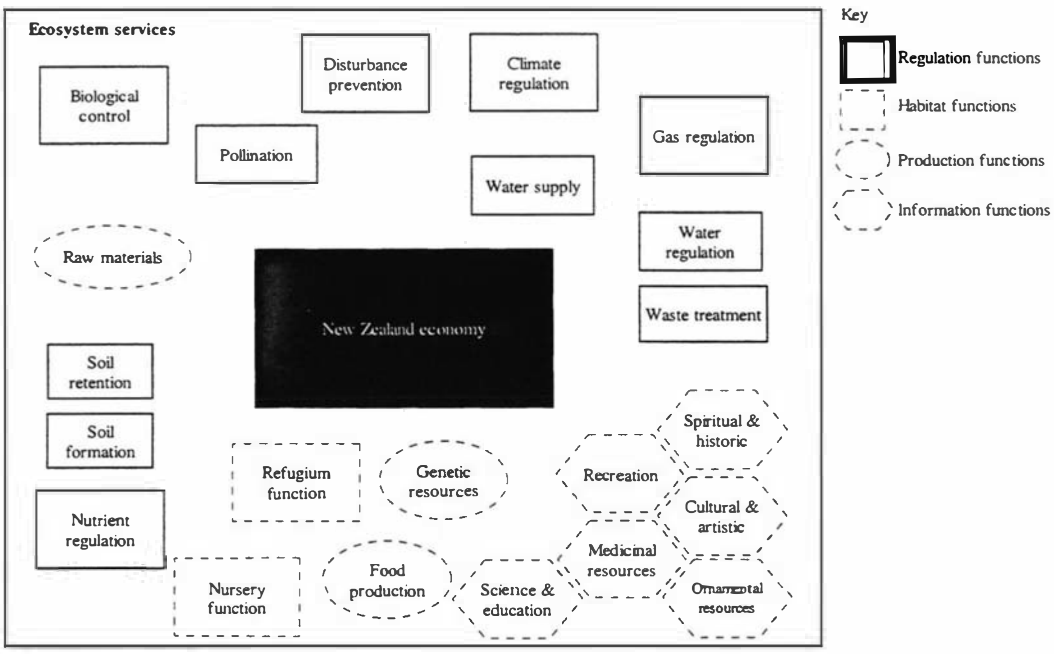

Figure 7-2: Diagram listing the 23 major categories of ecosystem services as identified by de Groot et al. (2002).

Waste output as a proxy for ecosystem services

Multipliers calculated as a useful output ($) to waste output (in physical terms) can be aligned with this ecosystem-service perspective of eco-efficiency, *if the 'waste output' is considered a proxy for the relevant ecosystem service input.* For example, the quantity of water-pollutant outputs from the economy can be considered a proxy of the waste treatment ecosystem service *input*. This proxy approach is appropriate because often it is difficult to measure the ecosystem service input directly. In these situations, the use of proxies make analysis based on ecosystem services empirically tractable.

This *proxy approach* does have at least one important limitation. It assumes that ecosystem services are able to treat all residuals from economic activity. If the ecosystem services become overloaded, waste generated by economic activity outstrips the ecosystem waste-processing capacity. In this case, using the quantity of waste produced as a proxy will overestimate the ecosystem service provision.

The use of CO_2 as a proxy is likely to overestimate the gas regulation and climate regulation-type ecosystem services. However, using water pollutants as proxies for water and waste water-related services could possibly be more accurate in the New Zealand context. This is because it appears that most New Zealand rivers fully 'treat' water pollutants and there is not significant ecosystem service overload. For example, data from the 68 National River Quality Network sites reveals that "New Zealand's rivers generally have very high quality water by international standards" (Statistics New Zealand, 2002, p. 35). This is based on five fresh water quality parameters: clarity, ammonia, soluble inorganic nitrogen, dissolved reactive phosphorous and biological oxygen demand. In general, the data shows that the upper reaches of most New Zealand rivers have high water quality. Middle and lower reaches tend to have elevated turbidity and nutrient levels, particularly in agricultural and urban catchments. Data also shows "pollution discharges from pipes or other point sources has reduced considerably over the past 10 years" (Statistics New Zealand, 2002, p. 35).

7.2.4 Assumptions and limitations of the use of ecological multipliers as measures of system-wide eco-efficiency

Assumptions

The ILM-based approach to calculating ecological multipliers relies on the standard Leontief matrix and, therefore, relies on the same assumptions as standard economic IO tables. For the standard accounting identities and mathematics in IO algebra (see Appendix 4) to hold when calculating ecological multipliers (i.e. in a static analysis), two crucial assumptions[11] must be made.

1) *Homogeneity*. For calculation purposes it is assumed that an IO sector consists of processes producing a single homogenous product with similar techniques. The main reason for the

[11] In dynamic applications of IO matrices, four other assumptions are generally made:
1) *Linear production functions*. The essence of the Leontief model is a technological relationship between the purchases (or inputs) of any sector and the output of that sector. This relationship is embodied in standard IO analysis as linear production functions, where inputs (purchases) are required in fixed proportions to output in each purchasing sector (Burton, 1985; Richardson, 1972).
2) *Fixed input structure*. That is, if output doubles, inputs are assumed to also double.
3) *No capacity constraints* exist in any sector. The lack of capacity constraints means that the supply of each good is perfectly elastic (Burton, 1985).
4) *Constant direct-input coefficients* (a_{ij}) over time. If the linear direct-input coefficients remain constant over time (see section 7.2.3), they provide a nexus for linking final demand to gross output. Constant direct-input coefficients over time implies the assumption of static technology.

homogeneity assumption is to avoid negative entries in the $(\mathbf{I}-\mathbf{A})^{-1}$ matrix (Costanza & Hannon, 1989, p.493). A negative value in the $(\mathbf{I}-\mathbf{A})^{-1}$ matrix implies that the column sector directly or indirectly produces (rather than requires) the row commodity. This is contrary to IO accounting conventions. Furthermore, a negative entry would imply that production of an additional unit of a commodity would result in a decrease in total (direct and indirect) input requirements rather than more. This is clearly absurd.

The assumption of homogeneity is a gross simplification of a complex economic-environment system where multi-product plants make it difficult to group together plants with similar output and input structures. The pragmatic approach is "to group processes and products which differ in some respects but which behave sufficiently uniformly to be used as a basis for aggregation" (Richardson, 1972, p. 8). The issue is even more acute when dealing with environmental outputs from the economy. The assumption of no joint products is at odds with a model where industries produce pollutants as well as commodities.

2) *Additivity*. That is, the total effect of carrying out several types of production is the sum of their separate effects. The additivity assumption, therefore, rules out external economies or diseconomies associated with production (Burton, 1985; Richardson, 1972).

Limitations

In addition to the simplifying assumptions, the method based on the inverse Leontief matrix could be criticised because of its heavy data requirements, restrictive boundary definition and its assumptions about the relationship between prices and physical flows.

A common criticism of the ILM-based approach is that it is expensive to implement because it requires a significant quantity of data. However, economic IO data are available for most countries. A greater challenge is gathering sectoral data on ecosystem services. As was demonstrated by the *Eco*Link database (see section 7.3.2) this data is generally available in New Zealand at an acceptable cost. Consequently, the ILM-based approach provides a relatively easily implementable method for calculating system-wide eco-efficiency indicators.

A further limitation relates to the boundary of the approach based on the ILM. The multipliers trace the direct and indirect use of ecosystem services through the economic system. Further linkages back through the ecological system are not accounted for.

A simple example serves to illustrate this point. Consider the diagram below showing a simplified process for the production of butter. Butter requires wood indirectly via the need for paper packaging. The ILM-based approach estimates the ecological multiplier of wood use per unit of butter by accounting for the flow of wood through the various economic processes as it is transformed into butter packaging. However, the ILM-based approach does not trace the linkages through the environment that produced the wood in the first place. That is, the solar energy, soil and nutrient inputs are not accounted for in the ILM-based method of calculating eco-efficiency indicators. Figure 7-3 below shows the scope of the ILM-based approach as those boxes lying within the shaded area.

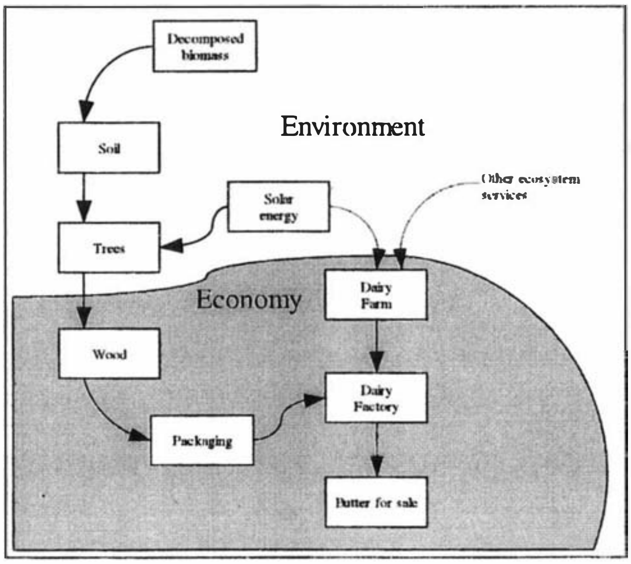

Figure 7-3: The boundaries of the inverse Leontief matrix based approach to calculating ecological multipliers using butter production as an example

This restrictive boundary definition is necessary to make the ILM approach tractable. Data on the complex links in an ecosystem are not readily available.

Another limitation relates to the assumption about the relationship between prices and physical flows. Generally, the IO technique assumes that a producing sector charges all purchasing sectors the same for its product. This assumption allows the analyst to use monetary flows as a proxy for material flows (Bicknell et al., 1998, p. 158). If sectoral prices are constant then the analyst can infer physical output between sectors by using the monetary flows in the transactions table. If, however, a producing sector is able to charge one sector more for its product than another, then use of the transaction table to infer physical product flows may lead to false conclusions.

A difficulty with attempting to include the environment in IO tables, is that the tables are biased towards factors that can easily be quantified. Qualitative environmental factors that are difficult to quantify (for example, amenity value) must necessarily be excluded altogether from analysis based on IO tables.

A final criticism of the use of an IO framework for calculating eco-efficiency multipliers is that the ecosystem services embodied in capital are not accounted for. Conceptually, in eco-efficiency analysis, one would like to consider the ecosystem services required to make the capital in plant and equipment to be as valid a contribution as those used to make the products themselves. However, capital formation and depreciation are not included in the interindustry matrix (Bullard & Herendeen, 1975). These could be endogenised but this creates problems in itself. For example, in order to balance the IO matrix, capital formation is forced to equal capital depreciation, which may not actually be the case. The standard approach is to exclude capital from the transaction matrix. However, it must be acknowledged that excluding resource requirements of capital from the analysis means that the calculated ecological multipliers will underestimate the 'true' value of the multipliers.

Strengths

The apparent naivety of IO analysis is misleading. The simplifying assumptions are offset by many compensating advantages, the most important of which is that they allow empirical estimation of indirect flows in a complex system. Consequently, a number of authors in different fields have used the IO framework to analyse the requirements for natural resources, particularly energy, in the production of various commodities (see for example, Bullard and Herendeen, 1975; Hite and Laurent, 1971; Peet 1987; Wright, 1975).

There are several reasons why IO tables are useful for eco-efficiency analysis in particular and economic-environmental analysis in general. First, the assumptions are not always too far from reality. For example, Richardson (1972, p. 9) notes that "it is possible for money values to be used as a measure of physical purchases in real terms, since relative price changes do not distort too much the input purchase pattern per unit of output."

Second, IO tables can answer the call of authors such as Billharz and Moldan (1997) and tie ecosystem services directly to the economic sectors that use them. Although IO models are based on economic transactions tables denominated in dollars, Victor (1971, p. 5) demonstrated that ecological inputs and outputs, such as pollution, can be "conveniently included in IO models, without upsetting the accounting identities." Therefore, the links between final demand, the production of goods and services and the use of ecosystem services can be explored using IO methods (Bicknell et al., 1998). The IO framework also imposes much-needed discipline on economic-environmental analysis. For example, many important accounting balances must be maintained (see Appendix 4) in constructing and IO table (Polenske, 1989, p. 41).

Third, an IO framework can help trace both the direct and indirect (i.e. total system) requirements of ecosystem services by the economy. By building on the inverse Leontief matrix (which quantifies direct and indirect flows), ecological multipliers can be calculated that trace the direct and indirect requirements throughout the economy.

Finally, the IO table is a flexible and accessible analytical tool. It can be made as detailed or as complex (for example in sectoral disaggregation) as necessary for any given purpose (Miernyk, 1965, p. 16). An advantage of this method of using IO tables is that results can be obtained quickly from published economic statistics without a detailed technical knowledge of the industrial processes involved (Wright, 1975, p. 38).

In conclusion, it seems that there are a sufficient number of advantages of the ILM-based approach to warrant its use in estimating eco-efficiency multipliers. As with any empirical work, awareness of underlying assumptions and limitations are needed when interpreting results.

7.3 Application of the inverse Leontief matrix-based approach to measuring system-wide eco-efficiency for New Zealand

Several applications of the inverse Leontief matrix-based approach to eco-efficiency measurement have been attempted in New Zealand to date. Peet (1987) and Lermit (1999) have applied the approach to energy and electricity use in New Zealand respectively. Bicknell et al. (1998) have used a variation of the method to estimate land multipliers and New Zealand's ecological footprint. McDonald and Patterson (1999) have applied the approach to cover many resource inputs and outputs to the environment. They provided the first attempt to estimate eco-efficiency multipliers for three regions in New Zealand. This present research expands the work of McDonald and Patterson (1999) to the national level by estimating a profile of sectoral system-wide eco-efficiency multipliers for New Zealand[12] as a whole for the years March year ended 1995 and March year ended 1998[13]. This is the first time national-level eco-efficiency multipliers have been estimated for New Zealand across many environmental media.

7.3.1 Economic data used

The economic IO matrices used in this analysis are based on the 1994/95 Inter-Industry Study of the New Zealand Economy (Department of Statistics, 1991)[14]. The 1994/95 matrix was aggregated and updated by McDonald and Patterson (1999) to 1997/98 using sectoral employment to output ratios[15].

Before a brief discussion of the IO tables for New Zealand, several methodological issues must be addressed; double counting, treatment of the household sector and treatment of imports.

[12] The New Zealand boundary is taken to be delimited by New Zealand's Exclusive Economic Zone boundaries (Seafriends, 2002).
[13] Hereafter referred to as 1994/95 and 1997/98 respectively.
[14] The Department of Statistics study updates the last full IO table conducted in 1986/87 using surveys on selected sectors.
[15] A RAS optimiser was used to balance rows and columns (McDonald & Patterson, 1999).

Double counting

The initial level of sectoral aggregation (48 sectors) was dictated to a large extent by the availability of ecosystem-service information (*Eco*Link provides ecosystem-service[16] information to a maximum disaggregation of 48 sectors). This level of aggregation was then amended to remove double counting in the electricity distribution and gas reticulation sectors. The remaining sector list together with the sector titles used in the text is shown in the Table 7-1 below:

Table 7-1: List of 46 sectors of the New Zealand economy used in this analysis

Sector number	Sector name	NZSIC codes	Sector group
1	Mixed livestock	11120, 11130, 11140	Primary production
2	Dairy farming	11110	Primary production
3	Horticulture	11150, 11170, 11190	Primary production
4	Services to Agriculture	112000	Primary production
5	All other farming	11160	Primary production
6	Fishing and Hunting	13000	Primary production
7	Forestry & Logging	12000	Primary production
8	Oil and Gas Exploration	22000	Primary production
9	Other mining	29000, 23000, 21000	Primary production
10	Meat Products	31110	Manufacturing
11	Dairy Products	311120	Manufacturing
12	Manufacture of other food	31100, 31200, 31100	Manufacturing
13	Beverage Manufacture	31300, 31400	Manufacturing
14	Textile Manufacture	32000	Manufacturing
15	Wood & Wood Products	33000	Manufacturing
16	Paper products	34100	Manufacturing
17	Printing & Publishing	34200, 83402	Manufacturing
18	Other Chemicals	35200, 35500, 35600	Manufacturing
19	Basic Chemicals	35100, 35300, 35400	Manufacturing
20	Non-metallic Minerals	36000	Manufacturing
21	Basic Metal Industries	37000	Manufacturing
22	Fabricated Metals	38100	Manufacturing
23	Equipment Manufacture	38200-38500	Manufacturing
24	Transport Equipment	38400	Manufacturing
25	Other Manufacturing	39000	Manufacturing
28	Water works	41030, 42000	Government
29	Construction	53000	Manufacturing
30	Trade	61000-62000	Trade
31	Accommodation	63000	Trade
32	Road transport	71120-71150	Transport
33	Services to Transport	71160-71190	Transport
34	Water Transport	71200	Transport
35	Air Transport	71300	Transport
36	Communications	72000	Commercial services
37	Finance	81100-81200	Commercial services
38	Finance services	81491-82300 excl 81200	Commercial services
39	Insurance	81200	Commercial services
40	Real Estate	83100	Commercial services
41	Business Services	83200	Commercial services

[16] Note that the *Eco*Link database refers to "resource inputs" and "pollutant outputs." As was explained above, the latter can be regarded as proxies for ecosystem service inputs.

42	Dwelling ownership	83122	Dwelling
43	Education	93100-93200	Social service
44	Community Services	93300-93400	Social service
45	Recreation Services	93900-94900	Social service
46	Personal Services	95000, 93500, 92030, 92011, 92012, 92020	Social service
47	Central Government	91010	Government
48	Local Government	91020	Government

Appendix 5.1.2 lists the ecosystem-service dimensions, and how, if appropriate or possible, double counting has been addressed. The main potential for double counting occurs in the energy resources. In general, in this work, the energy 'extraction' activity was measured in dollars, and the 'distribution' activity was accounted for by the physical energy data in delivered-energy terms (measured in joules). For example, coal mining activity was included in the IO table (in dollars) while coal distribution was accounted for in joules. Effectively, this meant that coal merchants and distribution activity (measured in dollars) had to be excluded from the economic accounts.

Treatment of the household sector

This thesis follows the standard IO accounting convention that excludes household consumption and other final demand from the inter-industry transactions matrix. Sensitivity analysis was conducted with an endogenous household sector. Results showed that closing the model with respect to households did make a significant difference to the estimated eco-efficiency indicators. In effect, an endogenous household sector led to an $\mathbf{(I-A)^{-1}}$ matrix with large household coefficients relative to other sectors. This in turn led to the household sector tending to inflate and dominate the ecological multipliers.

Imports

Data on ecosystem service inputs into goods imported into New Zealand is not easily available[17]. Consequently, imports are not included in this analysis of the eco-efficiency of goods and services in New Zealand[18]. The implications of this are that, if a commodity is produced abroad then the ecosystem-service requirements of its production will be omitted (Wright, 1975, p. 32). Consequently, it is likely that the multipliers calculated in this research overestimate the 'true' eco-efficiency of goods and services in New Zealand.

[17] The issue of data unavailability with respect to ecosystem service inputs is not unique to New Zealand. In the work by Muradian et al. (2002) to account for ecosystem services embodied in trade, the authors acknowledged the limitations of their analysis due to quality and availability of data. The authors concluded that "much more research is needed in ameliorating and expanding data collection and analysis" in this area (Muradian et al., 2002, p. 65).

[18] It is beyond the scope of this research to attempt to quantify the ecosystem service inputs into imports. This would be a fruitful area for future research in eco-efficiency.

7.3.2 Ecosystem service data

Ideally, an analysis of this sort should be comprehensive and include all 23 ecosystem service categories identified by de Groot et al. (2002). However, this analysis is limited by available information and because it is difficult to measure many ecosystem services directly. There is relatively good information on 'raw material' service inputs into New Zealand such as land, energy, water and minerals. For other ecosystem services, it is necessary to use 'proxy' measures. For example, instead of the ecosystem service 'gas regulation' and 'waste treatment' proxy measures of air and water pollutant discharges (in physical quantities) can be used[19].

Combining the data in the *Eco*Link database and other sources led to a data set of measures and proxies of ecosystem-service inputs to the New Zealand economy (shown as shaded boxes in Figure 7-4). These proxies cover four ecosystem goods (raw materials) and proxies for gas regulation, climate regulation, water supply and water regulation and waste treatment. Together, these link to at least 10 out of the 23 ecosystem services (shown by the arrows in Figure 7-4) identified by de Groot et al. (2002). Table 7-2 contains a summary of selected ecosystem service inputs and proxies into the New Zealand economy.

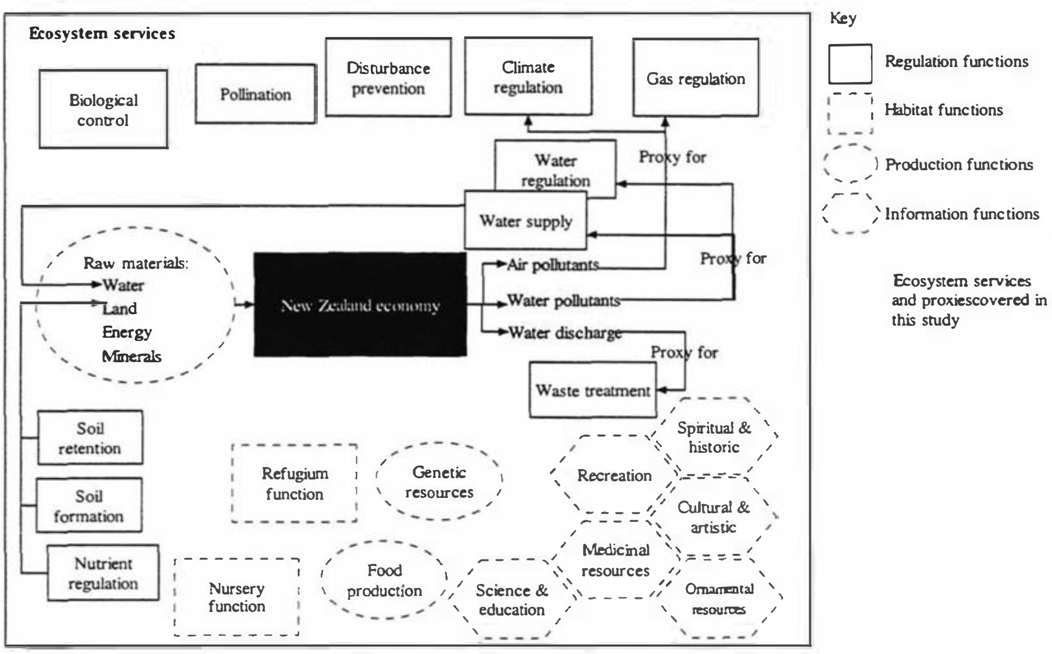

Figure 7-4: Diagram showing the ecosystem services and proxies covered by this study (shaded) and their links to the major ecosystem service groups as identified by de Groot et al. (2002)

[19] It has already been mentioned that there may be inaccuracies with the use of some proxies (see section 7.2.3).

Table 7-2: Estimates of ecosystem-service inputs into the New Zealand economy

Ecosystem service	Ecosystem service (measurement (M) or proxy (P))	Unit	Total (1994/95)	Total (1997/98)
Raw materials				
	Total Water Takes (M)	m^3/yr	$1,382.7 \times 10^6$	$1,229.9 \times 10^6$
	Land (M)	ha/yr	17.6×10^6	17.6×10^6
	Total Energy (M)	emjoule/yr	464.8×10^3	484.1×10^3
	Gold (M)	kg/yr	10.6×10^3	10.4×10^3
	Silver (M)	kg/yr	27.6×10^3	29.4×10^3
	Coal (M)	tonne/yr	3.1×10^6	3.5×10^6
	Ironsand (M)	tonne/yr	2.1×10^6	2.3×10^6
Other ecosystem services				
(a) water supply & water regulation				
	Total water discharges (P)	m^3/yr	$2,189.0 \times 10^6$	$2,157.5 \times 10^6$
(b) waste treatment				
	Water pollutants total:	kg/yr	7.3×10^6	6.7×10^6
	- Ammonia (NH_4) (P)			
	- Biochemical Oxygen Demand (BOD_5) (P)	kg/yr	28.4×10^6	26.9×10^6
	- Dissolved Reactive Phosphorous (DRP) (P)	kg/yr	3.7×10^6	3.4×10^6
	- Nitrate (NO_3) (P)	kg/yr	1.8×10^6	1.6×10^6
	- Total Kjeldahl Nitrogen (TKN) (P)	kg/yr	37.4×10^6	34.4×10^6
	- Total Phosphorus (TP) (P)	kg/yr	5.6×10^6	5.9×10^6
c) gas regulation and climate regulation				
	Carbon Dioxide (P)	tonne/yr	21.0×10^6	21.4×10^6
	Methane (P)	tonne/yr	5.9×10^3	6.2×10^3
	Nitrous Oxide (P)	tonne/yr	1.0×10^3	1.0×10^3

Details of the calculations used to estimate national-level ecosystem service inputs are contained in Appendix 5.2. Briefly, national estimates are available for land (from McDonald & Patterson, forthcoming), while energy inputs and energy-related air pollutants are available from the Energy-End Use database (EECA Energy Use Database, 1996). Other ecosystem-service proxy data are based on the information contained in the *Eco*Link database. This database contains information for three regions of New Zealand (Northland, Auckland, and Waikato). In 1997/98 these three regions covered 62% of the population and accounted for around half of New Zealand's GDP. The regional information was scaled up to a national level using value-added scalars (see Appendix 5.2 for more detail).

7.3.3 Overview of the results

Using the method outlined in section 7.2.1 above, system-wide ecological multipliers have been estimated for New Zealand. This is the first time a 'profile' of New Zealand's eco-efficiency has been developed at the national level in New Zealand using IO tables.

The full table of ecological multipliers for New Zealand is presented in Appendix 5.3. The indicators are presented in three groups for the two years 1994/95 and 1997/98:

- *Direct* multipliers meaning the direct ecosystem service use per dollar of output;

- *Indirect* multipliers calculated as the difference between total and direct multipliers. These measure the indirect ecosystem service requirement per dollar of final demand;
- *Total* multipliers calculated as the **F** matrix (Equation 7-6) and measure the total (direct plus indirect) ecosystem requirements per dollar of final demand.

Table 7-3 below presents a summary of selected indicators for the *mixed livestock*[20] and *insurance* sectors.

Table 7-3: Selected eco-efficiency indicators for selected sectors (physical units/$000)

	Unit	Mixed livestock	Insurance
1994/95			
Direct Intensity			
Total Water Takes	m^3/$000	0.03	0.00
Total land	ha/$000	2.86	0.00
Total Energy	GJ/$000	2.01	0.14
Total intensity			
Total Water Takes	m^3/$000	5.05	2.06
Land total	ha/$000	3.30	0.01
Total Energy	GJ/$000	4.25	0.98
1997/98			
Direct Intensity			
Total Water Takes	m^3/$000	0.19	0.00
Total land	ha/$000	2.86	0.00
Total Energy	GJ/$000	1.74	0.12
Total intensity			
Total Water Takes	m^3/$000	7.60	2.35
Total Land	ha/$000	3.42	0.01
Total Energy	GJ/$000	4.60	1.28

This table shows that in 1994/95 each $1000 of total output (or benefit) from the *mixed livestock* sector requires 0.03 m^3 of direct water inputs (surface and ground water). In contrast, the *insurance* sector does not use any water inputs directly. The calculation approach allows the tracing of ecosystem service requirements back an infinite number of stages of intermediate inputs through the New Zealand economic system. Thus, a $1000 increase in final demand for the *mixed livestock* sector in 1994/95 ultimately requires 5.05 m^3 of water inputs. Interestingly, an increase of $1000 in final demand for the insurance sector shows a total requirement of 2.064 m^3 of water inputs. This shows one of the most notable features of the system-wide eco-efficiency multipliers matrix. That is, even those sectors of the economy that do not show a direct ecosystem service requirement (such as *insurance* with respect to water) show requirements in the total effects matrix owing to the interdependence between sectors.

[20] For the remainder of this chapter, the sector titles will be italicised to aid identification.

The following discussion analyses each group of ecological multipliers in more detail. The discussion attempts to draw attention to those sectors with the most significant multiplier levels or changes. In doing so, this can alert policy makers interested in improving New Zealand's eco-efficiency to those sectors and ecosystem services in need of more immediate attention than others.

7.3.4 Water input and water discharge eco-efficiency multipliers

Water input volumes

Water is an essential ecosystem good and is used as an input into many production processes. Clean water is used for a variety of purposes ranging from an ingredient in food products, to use for cleaning. The details behind the water input and discharge data are recorded in the *Eco*Link Water Account Technical Report (McDonald & Patterson, 1999). The data are based on water abstraction (for surface and ground water) and discharge consents allocated by the three regional councils[21] over the two periods (1994/95 and 1997/98). Essentially, this means that *Eco*Link only accounts for part of the water inputs and outputs, as shown in Figure 7-5.

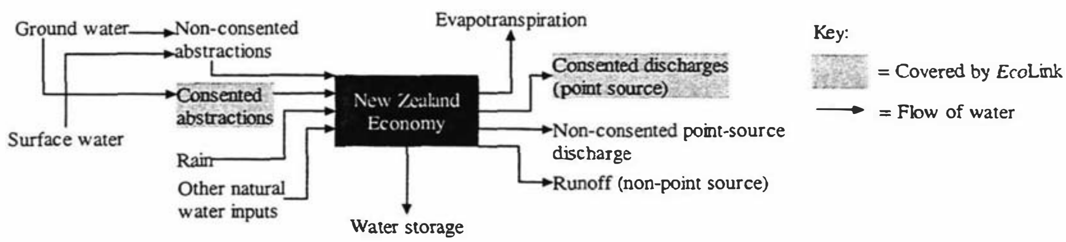

Figure 7-5: Water inputs to, and outputs from, the New Zealand economy covered by the *Eco*Link database

Estimated water abstractions for the New Zealand economy in the two periods are shown in Table 7-2.

21 The three regional councils are Northland Regional Council, Auckland Regional Council and Environment Waikato. Under the Resource Management Act 1991 (RMA) regional councils have responsibility to regulate, by issue of resource consents, the way people use land, water and coastal resources. Each Council is required to keep detailed records of these consents. It is important to note that these consents record the maximum allowable abstraction. Where possible these data were checked against compliance monitoring data. However, compliance monitoring data are not always available, therefore, it is possible that considered limits may differ from actual use.

Water-use multipliers

Two sectors stand out for policy attention based on their relatively high water-use multipliers; *other mining* and *horticulture*[22] (see Figure 7-6).

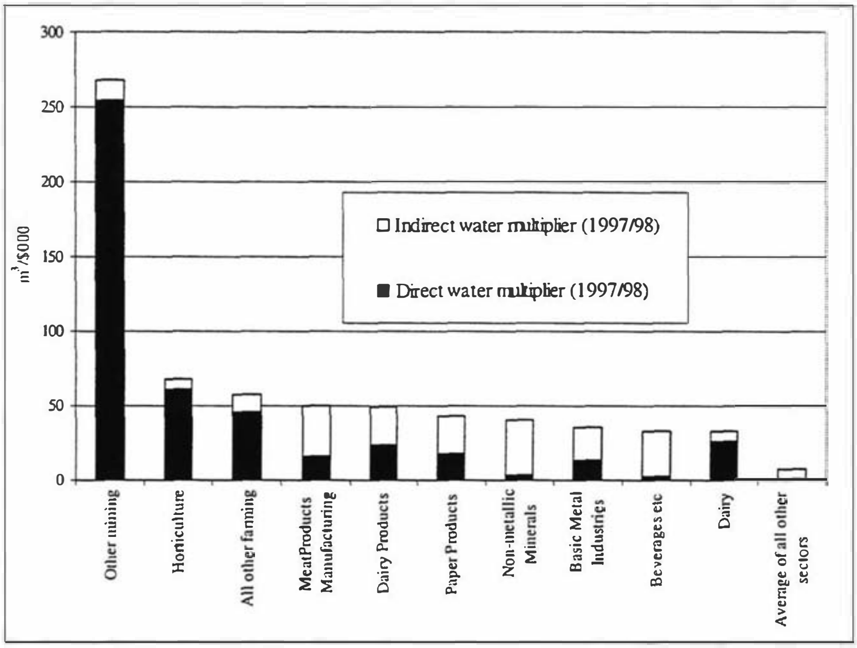

Figure 7-6: The 10 sectors with the highest water-use multipliers in New Zealand in 1997/98 (m^3/$000)

The water using sector with the highest water use multiplier is the *other mining* sector. In 1997/98 the *other mining* sector had a total water-input multiplier[23] of 267 m^3/$000. This sector uses a significant volume of water for extraction (as in the case of coal hydro-mining), transporting, and cleaning. In 1997/98 this sector accounted for approximately 15% of total New Zealand water abstractions. Of particular concern is the estimate that the water-input multiplier (total requirements) of the sector grew by 18.6% over the inquiry period. This can be explained in part by the discrepancy between changes in water use and contributions to value added. Total water abstractions increased by 19% over the two periods, while value-added contribution only increased by 3.4%.

The other sector requiring policy attention from a water efficiency perspective is *horticulture*. *Horticulture* is a significant user of consented water abstractions for irrigation. The *horticulture* sector's total water requirement multipliers for 1994/95 and 1997/98 were 70 m^3/$000 and 67

[22] *Water works and supply* multipliers were much higher than these sectors. However, it is not appropriate to compare *water works and supply* with other sectors since water works does not 'use' water in the strict sense. Rather it processes, cleans and supplies water to water users.
[23] That is, 'total system requirements' rather than total of 'ground and surface water abstractions.' To avoid confusion, the term 'total' in the context of water abstractions will be used to refer to total-system requirements unless otherwise stated.

m^3/$000 respectively. This shows that the ***horticulture*** sector improved its water use efficiency by around 4%.

Further information on the relative water multipliers of sectors can be gleaned by analysing sectors in groups. This analysis suggests, from a water-efficiency perspective, attention should be given to reducing the multipliers of the *primary production* [24] sectors. The *primary production* sectors' average water multiplier (total requirements) in 1997/98 is estimated as 51 m^3/$000. This is more than double the average of the *manufacturing* sector (22 m^3/$000), and *trade* (11 m^3/$000). The *primary production* sectors' water requirements are dominated by those sectors one would expect to be high water users: *other mining, fishing and hunting* (principally freshwater aquaculture), *horticulture* and *dairy farming*. While the water multiplier of *horticulture* decreased slightly over the period 1994/95 to 1997/98, *dairy farming* water multiplier grew. This latter point is interesting given the significant increase in *dairy farming* activity over the period; the growth in total milk production in New Zealand increased 21% from 8,997 million litres in 1994/95 season to 10,929 million litres in the 1997/98 season (New Zealand Dairy Board, 2000).

It is also interesting to note that the average indirect-requirement multipliers of the *primary production* sectors are small compared to direct multipliers (in 1997/98 indirect multipliers for this group were on average, one fifth of direct multipliers). This is in contrast to the *manufacturing* sectors. In the 1997/98 indirect multipliers were on average more than three times higher than direct multipliers. This is to be expected, as the manufacturing sector, by definition, requires significant inputs (including water) from other sectors of the economy. In other words, the manufacturing sectors have considerable backward linkages through the economy. An analysis of the inverse Leontief matrix reveals that the *manufacturing* sectors have a relatively high degree of interdependence with the rest of the economy[25]. In particular, these sectors show significant backward linkages with the *primary production*, *trade*, *finance*, *business services* and *transport* sectors. These comments on the difference between direct and total multipliers provide an important message for policy analysts. For the *manufacturing* sectors, it is important to monitor both the direct and indirect ecosystem service multipliers. This 'systems perspective' of the water efficiency of *manufacturing* sectors is more informative than simply focusing on direct water requirements alone and can help to identify those sectors with poor eco-efficiency in a system sense.

Water discharge multipliers

[24] See Table 7-1.
[25] As shown by their relatively high output multipliers.

Water discharges are used as proxies for the water regulation and water supply ecosystem services. The two sectors with the highest water discharge volumes in both periods were the *personal services* sector and the *other mining* sectors, accounting for around 42% and 25% of all discharges respectively. Not surprisingly, these sectors also showed the highest ratios of water discharge to value added of all sectors (see Figure 7-7).

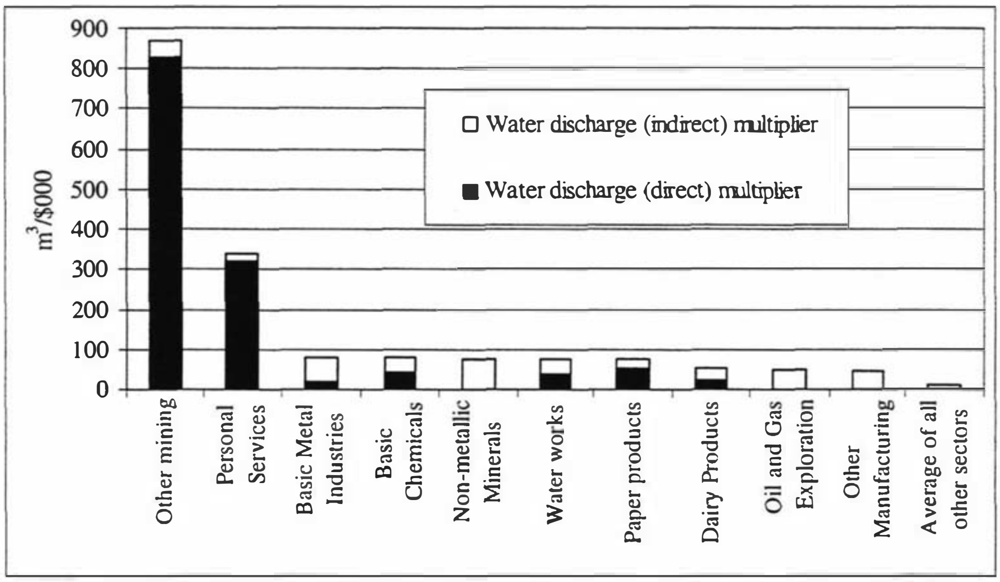

Figure 7-7: The 10 sectors with the highest water-discharge multipliers in New Zealand in 1997/98 (m^3/$000)

The predominance of the *other mining* sector in the water-discharge multipliers is consistent with the argument that this sector requires particular attention with respect to water use.

The water-discharge multipliers in the *other mining* sector appear to have increased over the period. This follows the growth in economic activity for this sector (3.5% increase in a value added) over the two periods, and the growth in water-input multipliers. In 1994/95 this sector's total[26] water discharge multiplier was 664 m^3/$000. In 1997/98 the multipliers had increased to 870 m^3/$000 (a 31% growth in water-discharge multipliers). This growth could be the result of sectoral shifts within the mining sector towards more water-intensive mining activities. According to the New Zealand Minerals Industry Association (2002), the relatively water-intensive gold mining increased 800% from 1986 to 1996. Another explanation could be the decline in the water efficiency of plant and equipment in the sector.

The other sector requiring attention from a water-discharge perspective is the *personal services* sector. The high water-discharge multiplier of this sector is not surprising considering it

[26] 'Total' in this case means total system requirements rather than the total of water discharges to land and water. To avoid confusion, 'total' in the context of water discharges will be used to refer to total system requirements unless otherwise stated.

contains *sewerage and urban drainage* (NZSIC 92012). In 1994/95 this sector's direct and total water discharge multipliers were estimated to be 320 m^3/\$000 and 338 m^3/\$000 respectively. These multipliers remained relatively stable between the two periods (although discharges to land increased as a proportion of total water discharges).

Analysing water-discharge multipliers by sector groups reveals that the *primary production* and *social service* sector groups should receive some attention. The *primary production* sectors' water-discharge multipliers (total requirements) are dominated by the *other mining* sector, which tends to increase the average for this group of sectors. Without the influence of the *other mining* sector, the *primary production* sector is still, on average, more water-discharge intensive than other sectors. In contrast, without the influence of the *personal services*, the *social services* group of sectors average (total) water-discharge multiplier is negligible.

7.3.5 Water pollutant eco-efficiency multipliers

Discharged water often carries with it pollutants from the production process. Measures of water pollutants are used as a proxy for the contribution of the waste treatment ecosystem service. Data on water pollutants[27] by sector is only available for a selection of physio-chemical parameters and for point-source discharges only. These include (McDonald & Patterson, 1999):

- ammonia (NH_4) which is very toxic to aquatic life and is often present in dairy effluent, sewage and some industrial discharges;
- biological oxygen demand (BOD_5) which is a measure of the potential for chemical contaminants in water to cause low dissolved oxygen levels;
- total phosphorus (TP) and total Kjeldahl nitrogen (TKN) which are measures of phosphorus and nitrogen respectively. Both nutrients promote nuisance plant growth and are related to eutrophication. TKN is a measure of total organic nitrogen[28];
- dissolved reactive phosphorus (DRP) which is an operational measure of orthophosphate and is also related to nuisance plant growths in water bodies;
- nitrate which is a major cause of eutrophication in receiving waters. It is generally produced as a run-off from agricultural land that has been worked with chemical fertilisers.

[27] Note that the data on water pollutants only cover those pollutants captured by consented water discharges (see Figure 7-5).
[28] The Kjeldahl method involves digestion of the organic material and the sample with boiling, concentrated sulphuric acid. As such, this method does not differentiate between nitrate-nitrate and nitrate-oxygen linkages (for example nitrates, nitrites etc). It does not pick up inorganic nitrogen (Fox Scientific, 2002).

Table 7-2 shows the estimated total pollutant discharges for the two periods.

Water pollutant multipliers

Water pollutant multipliers for *personal services*, *meat products*, *dairy farming* and *all other farming* tend to be greater than for the rest of the economy (both in direct and total[29] terms). This is consistent with expectations since all these sectors involve some sort of activity that involves direct water pollutant discharge. For example, the *personal services* sector includes the *sewerage and urban drainage* (NZSIC 92012) and *collection and disposal of refuse* (NZSIC 92011) subsectors, both of which involve significant pollutant discharges. Likewise, the *dairy farming* and *meat products* sectors are responsible for significant quantities of effluent as a result of their production processes. The multipliers are shown in Appendix 5.3 and for illustrative purposes, ammonia multipliers are shown in Figure 7-8.

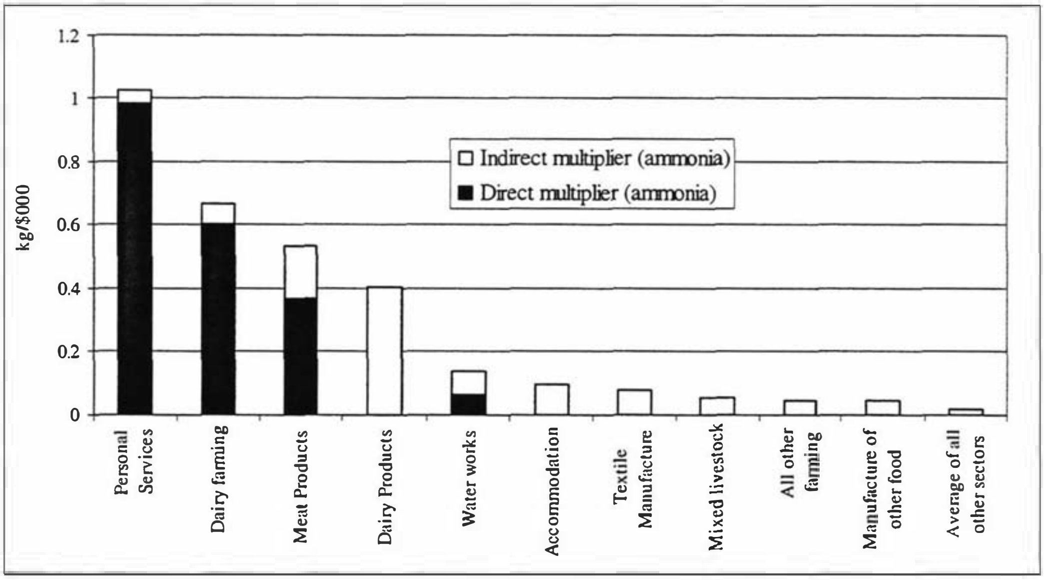

Figure 7-8: Illustration of water pollutant multipliers - the 10 sectors with the highest water-pollutant (ammonia) multipliers in New Zealand for 1997/98 (kg/$000)

Personal services sector

This sector has the highest multipliers of all pollutants, except nitrate. Interestingly, there is very little difference between direct and total water pollutant multipliers (on average total multipliers are 4% higher than direct multipliers). All direct and total water pollutant multipliers for this sector recorded slight decreases (approximately 8% drops for both the direct and total multipliers from the 1994/95 to 1997/98). These changes are not unexpected and

[29] 'Total' in this case means total system requirements rather than total of pollutants from discharges to land and water. To avoid confusion, 'total' in the context of water pollutants will be used to refer to total system requirements unless otherwise stated.

probably represent standard management practice to continually improve plant efficiency through capital replacement and retrofitting.

Dairy farming

The *dairy-farming* sector also exhibits very high water pollution loadings per dollar for all pollutants except TKN[30]. These high loadings are to be expected given the need for discharge consents for dairy shed effluent.

In contrast to the *personal services* sector, the indirect multipliers of *dairy farming's* water pollutants are relatively high. This suggests that *dairy farming* is more structurally interdependent with the rest of the economy than the *personal services* sector. Comparing these two sectors' output multipliers confirms this observation[31]. Further analysis of the inverse Leontief matrix suggests that the *dairy farming* sector has significant links (i.e. relatively high coefficients) to the *mixed livestock*, *basic chemicals* (which includes *chemical fertilisers* (NZSIC 35121)) and *trade* sectors. This high degree of linkages is expected since the *dairy farming* sector is a major purchaser of livestock, fertilisers, farming equipment and feed etc. Consequently, for an accurate system-wide perspective of water-pollutant discharge intensity in *dairy farming* it is particularly necessary to consider indirect multipliers.

A further rationale for a policy focus on *dairy farming* is that water-pollutant multipliers for the *dairy farming* sector grew over the period 1994/95 to 1997/98. Direct multipliers grew on average by 4% while total multipliers grew by 5%. This growth in multipliers is surprising since *diary farming* activity has increased (over the period value added increased by 8%). Given this increased activity, one would expect economies of scale with increased herd sizes and greater production. The growth in multipliers is not large, but it does follow the same trend as other eco-efficiency multipliers of the *dairy farming* sector (see for example, section 7.3.4).

Meat products sector

The *meat products* sector has relatively high water pollutant multipliers – especially nitrate multipliers. *Meat products* account for 96% of total consented point-source nitrate discharges in New Zealand. High nitrate loadings are associated with both the effluent from the rendering sections of meat works (where the intestines are cleaned prior to rendering) and the use of nitric acid for cleaning, which is a nitrate itself.

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[30] TKN measures organic nitrogen. Potential sources of organic nitrogen discharges from *dairy farming* are primarily cow faeces and milk. The latter tends not to be discharged to the environment for obvious reasons. Organic nitrogen from cow faeces (principally proteins in gut bacteria) tends not to be a point-source discharge issue except from the dairy shed. Also, cow faeces from the dairy shed is commonly collected and spread onto land. Therefore, the low TKN intensity for *dairy farming* is consistent with expectations.

[31] *Dairy farming* has an output multiplier of 2.02 while *personal services* has an output multiplier of 1.78.

As with the *dairy farming* sector, the *meat products* sector has relatively high indirect multipliers. Interestingly, the *meat products* sector has the highest output multiplier of all sectors in this study. A perusal of the inverse Leontief matrix shows the *meat products* sector has strong links with *mixed livestock* and the *trade* sectors in particular. The difference between direct and total multipliers is particularly pronounced for the DRP multipliers. The *meat products* sector's direct multiplier is negligible as this sector discharges very little DRP directly. However, the total intensity is an order of magnitude higher than the direct multiplier because the farming inputs into the *meat products* sector come with 'embodied' DRP.

Direct water pollutant multipliers of *meat products* tended to decrease over the period 1994/95 to 1997/98. In contrast, total multipliers increased by an average of 11% over this period. This is an indication that the water-pollutant multipliers of inputs to the *meat products* sector (primarily from the *mixed livestock* and *trade* sectors) have increased. This is the case with the average total multipliers of the *mixed livestock* and *trade* sectors increasing by 21% and 12% respectively over the period 1994/95 to 1997/98 period.

7.3.6 Land input eco-efficiency multipliers

All sectors require land inputs, whether it is for placing buildings on, running livestock or mining minerals[32]. Sectoral land appropriation in New Zealand is dominated by the *mixed livestock* sector. In 1997/98 it was estimated that it accounted for around 67% of total appropriated land.

With respect to land multipliers (hectares per $000), the *mixed livestock* sector is by far the most land intensive (in both direct and total-system requirement terms) with a total multiplier of 3.4 ha/$000 in 1997/98. Furthermore, given that the *livestock* sector is at the beginning of the production process, with few backward linkages, the direct and total land multipliers are very similar (a 16% difference). The direct land multipliers are dominated by the primary-production farming sectors; *other farming*, *dairy farming* and *forestry and logging* (see Figure 7-9).

[32] Land data were obtained from McDonald & Patterson (forthcoming) who calculated the land area appropriated by different sectors for the 1997/98 year. A sectoral breakdown of land appropriation for the year 1994/95 is not available. Consequently, it was assumed that the sectoral land mix remains constant between the two periods. This is not too unrealistic an assumption as it is unlikely sectoral land mix would change dramatically over three years.

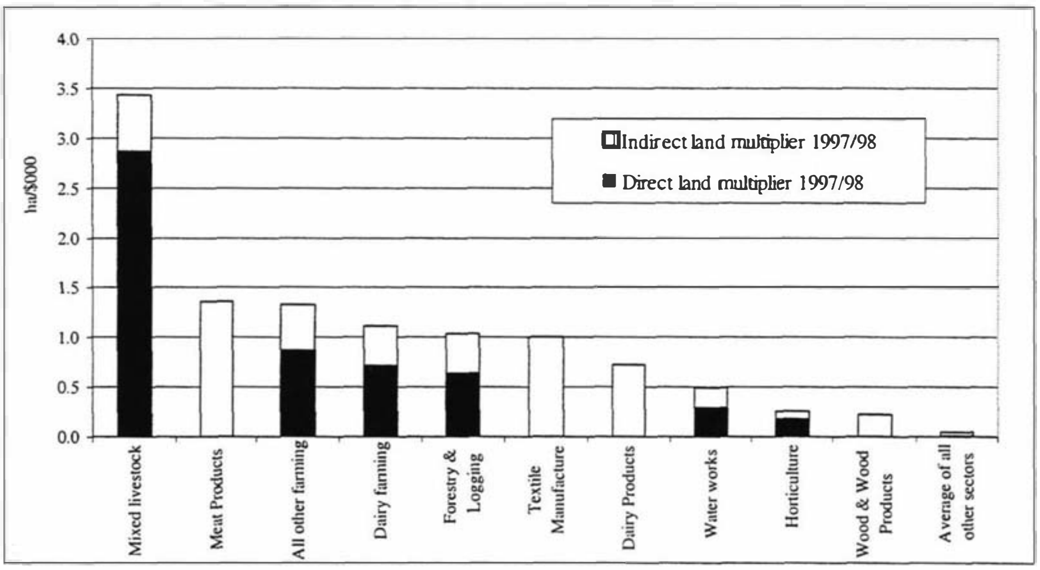

Figure 7-9: The 10 sectors with the highest land multipliers in New Zealand in 1997/98 (ha/$000)

System-wide land requirements offer a slightly different picture. The *mixed livestock* sector is still the most land intensive. However, manufacturing sectors that rely directly on inputs from land intensive *primary production* sectors also emerge as being relatively land intensive (see Figure 7-9). These sectors include *meat products*, *textile manufacture* (because of the wool inputs) and *dairy products*.

7.3.7 Mineral inputs eco-efficiency multipliers

Data on gold, silver, coal[33] and ironsand[34] as ecosystem raw material inputs into the New Zealand economy are available from the Crown Minerals section of the Ministry of Economic Development (Crown Minerals Group, 2001). These three minerals all enter the economy through the *other mining* sector. This is the only sector with a direct mineral-input multiplier. The *other mining* sector on-sells raw minerals to other sectors of the economy, in particular, to the *non-metallic minerals*, *basic metals* and *basic chemicals* sectors. When considering the total system requirements of mineral inputs, these latter sectors show relatively high total multipliers. For example, see Figure 7-10. The mineral input multiplier for the *other mining* sector is estimated to have grown by around 11% over the period 1994/95 to 1997/98.

[33] Coal is dealt with in the 'energy inputs' section. To avoid double counting, coal is excluded from the mineral inputs.
[34] This information was reported in calendar years and was adjusted to March years. The iron sand information was validated against data obtained from New Zealand BHP Steel Mining Ltd for their mines at Taharoa and Waikato Head.

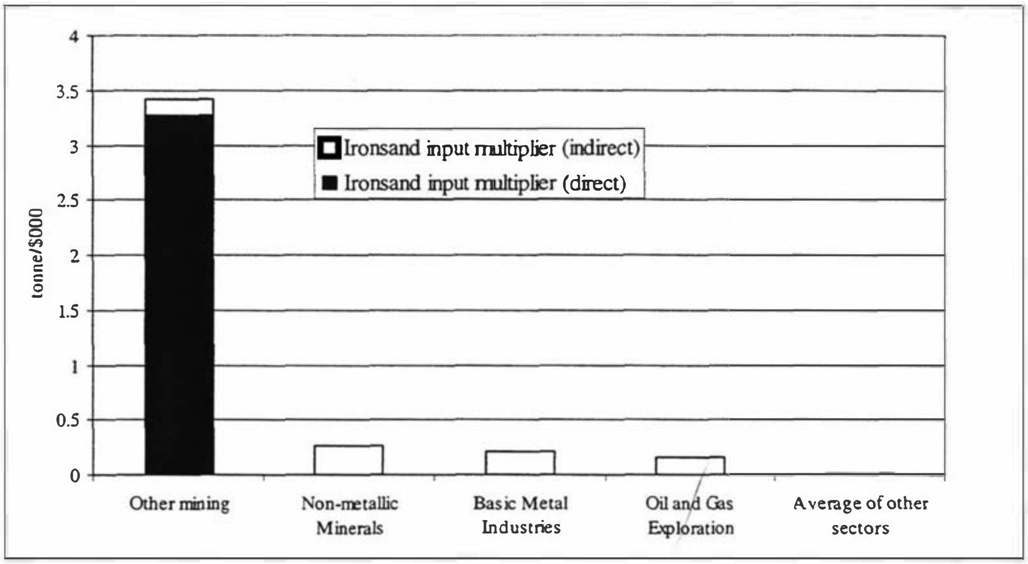

Figure 7-10: Ironsand input multipliers for New Zealand (1997/98)

The mineral inputs data highlights a limitation of IO matrices related to the homogeneity assumption. That is, the *other mining* sector is assumed to produce one homogenous output that then flows through the economy. Consequently, the silver and ironsand minerals are all treated as one product and follow the same path through the economy. This is unrealistic. Nevertheless, it is still important to trace mineral inputs into New Zealand because of their strategic importance (particularly in the case of ironsand).

7.3.8 Energy input eco-efficiency multipliers

Energy is another essential ecosystem raw material required for economic activity. Several sectors warrant attention from an energy[35] multiplier perspective. This research identifies the *road transport* (including rail) sector as the most energy intensive sector in the New Zealand economy in 1997/98 (see Figure 7-11). *Road transport's* direct and total-system multipliers of total energy in 1997/98 were 18.7 *em*joules/\$m and 22.3 *em*joules/\$m respectively. The *road transport* direct and total multipliers[36] have decreased over the period by 8% and 6% respectively.

The *basic metals* sector is also a relatively energy intensive sector in the economy. This finding is consistent with other studies (Jollands, Lermit, & Patterson, 1997). The *basic metals* sector

[35] Energy use data were obtained from the EECA energy use database. Unfortunately, the EECA database only provides data to the 33 sector level. The method of disaggregating the 33 sectors to 48 sectors is described in Appendix 5.2.3. Following the disaggregation, energy use was extrapolated to 1997/98 levels using value added data. This was the validated against published energy statistics from the Ministry of Commerce and Statistics New Zealand.
[36] Of total energy in *em*joule terms.

includes steel and aluminium manufacturing, both of which are relatively energy intensive processes.

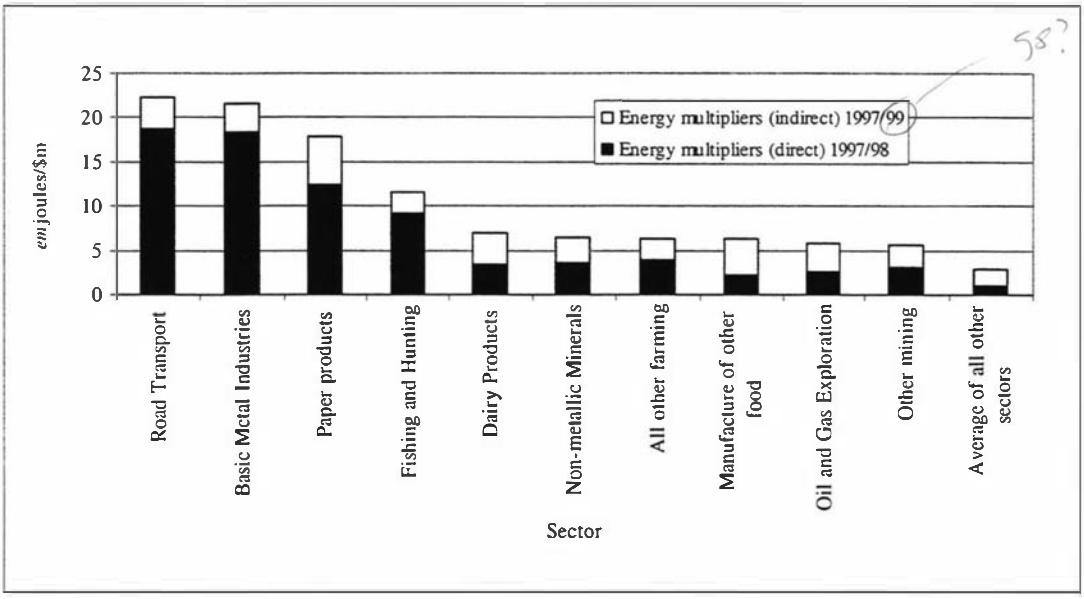

Figure 7-11: The 10 sectors with the highest energy multipliers in New Zealand for 1997/98 (*em*joules/$m)

It is interesting to note that the direct energy multiplier (*em*joule per $ of gross output per year) of the *basic metals* sector has decreased by 20% over the period 1994/95 to 1997/98. This demonstrates the success of the work in these firms to control the energy costs and reduce greenhouse gas emissions (see for example Comalco, 1999, p. 125). Even the total-system energy multiplier of this sector shows a decrease of 18% over the same period.

Other sectors with relatively high energy multipliers are estimated to be the *paper products, fishing and hunting*[37], *dairy products* and *nonmetallic minerals*.

In order to understand the complexities of the energy multipliers, it is instructive to investigate multipliers for the predominant different energy types: coal, electricity, petroleum products (diesel, fuel oil, LPG and aviation gasoline) and natural gas[38].

Coal

The most coal-intensive sector in New Zealand is the *basic metals* sector. This is because relatively large quantities of coal are used as a reductant in steel production and in the manufacture of anodes for aluminium production[39]. An analysis of the estimated direct and total

[37] This sector has a high energy intensity primarily because it includes the energy intensive (primarily marine diesel) deep sea trawling and fishing operations.
[38] Because different energy types are not being compared, it is appropriate to present the results in joules.
[39] Strictly speaking this coal is not used as an energy source but as a process input.

multipliers shows improved utilisation of coal per dollar of output. The direct coal multipliers for the *basic metals* sector are estimated as 8.9 GJ/$000 and 7.7 GJ/$000 for 1994/95 and 1997/98 respectively. This shows a 14% decline in the coal intensity for this sector.

Electricity

Electricity is the predominant and most widely used energy source in New Zealand. Electricity is most intensively used in the *basic metals* sector, primarily due to aluminium production. This finding is consistent with other studies (for example Lermit, 1999). The *basic metals* sector shows an improvement in both its direct and total electricity multipliers over the period 1994/95 to 1997/98 (14% improvement in direct electricity intensity and 13% improvement in total electricity intensity). This reflects the effort both major companies – BHP New Zealand Steel and New Zealand Aluminium Smelters – have given to energy management (Comalco, 1999) and can possibly be attributed to their participation in EECA's Energy Wise Companies Campaign[40]. It is interesting to note that the impetus for this improvement probably came from a desire to reduce electricity costs, electricity is a significant cost for both sectors.

Because of the importance of the electricity sector in the New Zealand economy it is instructive to look at electricity multipliers by sector groups. This also helps to 'strip out' the dominance of the *basic metals* sector in electricity.

Electricity multipliers in the *primary production* sector are dominated by the *agricultural services* and *dairy farming* sectors. Interestingly, the *dairy farming* sector became more electricity-intensive (in both direct (8% increase) and total (13% growth) terms) over the period 1994/95 to 1997/98. This is counterintuitive. Given the growth in dairy farming activity one would have expected economies of scale and decreased electricity multipliers. One explanation for this result could be the relatively low electricity prices. Real electricity prices for commercial users decreased by around 1.35% per annum over the period (Statistics New Zealand, 2000). Decreasing electricity prices provide less incentive for farmers to conserve energy. These increases add further weight to the argument that the *dairy farming* sector warrants policy attention from an eco-efficiency perspective.

The *commercial services* sector group shows low direct electricity multipliers relative to the primary and manufacturing sectors. However, these multipliers grew significantly over the period. In particular, the *communications services* sector direct and total electricity multipliers grew by 49% and 22% respectively. This growth is again likely to be a response to dropping real commercial electricity prices over the period. Interestingly, the total electricity multipliers

[40] See www.eeca.govt.nz

of commercial services sectors are significantly higher than the direct electricity multipliers (around 133% higher on average). This is because of their significant backward linkages through the economy[41]. An analysis of the eco-efficiency of these sectors must account for both direct and indirect effects.

Diesel, fuel oil, LPG and aviation gasoline

The transport sectors are the most intensive users of diesel, fuel oil, LPG and aviation gasoline. The *road transport* sector has significantly higher diesel, petrol and LPG multipliers (both in direct and total terms) than other sectors in New Zealand. The relative fuel multipliers are shown in Table 7-4.

Table 7-4: Selected fuel multipliers, direct and indirect for the New Zealand transport sector, 1994/95 and 1997/98 (GJ/$000)

	Road Transport	Services to Transport	Water Transport	Air Transport
	GJ/$000			
Diesel 1994/95 (direct)	9.050	-	2.415	-
Diesel 1994/95 (indirect)	1.234	0.358	0.707	0.274
Diesel 1997/98 (direct)	9.708	-	2.771	-
Diesel 1997/98 (indirect)	1.486	0.430	0.868	0.323
Fuel Oil 1994/95 (direct)	-	-	1.027	-
Fuel Oil 1994/95 (indirect)	0.032	0.025	0.133	0.029
Fuel Oil 1997/98 (direct)	-	-	1.178	-
Fuel Oil 1997/98 (indirect)	0.039	0.024	0.191	0.029
Petrol 1994/95 (direct)	7.306	-	-	-
Petrol 1994/95 (indirect)	1.048	0.277	0.366	0.248
Petrol 1997/98 (direct)	7.838	-	-	-
Petrol 1997/98 (indirect)	1.270	0.334	0.389	0.295

Of particular interest is that the multipliers for individual energy types appear to have increased over the period 1994/95 to 1997/98[42]. Direct multipliers for these fuels are estimated to have increased by around 7% over the period, while total multipliers increased just over 9%. This increase in individual energy multipliers is of concern in New Zealand, primarily because of the environmental and health concerns[43] associated with emissions from vehicles burning these

[41] An analysis of the inverse Leontief matrix shows significant linkages between commercial service sectors (especially to finance, business services and communication services).

[42] Note that in *em*joule terms, it was estimated that road transport multipliers had decreased over the period. This is a different result than the calculations done using joule units because the Quality Equivalent Method picks up changes in relative energy qualities of different energy types over time as a result of assumptions made about relative fuel efficiency improvements. For example, in the transport fuels calculation the quality of gas has decreased relative to liquid fuels over the period. In this section, the joule unit is used because energy types are not being added together.

[43] In particular, there is a concern about the health effects of carbon monoxide, NO_2, ozone, particulate matter and sulphur dioxide emissions from transport (Ministry for the Environment, 2000).

fuels. The increase in fuel multipliers can possibly be attributed to two causes. First, the *road transport* sector has undergone considerable deregulation in the past ten to 15 years. This deregulation has opened the way to increased competition for freight movement. This has led to an increase in the number of smaller vehicles vying for freight and the growth in short-haul (inner city) deliveries with low payloads (Energy Efficiency and Conservation Authority, 2001). As a consequence, energy use per dollar has risen.

The second potential cause is the decreasing real fuel prices over the period. For example, over the period the real retail diesel price decreased from 14.7 $/GJ in the year ended March 1995 to 14.2 $/GJ in 1998 (Statistics New Zealand, 2000). This decreasing price reduces the incentive of road vehicle operators (particularly commercial operators) to improve their energy use per unit of output.

Natural gas

Natural gas is used extensively throughout the economy. Two common sectors are again the most intensive users of natural gas per dollar: *paper products* and *basic metals* (in both direct and total terms). These sectors are followed closely by the *dairy products* sector. Interestingly, the *paper products* and *basic metals* sectors demonstrated improvements in natural gas utilisation (direct gas multipliers for the two sectors decreased by 4% and 14% respectively). This is possibly a result of the significant increase in real gas tariff (from 7.36 $/GJ in 1994/95 to 9.38 $/GJ in 1997/98 (Statistics New Zealand, 2000)). When considering total gas intensity, only the *basic metals* sector showed a decrease (by 11% over the period). In contrast, the *dairy products* sector increased its total intensity by 23%. This increase in the *dairy products* sector is consistent with the general trend towards increased output of energy intensive dairy products. For example there was a 19% growth in relatively energy intensive 'milk powder products' over the period 1994/95 to 1997/98 (New Zealand Dairy Board, 2000, p. 9).

7.3.9 Energy-related air pollutant eco-efficiency multipliers

Many production processes result in the release of air pollutants. Measures of air pollutant discharge are used as a proxy for the gas regulation and climate regulation ecosystem services[44]. Unfortunately, data on air pollution by sector are limited in New Zealand. Information that is available on a sector-by-sector basis relates to air pollutants from energy use; carbon dioxide,

[44] It has already been mentioned that there may be inaccuracies with the use of air pollutant proxies (see section 7.2.3).

methane, nitrous oxide[45] (EECA Energy Use Database, 1996). Total emissions of the three air pollutants increased over the period 1994/95 to 1997/98 (see Table 7-2).

Table 7-5: Energy-related air pollutant multipliers for selected sectors in New Zealand for 1994/95 and 1997/98 (tonne/$000)

		Paper Products	Basic Metals	Road Transport
Direct multipliers				
1994/95	Carbon Dioxide	1.39	1.33	1.19
	Methane	1.27×10^{-4}	7.58×10^{-5}	7.70×10^{-4}
	Nitrous Oxide	5.28×10^{-5}	9.96×10^{-5}	5.35×10^{-5}
1997/98	Carbon Dioxide	1.34	1.14	1.28
	Methane	1.22×10^{-4}	6.51×10^{-5}	8.26×10^{-4}
	Nitrous Oxide	5.07×10^{-5}	8.55×10^{-5}	5.74×10^{-5}
Total multipliers				
1994/95	Carbon Dioxide	1.82	1.52	1.40×10^{-5}
	Methane	2.16×10^{-4}	1.15×10^{-4}	8.79×10^{-4}
	Nitrous Oxide	7.02×10^{-5}	1.12×10^{-4}	6.32×10^{-5}
1997/98	Carbon Dioxide	1.84	1.36	1.52
	Methane	2.28×10^{-4}	1.17×10^{-4}	9.58×10^{-4}
	Nitrous Oxide	7.10×10^{-5}	9.87×10^{-5}	6.89×10^{-5}

Energy-related carbon dioxide emissions

The largest CO_2 emitting sectors, and those requiring particular policy attention, are the *paper products* (17.5% of total CO_2 emissions in 1997/98), *road transport* (17%), and *basic metals* (9.4%) sectors. An important point to note is the relatively large growth in CO_2 emissions of the *road transport* sector. From 1994/95 to 1997/98 CO_2 emissions from the *road transport* sector increased by 7%[46].

CO_2 multipliers followed a similar trend to CO_2 emission quantities (see Figure 7-12 and Table 7-5).

[45] Estimates of energy-related emissions were calculated using emission factors from the Ministry of Commerce (Ministry of Commerce, 1999), and are outlined in Appendix 5.2.4.

[46] This is similar to the Ministry of Commerce estimate that domestic transport CO_2 emissions have grown at around 3.5% pa (Ministry of Commerce, 1999, p. 1).

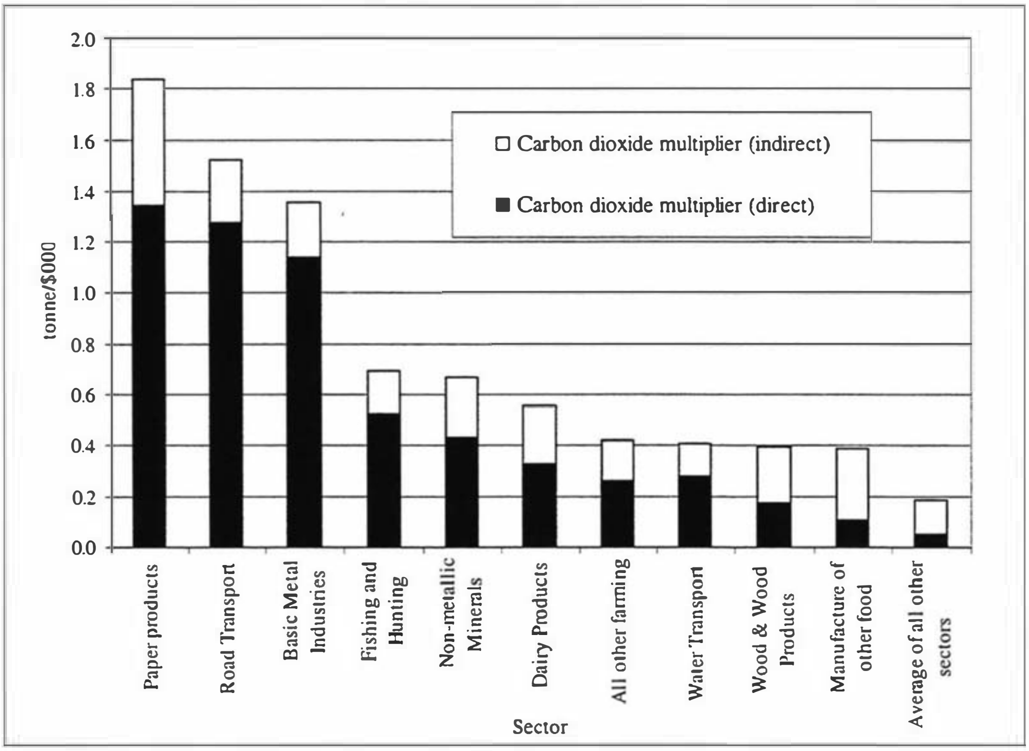

Figure 7-12: The 10 sectors with the highest CO_2 multipliers in New Zealand, 1997/98 (tonne/$000)

The *road transport* sector's CO_2 multipliers tended to increase (both direct and total) over the period 1994/95 to 1997/98. In contrast, the *basic metals* and *paper products* sectors demonstrated decreases (14% and 4% decreases in their respective direct multipliers). When considering total multipliers, *paper products'* CO_2 multiplier remained relatively constant, while *basic metals* continued to demonstrate improvements (11% decline in total CO_2 multiplier). Of particular note is the relatively large indirect CO_2 multiplier for the *paper products* sector compared to the *basic metal* and *road transport* sectors. On average, the *paper products* sector's indirect CO_2 multipliers account for 27% of total CO_2 intensity. This is compared to the *basic metals* and *road transport* sectors where the indirect multipliers account for around 16% of total CO_2 intensity. An analysis of the inverse Leontief matrix reveals that the *paper products* sector has relatively strong links with its primary resource base (*forestry*) as well as with *trade* and *finance* sectors.

The growth in CO_2 emission multipliers by *road transport* is of concern given New Zealand's Kyoto protocol commitments. Whereas attention is being given to decreasing CO_2 emissions in large industrial sectors, addressing CO_2 emissions in the *road transport* sector is more difficult.

Cars are numerous and mobile, and as yet no policy measure has been developed in New Zealand to control emissions from road vehicles[47].

Energy-related methane (CH_4) and nitrous oxide (N_2O) emissions

The highest methane multipliers are in the *road transport*, *paper products* and *other farming* sectors. The *trade* sector, while having relatively high methane emission volumes, does not feature in the top methane intensive sectors. This is because it is a large sector, with a high value added. Consequently, the value added denominator swamps out the methane numerator.

As with CO_2 emissions, *road transport* sector methane emission multipliers (both direct and total) grew over the period 1994/95 to 1997/98 (on average about 10% over the period) in line with that sector's overall increase in energy use. In contrast, direct multipliers of the *paper* products sector decreased (by 3.8%) over the period while that sector's total multipliers increased (by 6%).

Sectors with the highest nitrous oxide multipliers are the usual energy-intensive suspects: *basic metals*, *road transport* and *paper products*. According to the Ministry of Commerce (1999, p. 10) the growth in N_2O emissions over the period is "dominated by increasing diesel use." This helps to explain the relatively high and increasing nitrous oxide intensity of the *road transport* sector.

The other sector with a high N_2O emissions multiplier is the *basic metals* sector. This is related to the large volume of delivered coal and electricity used in this sector. The *basic metals* sector direct and total N_2O emission multipliers declined over the 1994/95 to 1997/98 period (by about 14% and 12% respectively). This continues the pattern of this sector's improving eco-efficiency.

7.4 Conclusion

Several conclusions can be drawn from this analysis. First, despite the necessary simplifying assumptions, the inverse Leontief matrix based approach used here can provide useful information for decision makers. For example, the approach can highlight those sectors warranting particular policy attention due to relatively high or growing multipliers[48]. The approach can also provide policy analysts with an assessment of system-wide eco-efficiency.

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[47] This particularly a problem with section 15(2) of the Resource Management Act 1991. The Ministry for the Environment is investigating amendments to this section to deal with the mobile vehicle-emission issue.

[48] It is worth reminding the reader that imports have been excluded from this analysis. As was mentioned in section 7.3.1 this is likely to underestimate the true eco-efficiency multipliers.

This 'systems perspective' is often missing from efficiency-related information (see for example Energy Efficiency and Conservation Authority, 1998).

A strength of this analysis is that it facilitates a deeper appreciation of ecosystem service requirements for economic activity. In particular, from a systems perspective, this method demonstrates that no sector is isolated from the environment. All economic activity relies on ecological services either directly or indirectly. The economic-ecologic linkages are far more complex and far-reaching than the direct eco-efficiency multipliers would suggest.

Following on from this observation, it can be argued that a consideration of direct eco-efficiency multipliers alone can be misleading. Sectors use inputs from other sectors that contain embodied ecosystem services. It is often more informative to consider total requirement multipliers. Consideration of total multipliers is particularly important for those sectors with significant backward linkages through the economy (high coefficients in the inverse Leontief matrix) and, therefore, relatively large indirect requirements. The analysis above suggests that consideration of total multipliers is particularly important for the following sectors:

- manufacturing sectors in general, and *paper products*, *meat products* and *dairy products* in particular;
- commercial sectors (such as *business services*, *finance* and *insurance* etc.).

A summary table showing the rankings of all sectors' total requirement multipliers in 1997/98 for each ecosystem service and proxy is shown in Table 7-6 (a rank of 1 indicates the sector has the highest total system requirement multiplier of all sectors). Shaded cells show those sectors with the two highest total multipliers for that ecosystem service.

Table 7-6: Rankings of all sectors' total system multipliers for 1997/98 for each ecosystem service (1=worst performance[49], 46=best performance[50]) with the two worst-performing sectors shaded

Ecosystem service	Water inputs	Water discharge	Water Pollutant - Ammonia	Water Pollutant – BOD_5	Water Pollutant - DRP	Water Pollutant - Nitrate	Water Pollutant - TKN	Water Pollutant - TP	Minerals	Land	Energy	Energy-related CO_2 emissions	Energy-related NH_4 emissions	Energy-related NO_2 emissions
	Ecosystem raw material measure[51]	Proxy for water regulation and water supply	Proxies for waste treatment						Raw material measures			Proxies for gas regulation and climate regulation ecosystem services		
Sector														
Mixed livestock	26	14	8	8	6	16	9	8	13	1	16	16	5	16
Dairy farming	11	12	2	4	3	10	5	3	16	4	20	22	18	20
Horticulture	3	18	15	14	12	30	12	14	18	9	30	26	23	27
Services to Agriculture	27	23	13	20	20	19	22	15	11	18	26	28	29	26
All other farming	4	13	9	2	10	6	4	1	20	3	7	7	3	7
Fishing and Hunting	30	42	44	45	45	24	45	45	40	28	4	4	4	4
Forestry & Logging	40	31	39	37	38	40	37	34	17	5	28	29	16	30
Oil and Gas Exploration	17	9	31	26	25	33	25	30	4	31	9	17	12	18
Other mining	2	1	37	35	34	37	34	37	1	17	10	15	11	14
Meat Products	5	11	3	6	8	1	3	4	14	2	15	12	10	10
Dairy Products	6	8	4	5	4	12	10	6	10	7	5	6	13	5
Manufacture of other food	12	25	10	12	22	5	20	7	26	12	8	10	7	9
Beverage Manufacture	10	17	14	13	13	13	13	11	9	14	13	14	17	12
Textile Manufacture	15	19	7	11	11	4	11	10	19	6	24	20	19	23
Wood & Wood Products	31	27	30	33	35	22	35	32	25	10	17	9	15	11
Paper products	7	7	29	31	30	26	29	29	30	15	3	1	2	2

49 That is, highest eco-intensity.
50 That is, lowest eco-intensity.
51 Note that the *water works* sector has not been shaded in this column, despite being one of the worst performing sectors from a water-use intensity perspective. It has not been highlighted because it is not a 'water-using' sector per se.

Printing & Publishing	25	20	32	27	26	39	27	28	37	26	18	11	20	15
Other Chemicals	28	24	36	39	39	20	39	22	12	21	25	25	27	25
Basic Chemicals	19	4	28	40	40	11	40	40	6	27	29	31	30	29
Non-metallic Minerals	8	5	26	24	24	29	23	27	2	25	6	5	8	6
Basic Metal Industries	9	3	35	38	37	35	38	38	3	37	2	3	6	1
Fabricated Metals	22	26	42	41	42	36	42	41	8	33	22	21	25	17
Equipment Manufacture	34	30	34	34	36	28	36	36	21	36	31	30	31	28
Transport Equipment	35	32	27	29	28	38	30	31	23	32	32	32	32	32
Other Manufacturing	16	10	21	25	27	9	26	25	5	20	19	23	22	19
Water works	1	6	5	3	2	8	2	5	15	8	14	27	40	8
Construction	24	15	18	15	14	23	14	16	7	19	27	19	21	24
Trade	29	28	16	23	23	25	24	23	24	24	21	18	9	21
Accommodation	14	22	6	9	9	2	8	9	29	11	23	24	24	22
Road Transport	23	21	12	10	7	17	7	13	27	30	1	2	1	3
Services to Transport	33	34	33	32	31	27	32	35	22	35	34	34	38	33
Water Transport	43	43	40	43	43	15	43	43	34	34	11	8	14	13
Air Transport	39	38	17	28	32	7	31	26	35	22	12	13	37	31
Communications	38	39	24	21	19	43	19	21	39	41	43	43	39	41
Finance	46	45	45	44	44	45	44	44	46	42	45	45	45	45
Finance services	41	44	43	42	41	41	41	42	45	45	42	42	43	43
Insurance	45	35	23	18	17	31	17	19	44	39	41	41	42	42
Real Estate	44	41	41	36	33	42	33	39	36	46	44	44	44	44
Business Services	42	36	25	22	21	32	21	24	41	38	36	36	36	36
Dwelling ownership	13	46	46	46	46	46	46	46	43	44	46	46	46	46
Education	32	40	38	30	29	44	28	33	42	43	39	37	26	39
Community Services	37	37	20	16	15	21	15	18	38	40	38	40	35	37
Recreation Services	21	16	11	7	5	14	6	12	32	13	37	35	28	38
Personal Services	20	2	1	1	1	3	1	2	33	29	40	38	33	40
Central Government	36	33	22	17	16	34	16	17	31	23	33	33	34	35
Local Government	18	29	19	19	18	18	18	20	28	16	35	39	41	34

This table helps to reinforce several interesting sectoral observations. These include:

- the most water-input intensive (m^3/\$) sectors in New Zealand (in both direct and total requirement terms) are the *other mining* and *horticulture*;
- the most water-discharge intensive (m^3/\$) sectors are the *other mining* and *personal services* sectors;
- *personal services*, *meat products*, *dairy farming* and *water works* sectors tend to have the highest water-pollutant multipliers;
- the *mixed livestock* sector is the most land-intensive sector in New Zealand;
- *basic metals*, *road transport* and *paper products* use the most energy per dollar of economic activity;
- sectors with the highest energy-related air emissions are the *basic metals*, *road transport* and *paper products* sectors.

Furthermore, some sectors stand out by virtue of the trends in their eco-efficiency multipliers. It appears that many aspects of the eco-efficiency of the *dairy farming* sector have worsened over the period 1994/95 to 1997/98. Similarly, the *other mining* sector has shown a worsening in its eco-efficiencies with respect to water use and discharge. The *road transport* sector has also shown increasing energy intensity over the same period.

Estimates of eco-efficiency multipliers for the *paper products* sector shows mixed performance. While water-use multipliers are estimated to have reduced over the period, water discharge and total energy multipliers have increased. In contrast, the *basic metals* sector has shown significant reductions in energy and energy-related air emission multipliers and increases in water-discharge multipliers.

It is worth making one final comment on the results presented in this chapter. All of the multipliers measure pressures on the environment from economic activity. The multipliers do not measure actual effects on the environment. One way to address the issue of 'effects' could be to convert the pressures to effects using theme equivalents (as in the case of van Esch, 1997). For example, all of the energy-related emissions could be converted to global warming potential equivalents. While this is straightforward for greenhouse gases, it is somewhat more difficult for issues such as water pollutants. It is beyond the scope of this research to investigate theme equivalents. This could be a fruitful area of future research.

The matrix of system-wide eco-efficiency multipliers of New Zealand, generated using the inverse Leontief based approach, provides much information. One major difficulty is that this profile does not provide an easily accessible overall assessment of eco-efficiency in sectors or in New Zealand as a whole. This issue of aggregation is a common methodological problem when dealing with indicators. A method for addressing the aggregation issue is the focus of the next chapter.

8 Aggregate eco-efficiency indices for New Zealand

> *"The multiple facets of complex environment/development problems require many indicators to assure experts that all critical factors are being followed, yet politicians keep calling for a few simple indicators of policy relevance"* (Dahl, 2000, p. 431).
>
> *"Everything should be as simple as possible, but not simpler"* (Einstein, cited in Meadows, 1998, p. 22).

The matrix of eco-efficiency multipliers presented in Chapter 7 presents a detailed picture (or profile) of eco-efficiency in New Zealand across many sectors and many environmental media. However, because of the volume of information in the profile, it may be unwieldy to use and interpret. This unwieldiness can be of concern when considering the information needs of those who make decisions that influence eco-efficiency in New Zealand.

The purpose of this chapter is to develop aggregate eco-efficiency indices[1] for use by decision-makers. To date, little work has focused on developing aggregate eco-efficiency indicators.

This dearth of aggregate eco-efficiency indicators is a symptom of a wider problem – the lack of aggregate environmental indicators. This is in contrast with the economic and social policy areas.

> *"Many highly aggregated economic and social indicators have been widely adopted and are frequently reported. ... But there are virtually no comparable national environmental indicators to help decision-makers or the public evaluate trends or assess the effectiveness of national efforts to maintain environmental quality"* (Hammond, Adriaanse, Rodenburg, Bryant, & Woodward, 1995, p. 3).

Hence, many authors (for example Alfsen & Saebo, 1993; Heycox, 1999; Luxem & Bryld, 1997; Opschoor, 2000; Walz et al., 1996) suggest further research into indicators should focus on the development of highly aggregated[2] indicators of the "environmental pressure that is associated with... the global material consumption of a national economy" (Billharz & Moldan, 1997, p. 389). High profile examples of this call for a focus on developing aggregate indices come from the United Nations and the Bellagio Principles[3]. The UN General Assembly Special Session that reviewed Agenda 21 in 1997 called for a "limited number of aggregated indicators" (quoted in Dahl, 2000, p. 427). Also, Principle 5 of the Bellagio principles proposes that

[1] Indicator-related issues such as definitions, the characteristics of a good indicator and a critique of indicators are discussed in appendix 1.
[2] Sometimes referred to as 'composite' indicators. However, 'aggregate' and 'composite' indicators are different. The term 'aggregate' can be a noun, adjective or verb. It means to collect together into one body; to unite or the sum total. The term 'composite' (adjective and noun) on the other hand, means to be made up of constituents that remain recognisable (Sykes, 1982). The distinguishing characteristic between the term aggregate and composite is that in the former the constituent parts are not recognisable, whereas in the composite term the constituent parts are still recognisable.
[3] Guidelines for Practical Assessment of Progress toward Sustainable Development quoted in Hardi (1997 p. 28).

"assessment of progress toward sustainable development should be based on a limited number of indicators or indicator combinations to provide a clear signal of progress" (Hardi, 1997, p. 28).

8.1 Rationale – the importance of aggregate indices of eco-efficiency in an ecological economic context

The work of this chapter on aggregate eco-efficiency indices emerges from three themes in ecological economic theory:

- the need for policy relevance in ecological economic research;
- the related emerging theory of indicators of sustainable development;
- issues of aggregation and commensuration theory.

8.1.1 Policy relevance

Chapter 6 has already established the need for policy relevance in ecological economic research. Ecological economics' aim to be policy relevant can in part be achieved by providing information that can assist the policy decision-making process. Increasingly, this information for policymakers comes in the form of indicators. Aggregating many indicators can assist decision-makers by highlighting patterns in the data (Cleveland, Kaufmann, & Stern, 2000, p. 302). It is no surprise, then, to find a significant amount of interest in aggregate indices in ecological economics literature (see 8.1.3 below).

8.1.2 Indicators in ecological economics

"Indicators of sustainable development need to be developed to provide a solid basis for decision-making at all levels and to contribute to the self-regulating sustainability of integrated environment and development systems" (United Nations Conference on Environment and Development, 1992, chapter 40.4). Ecological economics follows this call. In ecological economics, indicators are seen as one approach to put into effect the concept of sustainability and to introduce it to the policy-monitoring arena (Button, 2002; Callens & Tyteca, 1999; Kammerbauer et al., 2001). According to Gustavson et al. (1999, p. 118) "using sustainable development as a planning goal or tool necessitates the identification of indicators that will assist policy-makers in identifying appropriate policies and in monitoring the effectiveness of policy interventions." In the context of sustainability Meadows (1998, p. x) argues that efficiency is one of the "three most basic aggregate measures of sustainable development."

Indicators also help ecological economics pursue its goal of linking economic activity with the environment. As Button (2002, p. 223) states, "the need for indicators is ultimately to provide guidelines as to the damage that is being done to the... environment and the links this has with economic activities."

Indicators are mentioned extensively throughout ecological economic literature and are applied to a wide range of issues. For example, many recent articles in the journal Ecological Economics apply indicators to a range of issues including resource depletion (Béné, Doyen, & Gabay, 2001; Herendeen & Wildermuth, 2002), health (Gangadharan & Valenzuela, 2001), energy (Stern, 2002), trade (Muradian, O'Connor, & Martinez-Alier, 2002), climate change (Ansuategi & Escapa, 2002), urban development (Button, 2002), soil health (Alexandra & de Bruyn, 1997; Gilbert & Feenstra, 1994), tropical mountain development (Kammerbauer et al., 2001), agriculture (Pannell & Glenn, 2000) and sustainable development (Gustavson et al., 1999).

8.1.3 Aggregation and commensuration

It is often argued that decision makers have specific requirements of indicators. Boisevert, Holec and Vivien (1998, p. 106-107) summarise the nature of the demand for indicator information from decision makers as follows:

- Only a limited number of indicators should be used to convey the general state of the environment. Too many indicators can compromise the legibility of the information.
- Information should be presented in a format tailored to decision making. This requires the construction of indicators that reduce the number of parameters needed to give precise account of a situation.
- In the context of sustainable development (and eco-efficiency) decision-makers are interested in the economy-environment interface. Indicators should therefore, concentrate on the interaction rather than on just the environment itself.

Often, constructing eco-efficiency indicators that are useful for decision-makers cannot rely on scientific data as it stands. Rather, the challenge is to transform the data to produce condensed, or aggregate, information for decision makers. An alternative to an eco-efficiency profile is some grand aggregate index[4] or indices of eco-efficiency performance. A grand index may be easier for decision-makers to use because it summarises important information in one or a few numbers.

The general preference for scalars (aggregated indices) or matrices (indicator 'profiles') is a controversial and long-standing methodological problem associated with the use of indicators.

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[4] As stated in Chapter 6, the terms 'index' and 'indices' (used to refer to the aggregates formed by combining two or more indicators) are distinguish from the terms 'indicator' and 'sub-index' (used to refer to the components of the aggregate indices).

Essentially the debate centres on the amount of information that is lost in the simplification made possible by the index.

In an eco-efficiency profile, the observer's eye scans the individual indicators and is implicitly asked to aggregate the indicators to form an overall impression of eco-efficiency. Because the mathematical aggregation of different eco-efficiency variables to form a single number does not occur, proponents of profiles see them as giving "less chance for misinterpretation or misunderstanding than aggregated indices" (Ott, 1978 p. 26). People who are familiar with the complexities of monitoring environment-economy interactions generally prefer profiles and view the potential distortion occurring in an index as unacceptable.

In contrast, when calculating an eco-efficiency index, the aggregation process is carried out using a mathematical equation and not necessarily by the observer. This aggregation necessarily simplifies the information presented in the matrix of indicators. People who are removed from the measurement process have a greater willingness to accept the simplification, and potential distortion of information for the sake of obtaining an easy-to-understand, sometimes crude, picture of eco-efficiency.

Ecological economists have shown considerable interest in developing aggregate indices. This interest is demonstrated by the attention given to many aggregates including the:

- Index Of Sustainable Economic Welfare (ISEW) and the Genuine Progress Indicator (GPI) (see for example, Daly & Cobb, 1994; Hamilton, 1999; Neumayer, 2000; Stockhammer, Hochreiter, Obermayr, & Steiner, 1997);
- Ecological footprint (See articles in volume 32 (3) of Ecological Economics);
- Sustainable net benefit index (Lawn & Sanders, 1999);
- Human development index (Neumayer, 2001; Sagar & Najam, 1998);
- Net national product (Adger & Grohs, 1994);
- Pollution index (Khanna, 2000);
- Unified global warming index (Fearnside, 2002);
- Sustainable national income index (Gerlagh, Dellink, Hofkes, & Verbruggen, 2002);
- Index of Captured Ecosystem Value (Gustavson, Longeran, & Ruitenbeek, 2002).

However, within ecological economics, and beyond, there is ongoing debate on the appropriateness of aggregating indicators and aggregation in general.

Strengths of aggregate indices

Proponents of indices argue that there are several necessary reasons for aggregation. The obvious benefit of an aggregate index is its production of a single or a few numbers. This makes using indices for decision making relatively straightforward. Aggregate indices assist decision-makers by reducing the clutter of too much information, thereby helping to communicate information succinctly and efficiently (Alfsen & Saebo, 1993; Callens & Tyteca, 1999; Gustavson et al., 1999; Heycox, 1999; van den Bergh, 1996; Williams, 1994). As Meadows (1998, p. 22) states "aggregation is necessary to keep from overwhelming the system at the higher levels of the hierarchy." Heycox (1999, p. 191) reflects this and states that "a complex, information-rich world requires frameworks that organise data to reveal succinct views and interrelationships."

By simplifying and assisting with communication, aggregate indices (such as eco-efficiency indices) can improve the way decision making incorporates environment-economy interactions as called for by the WCED (1987). Opschoor (2000, p. 363) states, "I do see the need for reducing the multitude of environmental impacts of human activity to a limited set of numbers in order to merge economics and the environment in decision making."

Finally, an aggregation function formalises what is often done implicitly. Ultimately, when making a decision, the decision maker must go through a process of condensing information to make simple comparisons. Proponents of aggregate indices argue that it is better to make this process explicit through an aggregation function than relying on the implicit aggregation that inevitably happens using an indicator profile.

Weaknesses of aggregate indices

Critics of aggregate indices cite equally persuasive arguments. They argue that aggregate indices can lead to incorrect conclusions. Development of the aggregation equation almost always requires more assumptions and arbitrary decisions than the design of a profile. Thus, aggregate indices are frequently criticised by scientists familiar with the data, who feel that the assumptions can lead to a loss of information (Meadows, 1998, p. 22) and introduce serious distortions (Lindsey, Wittman, & Rummel, 1997). Critics caution that the distortions can lead the observer to misinterpret the data. As Meadows (1998, p. 4) states "if too many things are lumped together, their combined message may be indecipherable." However, it is important to note that "it is not that more detailed information is lost – usually it is possible to look at the details of how any aggregate indicator has been constructed – but rather that decision-makers are too busy to deal with these details" (Costanza, 2000, p. 342).

If users are not careful and informed about their use of aggregate indices, they can be ignorant of the source of the numbers, how the numbers were aggregated, and the uncertainties, weights, and assumptions involved, etc. This again can lead to spurious conclusions.

Tschirley (1997, p. 224) disagrees that politicians and decision makers necessarily want highly aggregated information. It is commonly thought that politicians "have short time horizons and cannot digest large amounts of information." Tschirley (1997) maintains that the experience of a number of countries reveals that:

- politicians are able to and often do use a wide array of information in making decisions
- their decisions change as new information becomes available
- their information comes from a wide array of formal and informal sources.

Tshirley (1997) maintains that analysts should avoid the temptation to arrive at a single index in the early stages of indicator development.

One of the major limitations of aggregate indices is the manner in which the constituent variables to be included in the index are determined (Lohani & Todino, 1984). Generally, the parameters are chosen on the basis of expert opinion. Critics argue that there is no single satisfactory method of selecting parameters. Therefore, an index is always in danger of missing important parameters. However, it is generally not feasible or practical to monitor the hundreds of potential environmental variables.

Another problem with aggregate indices is that it is difficult for them to capture the interrelationships between individual variables (Lohani & Todino, 1984). Gustafsson (1998, p. 259) warns against reductionistic views, encouraged by aggregate indices. Physical processes that occur in the economy-environment interactions are so complex and interdependent. And, often a stress on one part of the system affects other system elements as well. It is unrealistic to expect aggregate indices or a single index to capture this complexity. As Gustavson et al. (1999, p. 117) state it is "important to link sustainable development goals to movements of a *small slate of individual indicators* as single indicators can rarely be linked to any specific sustainable development goal" (italics in original).

Commensuration

Aggregation can also be faced with the problem of commensuration – that is, adding together quantities measured in different units. At the crux of commensuration is the fundamental issue of theories of value. To date, the debate over an appropriate theory of value for ecological economics remains unresolved.

Several ecological economists have developed methods for commensurating energy and mass flows in ecological and economic systems – so-called 'ecological pricing' methods (Costanza & Hannon, 1989; Patterson, 2002a). As Judson (1989) argues, these methods represent a broad convergence of 'embodied energy theories of value' and the Sraffian method of price determination. These methods depend on commensurating energy and mass flows in terms of biophysical interdependencies in ecological/economic systems, as opposed to the subjective preference methods in neoclassical economics.

In contrast, Martinez-Alier et al. (1998, p. 278) argue against the pursuit of a "common measure through which different values can be traded off one with another." These authors argue that the economy-environment interface is a site of conflict between competing values and interests and different groups and communities that represent them; therefore value conflict is unavoidable. In their view, it is inappropriate to shoehorn these disparate values into one cardinal set. In their view, "*ecological economics rests on a foundation of weak comparability [incommensurability] only*" (Martinez-Alier et al., 1998, p. 278, italics in original, comments in brackets added). Weak comparability, or incommensurability, entails the rejection not just of monetary reductionism (the attempt to reduce all values to a monetary numeraire) but also any physical reductionism (the attempt to reduce all values to a physical numeraire – for example, energy or matter). Martinez-Alier et al. suggest dealing with incommensurability through the use of multi-criteria evaluation tools[5].

The work by Spash and Hanley (1995) appears to support Martinez-Alier et al.'s approach. Spash and Hanley demonstrate that, in some instances[6], it is possible to find belief systems that deny tradeoffs (or lexicographic preferences). Without hierarchies of values, commensurability is impossible.

What then, is the way forward with this unresolved debate in ecological economics? Patterson (1998) charts a useful course. He suggests that in the pursuit of methodological pluralism, ecological economics should not take a monolithic approach based on a single theory of value. Adopting a 'unifying' theory of value can be seen as reductionistic and foreclosing other methodological options (Patterson, 1998).

However, there are times when adopting a theory of value is necessary or useful. For example, in the policy arena, an empirical approach to commensuration can help policymakers to evaluate

[5] There is an interesting tension here. On the one hand ecological economic theory promotes methodological pluralism, and a focus on problems not tools (Costanza, Daly, & Bartholemew, 1991). On the other hand, Martinez-Alier et al. appear to be promoting the use of *one* technique for all multi-dimensional issues.

[6] In their work, Spash and Hanley found evidence of lexicographic preferences for biodiversity in the United Kingdom.

alternative policy options. In these situations, adopting a theory of value that meets the needs of the analysis can be useful and appropriate.

To conclude the discussion on aggregate indices it is important to note that, in reality, the two opposing views regarding the merits of aggregate indices are not as black and white as may appear. In fact, the two views are necessarily complementary. A high level of indicator aggregation is necessary in order to intensify the awareness of economy-environment interaction problems. But, even given the advantages of aggregate indices, no single index can possibly answer all questions. Multiple indicators will always be needed, as will intelligent and informed use of the ones we have (Costanza, 2000).

For eco-efficiency, what is required is a judicious mix of aggregate indices and sub-indicators. Having provided a matrix of eco-efficiency multipliers in Chapter 7 this thesis now turns to developing aggregate indices for eco-efficiency in New Zealand.

8.2 Methodological considerations for aggregating eco-efficiency indicators

8.2.1 A general mathematical structure of an eco-efficiency index

It is possible to construct a general mathematical framework that accommodates the many options for aggregating eco-efficiency indicators. The calculation of an eco-efficiency index consists of two fundamental steps:

- calculation of the subindices used in the index (as in Chapter 7);
- aggregation of the subindices into the overall index or indices.

Suppose we have a set of eco-efficiency indicators in which ε_{11} denotes the ratio of ecosystem service type 1 in sector 1 (E_{11}) per unit of economic output in sector 1 (X_1), ε_{21} denotes the calculated value for the second eco-efficiency indicator in sector 1, and ε_{ij} denotes the value of the ith indicator in the jth sector. The set of indicators for m ecosystem services and n sectors is denoted as (ε_{11}, ε_{21}, ..., ε_{ij}, ..., ε_{mn}).

Following the calculation of the ε_{ij}, the second mathematical step is to form the final index using the aggregation function (g) (Equation 8-1):

$$I = g(\varepsilon_{11}, \varepsilon_{21}, \cdots, \varepsilon_{mn})$$ **Equation 8-1**

Where I is some aggregate eco-efficiency index.

The flow of information in the estimation of the aggregate index is summarised in Figure 8-1.

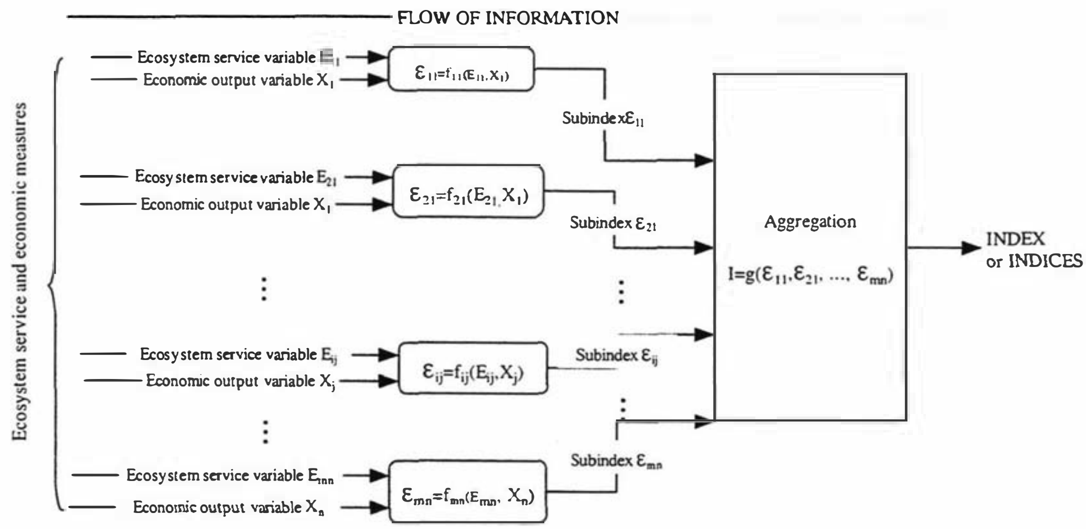

Figure 8-1: Information flow process in an eco-efficiency index (after Ott (1978))

The aggregation function, Equation 8-1, usually consists either of a (Ott, 1978, p. 50):

- summation operation, in which individual indicators (or subindices) are added together;
- multiplication operation, in which a product is formed of some or all of the subindices;
- a maximum or minimum operation, in which just the maximum subindex or minimum subindex respectively is reported.

8.2.2 The aggregation process

A significant gap in ecological economic theory relating to aggregate indices is the lack of a framework to guide aggregation. This thesis presents such a framework, and then proceeds to apply it in the following sections.

The process of estimating aggregate eco-efficiency indices follows a generic approach outlined in Figure 8-2.

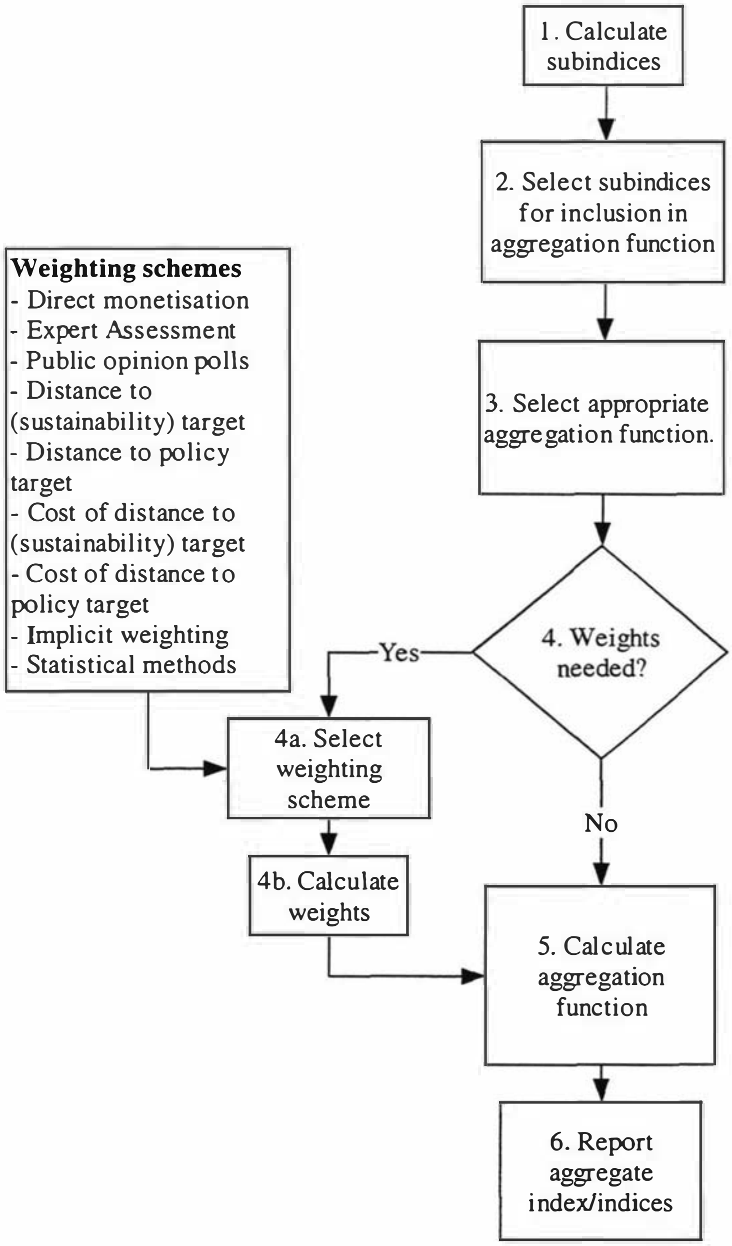

Figure 8-2: A generic process for calculating aggregate indices

Step 1 has already been covered in Chapter 7[7]. The discussion below presents the results of steps 2 through 6.

8.2.3 Selecting subindices for inclusion in the aggregation function

The selection of the variables for inclusion in aggregation is a contentious issue and must be approached with some caution (Lohani & Todino, 1984). Several considerations dictate the variable selection. First, the range of the subindices should provide a cross-sectional representation of the principal factors of interest. In the context of ecological indicators this

[7] That is, the ecological multipliers calculated in Chapter 7 are used as the subindices in this chapter.

suggests a need for a representative coverage of ecosystem services for which data are available (Yu et al., 1998).

Second, the problem of 'multicolinearity' should be addressed by eliminating those variables that are correlated (Yu et al., 1998). A standard test for this is the correlation coefficient. For example, variables that are highly correlated with one another can be considered substitutes. By including only one subindex from a highly correlated set and excluding the others, one not only accounts for the trend in the variables, but also achieves parsimony in the data matrix.

Finally, and perhaps most importantly, there is a need to balance the need for data parsimony with relevance to purpose. For example, often there is policy interest in both energy and CO_2 emissions. Obviously, these are correlated. However, if decision makers require an aggregate that reports both CO_2 and energy, the analyst (often implicitly) considers the balance between policy relevance and statistical integrity.

8.2.4 Selection of appropriate aggregation functions for eco-efficiency indicators[8]

There is considerable debate over the most appropriate function for aggregating subindices. Many aggregation functions are available for developing aggregate indices including linear sum, maximum and minimum operators, weighted linear sum, root mean power, root mean square and multiplicative aggregation functions.

Several aspects must be considered when choosing the most appropriate aggregation function. First, the functional form of subindex is important. Subindices can be either of an increasing or decreasing-scale form. In increasing-scale subindices higher values are regarded as a 'worse' state than lower values. In decreasing-scale subindices, higher values are associated with 'better' states than lower values. The eco-efficiency multipliers estimated in Chapter 7 are of the increasing-scale form (high ecosystem-service use per dollar is regarded as less desirable than low ecosystem-service use per dollar).

The second aspect to consider when selecting the most appropriate aggregation function is the strengths and weaknesses of the aggregation function itself. In particular, Ott (1978) identifies two potential problems with aggregation functions:

- an overestimation problem[9], where the aggregate index I, exceeds a critical level, say 100, without any subindex exceeding that critical level;

[8] Note that, while this section presents some generic discussion of selection of appropriate aggregation functions, it is particularly focused on the selection of aggregation functions that are appropriate for the multipliers estimated in Chapter 7.

[9] Also referred to as as 'ambiguity' (Ott, 1978).

- an underestimation problem[10], where an index I does not exceed a critical level, say 100, despite one or more of its subindices exceeding that critical level.

These two problems are particularly an issue with dichotomous subindices (where subindices take on just two values, such as acceptable or not acceptable). The most appropriate aggregation function will minimise one or both of the overestimation and underestimation problems.

Another aspect to consider when selecting the most appropriate aggregation function is the parsimony principle. When competing aggregation functions produce similar results with respect to overestimation and underestimation, the most appropriate function will be that which is the 'simplest' mathematically. In other words, simple mathematical functions are preferred over complex functions.

Finally, an aggregation approach is successful if all assumptions and sources of data are clearly identified, the methodology is transparent and publicly reported, and the index can readily be disaggregated to the separate components and no information is lost (Hammond et al., 1995, p. 15).

In order to select the most appropriate aggregation function for the eco-efficiency indicators in Chapter 7, the additive, maximum operator and multiplicative aggregation functions are investigated below and compared with the criteria outlined above. The following analysis employs a graphical technique used by Ott (1978) which is useful for demonstrating the behaviour and limitations of the candidate aggregation functions. The technique uses a two-dimensional plane to investigate the behaviour of aggregation functions for combining two (dichotomous) subindices. The conclusions from the graphical analysis can be expected to apply also to the more general case in which more than two eco-efficiency variables are involved. This will assist in choosing the most appropriate aggregation function for the eco-efficiency indicators.

The eco-efficiency multipliers estimated in Chapter 7 are not dichotomous[11], but rather 'continuous' (i.e. those where threshold limits are not established or regarded as important). For demonstration purposes, it is assumed that some critical eco-efficiency level has been defined. This assumption is not too unrealistic because thresholds are often implicitly set – either through international benchmarks or economic imperatives. This assumption can be relaxed later in the analysis.

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[10] Also referred to as as 'eclipsing' (Ott, 1978).

[11] That is, where there is a threshold established for the indicator, above or below which is considered an unacceptable level.

Linear sum (unweighted) aggregation function

The simplest aggregation function that can be applied is a simple, linear, additive approach (Lindsey et al., 1997). The general form of the linear sum (unweighted) aggregation function is:

$$I = \sum_{i=1}^{n} \varepsilon_i$$ **Equation 8-2**

This approach is only appropriate when subindices are in common units. The eco-efficiency multipliers estimated in Chapter 7 are not all in the same units, so a simple 'linear sum' would be an inappropriate aggregation function[12].

Weighted linear sum aggregation function

By multiplying each subindex by an appropriate coefficient, or 'weight,' the linear sum aggregation function can be modified to allow for the aggregation of subindices measured in different units. When weights are used in the summation process, the indices are called linear weighted sums. The weighted linear sum has the following general form:

$$I = \sum_{i=1}^{n} w_i \varepsilon_i$$ **Equation 8-3**

Where w_i are the weights.

It can be shown that the weighted linear sum function does not suffer from an overestimation problem. However, another problem is introduced. This problem is referred to as 'underestimation' (the problem where one subindex equals or exceeds a critical level without the index exceeding that critical level).

Consider a two-variable case

$$I = w_1 \varepsilon_1 + w_2 \varepsilon_2$$ **Equation 8-4**

Where

$$w_1 + w_2 = 1$$ **Equation 8-5**

In this simple index, it is assumed that ε_1 and ε_2 are dichotomous subindices in which $\varepsilon_1=0$ and $\varepsilon_2=0$ represent zero eco-intensity[13] of a sector for ecosystem service inputs E_1 and E_2 (say coal and gas), and $\varepsilon_1 \geq 100$ and $\varepsilon_2 \geq 100$ represents levels of eco-intensity that are above an accepted level.

[12] It can also be shown that simple linear sums incur an overestimation problem. It is not necessary to demonstrate this for the purpose of this thesis.
[13] The reciprocal of eco-efficiency.

In Equation 8-4 a low aggregate intensity is reported properly, because if both subindices are less than 100, then I will be less than 100. Likewise, if both subindices are 100, then $I=100$ because:

$$I=w_1(100)+ w_2(100) \quad \textbf{Equation 8-6}$$

Thus, there is no 'overestimation region' in the weighted linear sum function.

It is relatively straightforward to demonstrate the underestimation problem associated with weighted linear sums. Assume, for example, that $w_1=w_2=0.5$. Consider a situation where the weighted linear sum of ε_1 and ε_2 equals of 100; say, $\varepsilon_1=50$ and $\varepsilon_2=50$, then $I=100$. A variety of other combinations of subindex values ($\varepsilon_1,\varepsilon_2$), will give readings of $I=100$. These combinations result in a straight line denoting all possible combinations of ε_1 and ε_2 that give $I= 100$. This is shown in Figure 8-3 as the line $I=0.5\varepsilon_1+ 0.5\varepsilon_2=100$.

Now suppose that $\varepsilon_1=50$ and $\varepsilon_2=110$, indicating an exceedance of the acceptable level of eco-intensity for ecosystem service variable E_2. This gives an index $I=80$. Because the overall index is less than 100, violation of the threshold is eclipsed. Investigation of this phenomenon on the two-dimensional graph reveals two 'underestimation' regions (shaded areas of Figure 8-3). These regions can be shown to lie between the line $I=0.5\varepsilon_1+0.5\varepsilon_2$ and the threshold value. In the upper region, $\varepsilon_2\geq100$ without I exceeding 100. In the low region, $\varepsilon_1\geq100$ without I exceeding 100.

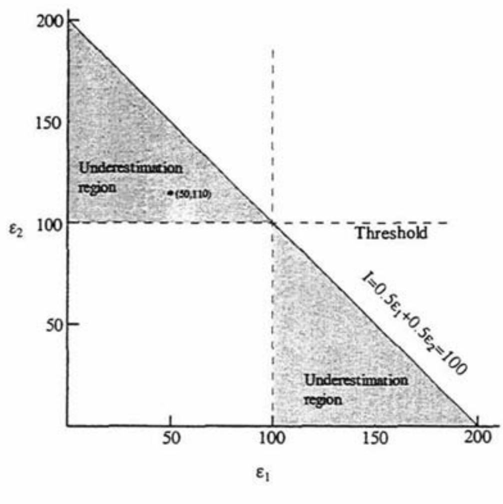

Figure 8-3: Plot of weighted linear sum aggregation function showing underestimation regions for which a subindex exceeds 100 without the index exceeding 100

The 'overestimation' and 'underestimation' problems are particularly problematic with dichotomous indices. The problems can be dealt with using more complex additive forms such as the root-sum-power and root-mean-square[14]. In the case of continuous indices (such as eco-efficiency), Ott (1978) states that over and underestimation are not particularly problematic and that the weighted linear sum can be considered as an appropriate aggregation function for continuous increasing-scale sub indicators.

Maximum operator[15] aggregation function

The general form of the maximum operator is shown in Equation 8-7 below:

$$I=max\{\varepsilon_1, \varepsilon_2, \ldots \varepsilon_i \ldots \varepsilon_n\}$$ **Equation 8-7**

In the maximum operator, I takes on the value of the largest of any of the subindices, and $I = 0$ if and only if $\varepsilon_i=0$ for all i. As with other aggregation functions it is instructive to examine the properties of the maximum operator.

Ott (1978) has shown that the maximum operator exhibits no over – or under – estimation problem when used with dichotomous subindices[16]. The limitations of the maximum operator become apparent when considering continuous subindices. That is, where fine gradations of eco-efficiency, rather than discrete levels, are of interest. Consider, for example, an eco-efficiency index consisting of four subindices and using the maximum operator. Suppose this index is used to report eco-efficiency for two different years. In year 1, the subindices were as follows: $\varepsilon_1=98$, $\varepsilon_2=110$, $\varepsilon_3=80$, and $\varepsilon_4=0$. In year 2, $\varepsilon_1=0$, $\varepsilon_2=110$, $\varepsilon_3=5$, and $\varepsilon_4=0$. The maximum operator gives the same value, $I = 110$, for both cases. Some observers will be sceptical of this result because it tends to hide the fact that year 2 exhibits generally better eco-efficiency than year 1.

If it is important to measure fine gradations of an indicator (in this case eco-efficiency) over the entire range of each variable, Ott (1978, p. 79) states that "the maximum operator would be unsuitable, and the arithmetic mean (weighted linear sum) might be more appropriate."

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[14] The general form of the root sum power is $I=\left[\sum_{i=1}^{n}\varepsilon_i^p\right]^{1/p}$ where p is some power, and the general form for the root-mean square is $I=\sqrt{\sum_{i=1}^{n}\left(\frac{\varepsilon_i^2}{n}\right)}$

[15] The minimum operator is used for decreasing scale indices

[16] Consider the two sub-indicators case. The maximum operator exhibits no overestimation region because if the overall index exhibits poor eco-efficiency ($I\geq100$), then at least one sub index must exhibit poor eco-efficiency ($\varepsilon_i\geq100$ for some i).
Similarly, with the maximum operator there is no underestimation region. If one sub index exhibits poor eco-efficiency ($\varepsilon_1\geq100$), then the overall index exhibits poor eco-efficiency. Consequently, Ott (1978 p. 78) states that the "maximum operator is particularly well suited for combining dichotomous sub indices."

Weighted product aggregation function

Multiplicative aggregation forms have found use primarily in indices that have decreasing scales. The most common multiplicative aggregation function is the weighted product, which has the following general form:

$$I = \prod_{i=1}^{n} \varepsilon_i^{w_i}$$ **Equation 8-8**

Where

$$\sum_{i=1}^{n} w_i = 1$$ **Equation 8-9**

It can be shown, that in general, the multiplicative approach is not well suited for aggregating increasing scale subindices[17]. Take the simple two-subindices case. The general multiplicative equation form is written as

$$I = \varepsilon_1^{w_1} \varepsilon_2^{w_2}$$ **Equation 8-10**

where $w_1 + w_2 = 1$

Consider the simple case where w^1 and w^2 are both 0.5. Thus, Equation 8-10 becomes:

$$I = \varepsilon_1^{0.5} \varepsilon_2^{0.5}$$ **Equation 8-11**

This equation can be graphed in a two-dimensional space of ε_1 versus ε_2. First, we solve Equation 8-11 for ε_2 as a function of I and ε_1.

$$\varepsilon_2 = \frac{I^2}{\varepsilon_1}$$ **Equation 8-12**

Now Equation 8-12 is plotted on the two-dimensional space for selected values of I (Figure 8-4).

[17] Note that no other author has used this approach to evaluate the relevance of multiplicative aggregation functions to increasing scale subindices. For example, Ott (1978) restricts his analysis to decreasing-scale subindices.

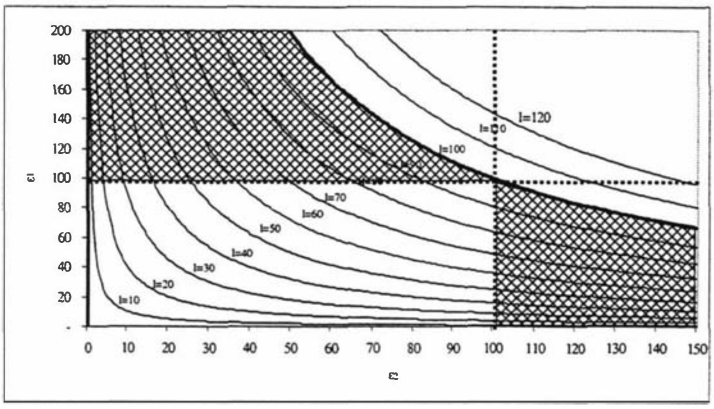

Figure 8-4: Plot of multiplicative aggregation function in the ε_1, ε_2 space for selected values of I showing underestimation region for which a subindex exceeds 100 without the index exceeding 100

The curves are asymptotic to the two axes, and all curves have slopes of negative 1 at points along a 45-degree line bisecting the two axes[18]. This graph shows that I=100 when both ε_1 and ε_2 = 100. That is, there is no overestimation region. However, there is a significant underestimation region (shown as the shaded area of Figure 8-4). In fact the underestimation region is infinite because I is asymptotic to the X and Y axes. The underestimation region from the multiplicative aggregation is therefore larger than the discrete underestimation region from the weighted additive procedure.

Even once the dichotomous assumption is relaxed, it can be argued that weighted summation is more appropriate than the multiplicative function. This is because, from a parsimony perspective, the weighted sum is generally easier to compute and understand than the multiplicative form.

Recommended aggregation function for eco-efficiency multipliers

The analysis above (summarised in Table 8-1) demonstrates several lessons with respect to the most appropriate aggregation function for the eco-efficiency indicators:

- the (unweighted) linear sum is not appropriate for aggregating indicators measured in different units (i.e. the variables are incommensurable);
- the weighted linear sum does incur an underestimation region. However, it is less than that incurred by the weighted-product aggregation function;
- the weighted-product function is less parsimonious than the weighted sum;
- the maximum operator is not sensitive to fine gradations of eco-efficiency.

[18] If the two weights were not equal, the shapes of the curves would change. The curves would still be convex to the origin but they would not be symmetrical about the 45-degree line bisecting the axes.

From the analysis, it appears that the weighted linear sum is the most appropriate aggregation function for increasing-scale eco-efficiency indicators.

Table 8-1: Summary of findings on the appropriate aggregation functions for increasing-scale eco-efficiency indicators

Aggregation function	Characteristics when applied to increasing-scale eco-efficiency indicators
Additive	
- linear	Not appropriate for incommensurable indicators
- weighted	Underestimation; no overestimation; parsimonious
Maximum operator	Unsuitable for continuous indicators
Multiplicative	
- weighted product	No overestimation; very large underestimation; marginally more computationally complex than weighted sum.

8.2.5 Weighted-sum aggregation function: the challenge of setting the weights

A significant challenge with the weighted linear sum aggregation function is how to select the appropriate weights needed for commensuration. In the case of eco-efficiency, weights are required for the various ecosystem services. Setting weights often requires explicit value judgements on the relative importance of different ecosystem services. For example, should water input have a higher or lower weight than energy or land input in New Zealand? Thus, "it is when the hidden decisions are made explicit that the arguments begin. The problem for the years ahead is to work out an acceptable theory of weighting" (Hardin, 1968, cited in Jesinghaus, 1997, p. 84).

A number of methods can help to establish weights. Jesinghaus (1997, p. 84) suggests seven alternative weighting schemes for valuing environmental pressure. A similar weighting taxonomy can be applied to eco-efficiency indicators, with the addition of statistical weighting techniques.

1) **Direct monetisation**. This approach generally uses contingent valuation methods[19] to estimate the economic importance people assign to various aspects of the environment. This approach is based on two fundamental assumptions: that a relationship exists between an individual's willingness to pay (WTP) and personal utility, and that economic analysis that is applied to traditional markets can be applied to contingent markets (Edwards, 1987). Contingent valuation establishes values, or weights, in dollar terms, which are often directly usable by decision-makers, at least in theory. In practice, these approaches have been widely criticised. Questions are often raised about the quality of contingent valuation-generated data, as they are contingent, and may be subject to strategic manipulation by participants (Randall,

[19] Such as willingness-to-pay (WTP) and willingness-to-accept (WTA).

1987)[20]. Further, there is no empirical evidence that WTP actually reflects personal utility (Sagoff, 1988b). Also, minimal formal economic theory exists to guide researchers in understanding how individuals form values in contingent-valuation contexts (Shogren & Nowell, 1992).

From an ethical view, Sagoff (1988a) argues against an approach to environmental decision making based on neoclassical economic contingent valuation. He argues that in environmental decision making situations, individuals act as citizens[21] rather than consumers[22]. However, the contingent valuation approach assumes 'individuals as consumers' properly address views on environmental matters. In Sagoff's view, this is inappropriate and will lead to inappropriate results (Blamey & Common, 1994).

2) **Expert assessments and impact equivalents**. Contingent valuation methods "soon reach their limits when applied to physical indicators, which have little or no meaning to the interviewed person" (Jesinghaus, 1997, p. 85). While most people might be able to guess how much they would be willing to pay for cleaner water or air, WTP will fail if the person is asked to judge the relative importance of methane intensity versus carbon dioxide intensity. In this case, it is appropriate to ask experts (Walz et al., 1996).

In some areas, experts are able to estimate weights based on the relative potential effect of an emission or deposition. The Netherlands use this approach and express aggregate indicators in 'theme equivalents' terms (van Esch, 1997). Another example is the Intergovernmental Panel on Climate Change (IPCC) use of global warming potentials to establish an aggregate in carbon dioxide equivalents (Fearnside, 2002). A similar approach is taken in the United States Environmental Protection Agency's Pollutant Standard Index (Environmental Protection Agency, 1994).

Often, there is no scientific evidence on the relative importance of different aspects of the environment. In these cases, Jesinghaus (1997) recommends a kind of 'WTP for experts' – given a set budget of points, experts are asked to rank issues. This is the approach taken in the Virginia Environmental Quality Index (Khanna, 2000). In this instance the weights are determined by a survey of environmental experts using the Delphi technique.

This method is particularly suitable when considering a single ecosystem service. However, when applied to multiple ecosystem services (as in the case of eco-efficiency multipliers in Chapter 7), the method becomes complex and requires scientists to display multidisciplinary skills – a rare commodity.

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[20] Randall (1987) argues that this problem can be reduced by good contingent market and question design.
[21] With a concern for the public interest.
[22] With a concern for personal interest.

3) Public opinion polls. As an alternative to allowing experts to set the relative weights of subindices, one could ask the general public (Walz et al., 1996; Hope & Parker, 1995). It is debatable whether public opinion polls are the best way to decide on weights for issues of which the public have little knowledge. European experience (Adriaanse, 1993) suggests that local issues (such as noise and traffic) dominate public perception of environmental issues. More pervasive and unseen environmental problems such as global warming tend to be overlooked. Another potential issue with public opinion polls is that the weights vary from country to country and temporally. This makes their comparison difficult (Patterson, 2002b).

4) Distance to (sustainability) target (DST). Like schemes 2 and 3, this method also measures the 'urgency' of a problem. In the DST scheme, urgency is related to an actual target. The urgency (or weight) is high if the distance to target is far away, and low if the target is reached (Walz et al., 1996). This scheme requires experts to formulate the operational target. While in scheme 2, experts only have to give relative weights, with DST, sustainability goals have to be formulated in absolute figures. The definition of sustainability targets is influenced by the person's own values, and the weight that person attaches to 'the environment.' For example, one would expect industry experts to have completely different views on 'sustainable' levels than experts from environmental NGOs. Therefore, DST requires consensus on a sustainability definition – a formidable and perhaps unachievable task (Pezzoli, 1997).

5) Distance to (policy) target (DPT). One way to avoid the problem of having to define 'sustainability' is to use policy-defined targets (Adriaanse, 1993). For example, this approach forms the basis of New Zealand's National Energy Efficiency and Conservation Strategy monitoring (Lermit & Jollands, 2001) and New Zealand's waste-management strategy (Ministry for the Environment, 2002). The DPT approach has several advantages. Policy makers are generally comfortable with the use of distance to policy-targets as weights, especially where the targets are set by the policy maker themselves. This approach is technically appropriate where there is a well-defined methodology or a strong political will for establishing the absolute policy goals as could be argued for energy efficiency and waste management in New Zealand. Often, a well-defined methodology and/or political will are not evident. In such cases, establishing policy targets can be a time-consuming and cumbersome process. Also, policy targets often differ across countries, making international comparisons inappropriate.

6) Cost of distance to sustainability and policy targets. These methods are very similar to the distance to sustainability target approach mentioned above. The approaches rely on the assumption that the monetary cost to reach a goal and the distance to a goal are roughly proportional (Jesinghaus, 1997). This assumption is questionable, especially when faced with ubiquitous diminishing marginal returns to expenditure on achieving the target. Another difficulty with this method is that it is often very difficult to attach direct monetary values to actions such as environmental reparation required to achieve the target.

7) Implicit weighting. This scheme is a weighting procedure where 'weights' are based on a common physical unit. For example, consider the level of water pollution discharged in New Zealand per year. An aggregate measure of water pollution can be calculated by adding the physical quantity (measured in kilograms) of each water pollutant. In this case, the weighting function implicitly uses the relative contribution (measured in tonnes) to the total water pollution discharge. While this approach might be statistically correct, its 'analytical soundness' is low. A significant problem with this approach is that it treats all components as having the same environmental impact. Obviously, in the case of water pollutants, some components are more toxic (such as ammonia) than others (organic material).

8) Statistical methods. Statistical methods are another category that can be added to Jesinghaus's list of weighting schemes. Statistical methods offer an alternative to more 'subjective' systems of setting weights. Statistics provides a useful multivariate technique, principal components analysis[23] (PCA) that is useful for setting weights in the context of multi-dimensional data like eco-efficiency.

PCA is a weighted linear sum function. It weights data by combining original variables into linear combinations that explain as much variation as possible. In this way, PCA provides a relatively 'objective' approach to setting weights that is dictated by the data rather than the analyst. In effect, it 'lets the data speak.' Callens and Tyteca (1999) suggest PCA is also a useful tool for improving the 'efficiency' of indicators. A unique advantage of PCA is that it reports the amount of variance in the data that is explained by the resulting aggregate indices.

PCA suffers from several limitations. The technique treats all components as having the same environmental impact. This limitation, combined with the requirement to make judgments about the input data and number of principal components, means any pretences to objectivity are illusory (see section 8.3.2 for a critique of PCA).

8.2.6 Final selection of weighting scheme for this research

There is still considerable debate among experts about which weighting system to use. While each approach has merits, one advantage of PCA over many others is its relative 'objectivity.' Unfortunately, PCA has received little attention to date in indicator aggregation literature in

[23] Other 'interdependence'-type multivariate techniques appropriate for metric variables are factor analysis and cluster analysis (Sharma, 1996). These are not appropriate for use in the context of setting weights. For a detailed discussion of these techniques, refer to Sharma (1996).

general and eco-efficiency literature specifically. The following sections attempt to remedy this and investigate the usefulness of PCA as an aggregation approach.

8.3 Principal components analysis as an aggregation approach for eco-efficiency indicators

In this chapter, a principal components analysis[24] is performed using the wide range of eco-efficiency multipliers calculated in Chapter 7. The objective is to identify the interrelationships and reduce the effective redundancy in the eco-efficiency profile. In doing so, PCA can be used to define aggregate indices of eco-efficiency in New Zealand.

8.3.1 A description of principal components analysis[25]

Principal components analysis (PCA) is designed to reduce the number of variables to a small number of indices (called the principal components) that are linear combinations of the original variables (Heycox, 1999, p. 211; Manly, 1994, p. 12; Sharma, 1996; Yu et al., 1998). PCA provides an 'objective'[26] way of 'aggregating' indicators so that the variation in the data can be accounted for as concisely as possible.

The object of PCA is to take p variables $\varepsilon_1, \varepsilon_2, ..., \varepsilon_p$ and find linear combinations of these to produce principal components $Z_1, Z_2, ...Z_p$ (Manly, 1994, p. 76). Principal components are established by mathematical linear transformations of the observed variables under two conditions (Marcoulides & Hershberger, 1997, p. 164). The first condition is that the first principal component accounts for the maximum amount of variance possible, the second the next, and so on. The second condition is that all components are uncorrelated with each another. The lack of correlation is a useful property because it means that the indices are measuring different 'dimensions' in the data.

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[24] PCA has been extensively employed in the past for analytical purposes. PCA has been applied in many areas, including energy economics (Assimakopoulos, 1992; Watanabe & Widayanti, 1992), environmental indicators (Balicki, 1999; Yu et al., 1998; Da Silva & Sacomani, 2001; Williams, 1994), and social indicators (Crampton, Salmond, & Sutton, 1997). In general the environmental indicator studies revealed that relatively few principal components, typically the first two or three components, account for more than 60% of the total variation. This points to a large redundancy of the existing environmental indicators (Yu et al., 1998). Interestingly, no studies of eco-efficiency have employed PCA despite the multi-dimensional nature of eco-efficiency. Also, most past applications of PCA to environmental indicators have tended to focus on a particular environmental media (e.g. air or water). This present study extends PCA to multiple ecosystem-service dimensions.

[25] This provides an overview of the PCA approach. A more detailed mathematical exposition of the eigenstructure approach to PCA is provided in appendix 6.

[26] Note it is misleading to consider that PCA is totally objective. Subjectivity is required in several parts of the PCA process – selection of variables, selection of principal components etc.

The expectation when conducting PCA is that correlations among eco-efficiency variables ($\mathcal{E}_{ij}$) are large enough so that the first few principal components account for most of the variance. If this is the case, "no essential insight is lost by applying the first few principal components for further analysis or decision-making, and parsimony and clarity in the structure of the relationships are achieved" (Yu et al., 1998, p. 103).

PCA is essentially a non-parametric method. In other words, it makes no assumptions about the underlying statistical distribution of the data and therefore, no evaluation of normal (Gaussian) distribution of the data is necessary[27] (Sharma, 1996).

A principal components analysis starts with data on p variables (such as water use per dollar of value added) for n individuals (or in the case of eco-efficiency, sectors). The first principal component is then the linear combination of the variables $\mathcal{E}_1, \mathcal{E}_2, \ldots, \mathcal{E}_p$ (Manly, 1994, p. 78) weighted by some constant γ_{ij} where i is the principal component number and j is the variable number.

$$Z_1 = \gamma_{11}\mathcal{E}_1 + \gamma_{12}\mathcal{E}_2 + \ldots \gamma_{1p}\mathcal{E}_p$$

Equation 8-13

that varies as much as possible for the observations. However, because var(Z_1) can be increased by choosing any set of values for $\gamma_{11}, \gamma_{12}, \ldots \gamma_{1p}$, a restriction that $\gamma_{11}^2 + \gamma_{12}^2 + \ldots + \gamma_{1p}^2 = 1$ is also imposed.

In order to use the results of PCA it is useful to understand the nature of the equations themselves. In fact, a PCA just involves finding the eigenvalues of the sample covariance matrix (**C**) (see below and Appendix 6). The variances of the principal components are the eigenvalues (λ) of the matrix **C**. Assuming that eigenvalues are ordered as $\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq \ldots \lambda_p \geq 0$, then λ_i corresponds to the ith principal component

$$Z_i = \gamma_{i1}\mathcal{E}_1 + \gamma_{i2}\mathcal{E}_2 + \ldots \gamma_{ip}\mathcal{E}_p$$

Equation 8-14

In particular, var(Z_i)= λ_i and the constants $\gamma_{i1}, \gamma_{i2}, \ldots \gamma_{ip}$ are the elements of the corresponding eigenvector, scaled so that the sum of γ_{ij}^2 equals 1 (Manly, 1994, p. 79). An important property of the eigenvalues is that they add up to the sum of the diagonal elements (the trace) of **C**. That is,

$$\lambda_1 + \lambda_2 + \lambda_3 + \ldots \lambda_p = c_{11} + c_{22} + \ldots c_{pp}$$

Equation 8-15

[27] However, if the assumption of multivariate normality does hold, then statistical tests for choosing components can be used.

As c_{ii} is the variance of $\mathcal{E}_i$ and λ_i is the variance of Z_i, this means that the sum of the variances of the principal components is equal to the sum of the variances of the original variables. Therefore, in a sense, the principal components account for all of the variation in the original data (Manly, 1994, p. 80). The eigenvalue for a principal component indicates the variance that it accounts for out of the total variance (Manly, 1994, p. 81).

The process for conducting PCA is well documented in multivariate statistics literature (see for example Manly, 1994; or Sharma, 1996). In general, there are seven standard steps in a principal components analysis. These are summarised in Appendix 6.

8.3.2 Critique of principal components analysis

PCA can be criticised from several perspectives. First, some argue that PCA lacks precision and is more 'subjective' than other statistical techniques (Poot, 1983; Vega, Pardo, Barrado, & Debán, 1998). While there are techniques for reducing subjectivity in PCA (see Appendix 6), subjective assessment is required both in the selection of the (number of) principal components and their interpretation. According to many statisticians, subjectivity should be avoided because it allows the analyst's values to influence the results. Reliance on 'objective,' transparent, rigorous statistical tests is preferable to 'subjective' decisions based on 'hunches.' However, statistic's apparent objectivity is misleading. Subjective decisions are required in even the most rigorous statistical tests (for example, in the selection of confidence intervals etc). It is questionable whether PCA is necessarily any more subjective than other statistical techniques, but it can be less 'subjective' than some of the other weighting schemes mentioned in section 8.2.5.

Reliance on subjective assessment does not necessarily mean that PCA should be discarded. Rather, care must be taken when interpreting and reporting principal components. Integrity demands that any reported analysis makes it clear that the results are not qualified by any significance tests.

Two pronounced shortcomings of this present analysis are that it is static and does not take into account the thresholds. PCA does not accommodate dynamic changes to the structure of the environment-economy interface. Rather it is limited to providing comparative static snapshots through time. PCA is also unable to account for thresholds or criticality. Consequently, questions concerning the appropriate scale of resource use cannot be answered using this approach.

Other criticisms levelled at PCA are that it does not always 'work,' is not always applicable, or is dependent on sample size. PCA does not always work in the sense that it may not reduce a large number of original variables to a small number of transformed variables that explain a large degree of variance. This is particularly the case where the original variables are uncorrelated. PCA is most appropriate as an aggregation approach when the original variables are highly correlated (Manly, 1994, p. 77). It is an additive function and is useful for aggregating increasing-scale eco-efficiency multipliers. However, it is of limited value to decreasing-scale indicators.

As with any statistical technique, the precision of the results, which depends on sample size, is an important issue. Grossman et al. (1991) suggest a rule of thumb for the number of observations required to provide a robust[28] solution in PCA: the number of observations (n) must be greater than three times the number of variables (p).

An important assumption of PCA is that the empirical observation data set contains a detectable, and relevant structure. In fact, there is no independent way of testing this assumption, although the interpretability of the results can be used as an indirect test (Grossman et al., 1991, p. 346).

With respect to eco-efficiency indicators, it is important to acknowledge another potential limitation of PCA. PCA weights are based on explained variance rather than on scientific evidence that reflects environmental criteria. That is, it is possible that the PCA weights may not make 'conceptual sense' in terms of established environmental criteria such as environmental impact. Ideally, weights should reflect these criteria. It is often difficult to empirically measure the relative weights based on an environmental criteria. This is the case in this analysis of eco-efficiency when many aspects of the environment are considered at once. In this case, scientific measurements, expert opinion and even public opinion on the relative environmental pressures are not available. PCA offers a weighting scheme in such a scientific and public-opinion vacuum.

In summary, PCA provides a rigorous alternative weighting scheme for aggregating eco-efficiency indicators where:

- the analyst wishes for a less 'subjective' weighting scheme than others mentioned in section 8.2.5;
- comparative static observations are acceptable or useful;
- the original variables are increasing scale and highly correlated;
- there are sufficient observations to provide a stable solution;
- many aspects of the environment are considered at once and there is limited or no information on relative environmental criteria.

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[28] In the sense that the analyst can be reasonably confident that the identified components are representative of the population.

8.4 Using principal components analysis to determine aggregate eco-efficiency indices for New Zealand

PCA is used to estimate aggregate eco-efficiency indices for New Zealand. These indices significantly reduce the redundancy in the 263 by 46 eco-efficiency multipliers matrix estimated in Chapter 7. These multipliers measure certain attributes of New Zealand's eco-efficiency, and individually contribute an unknown extent to New Zealand's overall eco-efficiency. As there is a significant amount of duplication in the profile, the first step is to select those eco-efficiency subindices that are useful for the PCA.

8.4.1 Choosing variables for inclusion in the principal components analysis

Section 8.2.3 outlined several considerations in the selection of subindices for inclusion in the aggregation function. This PCA should include a cross-sectional representation of ecosystem services. Therefore, this PCA covers ecosystem goods of water, energy, land and minerals, as well as proxies for the ecosystem services of water regulation and water supply (water discharge) and waste treatment (water pollutants[29]) and gas and climate regulation (energy-related air emissions). The PCA should also reduce multicolinearity between variables. This is achieved by using total energy use per dollar per sector rather than the individual energy type multipliers. This is because total energy multipliers essentially summarise the information contained in the individual energy type subindices.

A similar argument can be used with respect to the different multiplier types (direct, indirect and total). The total multipliers are the sum of the direct and indirect multipliers. It can be argued that the total multipliers 'contain' the information in the direct and indirect multipliers. Certainly use of total multipliers leads to a more parsimonious data matrix. For these two reasons, total system multipliers are used in this PCA.

Similarly, other variables that are highly correlated in the data matrix can also be excluded. For example, all mineral input variables are 100% correlated with one another (see Chapter 7). By including one mineral input variable and excluding the others in the analysis, one not only accounts for the mineral inputs into an economy, but also achieves parsimony in the data matrix.

Section 8.2.3 also stated there is a need to balance data parsimony with relevance to purpose. Based on the parsimony and multicollinearity arguments, it could be argued that the air emissions and water pollutant subindices should be eliminated. The air emissions are estimates based on energy use and the water pollutants are highly correlated with water discharges. However, there is significant policy interest in both air emission (particularly CO_2 emissions)

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[29] Note that total water inputs, water discharges and water pollutants refer to point source quantities only.

and water pollution issues (Ministry for the Environment, 2001) in New Zealand. Therefore, it was decided to retain both air emissions and water pollutant subindices in the PCA.

The final set of variables used for the PCA are shown in Table 8-2:

Table 8-2: Final variables used in this Principal Components Analysis for determining aggregate eco-efficiency indices for New Zealand

Ecosystem Goods		
Water inputs	ε_1	m^3/$ (sum of ground and surface water takes)
Land	ε_2	ha/$
Energy	ε_3	emjoules/$[30]
Minerals	ε_4	tonne/$[31]
Ecosystem services		
Proxy for water regulation and water supply services:		
Water discharge	ε_5	m^3/$ (sum of discharge to land and water)
Proxies for waste treatment service:	ε_6	m^3/$ (sum of discharge to land and water)
Water pollutant – Total ammonia[32]		
Water pollutant – Total BOD_5	ε_7	m^3/$ (sum of discharge to land and water)
Water pollutant – Total DRP	ε_8	m^3/$ (sum of discharge to land and water)
Water pollutant – Total Nitrate	ε_9	m^3/$ (sum of discharge to land and water)
Water pollutant – Total TKN	ε_{10}	m^3/$ (sum of discharge to land and water)
Water pollutant – Total TPD	ε_{11}	m^3/$ (sum of discharge to land and water)
Proxies for gas regulation and climate regulation services		
CO_2 emissions (energy related)	ε_{12}	tonne/$
CH_4 emissions (energy related)	ε_{13}	tonne/$
NO_2 emissions (energy related)	ε_{14}	tonne/$

For each of these 14 variables, there were 92 observations[33]. This exceeds the 3 to 1 ratio, which could be regarded as a rule-of-thumb for the minimum requirement in PCA to provide a stable solution (Yu et al., 1998; Grossman et al., 1991).

Table 8-3 summarises the mean value and standard deviation of the 14 variables used in this PCA. The covariance matrix of the 14 variables was calculated from standardised data and, therefore, coincides with the correlation matrix (also shown in Table 8-3). Some clear eco-

[30] Energy total adjusted for energy quality (see Chapter 6)
[31] Ironsand input was used as the surrogate for mineral data. As discussed above, any mineral input could have been chosen.
[32] Note that water pollutants measure only point source discharges. Also note that while it appears the data set is weighted in favour of water pollutants, this is not necessarily the case. All water pollutants were retained for three reasons:

- The water pollutants are different in their impact on the environment, and together they add to the picture of environmental impact of economic activity;
- Water pollution issues are currently high on the public agenda in New Zealand;
- There is no accurate way of aggregating these pollutants into a single figure.

[33] That is, the 46 sectors (observations) in 1994/95 and 1997/98 data were pooled. This is admissible, because it can be argued that total multipliers are independent over time. In other words, it is impossible to accurately predict total multipliers in one year based on previous year's data.

efficiency relationships can readily be inferred: high and positive correlation (underlined values) can be observed between water discharges and minerals ($r = 0.89$); the various water pollutants ($r = 0.68$ to 1.0); and energy and air emissions ($r = 0.71$ to 0.97).

Table 8-3: Mean, standard deviation and correlation matrix of eco-efficiency sub indices selected for PCA

	Water input	Land	Energy	Minerals	Water discharge	Water pollutant Ammonia	Water pollutant BOD_5	Water pollutant DRP	Water pollutant Nitrate	Water pollutant TKN	Water pollutant TPD	CO_2	CH_4	NO_2
Mean	6.92E-02	2.68E-04	4.78E-06	9.61E-05	4.67E-02	8.00E-05	3.93E-04	5.08E-05	1.09E-05	4.87E-04	9.69E-05	3.16E-04	8.63E-08	1.57E-08
Std dev	3.23E-01	5.85E-04	5.08E-06	4.76E-04	1.22E-01	1.97E-04	1.26E-03	1.80E-04	5.08E-05	1.75E-03	2.75E-04	3.67E-04	1.32E-07	1.88E-08
Observations	92	92	92	92	92	92	92	92	92	92	92	92	92	92
Water input	1.00													
Land	0.06	1.00												
Energy	0.02	0.00	1.00											
Minerals	0.08	-0.06	0.05	1.00										
Water discharge	0.17	-0.05	0.06	<u>0.89</u>	1.00									
Water pollutant Ammonia	0.04	0.22	-0.07	-0.06	0.28	1.00								
Water pollutant BOD_5	0.08	0.04	-0.09	-0.04	0.37	<u>0.83</u>	1.00							
Water pollutant DRP	0.08	-0.01	-0.09	-0.04	0.37	<u>0.81</u>	<u>0.99</u>	1.00						
Water pollutant Nitrate	-0.01	0.28	-0.01	-0.03	0.01	0.41	0.09	0.05	1.00					
Water pollutant TKN	0.08	-0.01	-0.09	-0.04	0.37	<u>0.79</u>	<u>0.99</u>	1.00	0.10	1.00				
Water pollutant TPD	0.05	0.20	-0.05	-0.05	0.28	<u>0.68</u>	<u>0.85</u>	<u>0.77</u>	0.10	<u>0.78</u>	1.00			
CO_2	-0.03	-0.01	<u>0.96</u>	0.03	0.05	-0.07	-0.09	-0.09	-0.01	-0.09	-0.05	1.00		
CH_4	-0.05	0.07	<u>0.71</u>	0.02	0.01	-0.02	-0.03	-0.04	0.01	-0.04	0.02	<u>0.67</u>	1.00	
NO_2	0.04	-0.01	<u>0.97</u>	0.04	0.06	-0.06	-0.08	-0.08	0.00	-0.08	-0.04	<u>0.94</u>	0.57	1.00

Note: underlined values indicate high and positive correlation coefficients.

8.4.2 Identification and description of the principal components

The PCA was performed using the PRINCOMP procedure of the SAS system (SAS Institute, 1985). An important point to note is that the PRINCOMP procedure used here standardises data to zero mean and unit variance. Standardisation of the data is important in this study given that the variables display widely different means and relatively large standard deviations (see Table 8-3 above).

The PCA results presented in this section were compared against a number of runs of the SAS PCA code on different groups of observations on the 14 variables[34]. This sensitivity analysis demonstrated that the PCA results are robust for the data concerned and do not vary appreciably with different combinations of the data[35].

The eigenvalues and eigenvectors of the correlation matrix are given in Table 8-4 and Table 8-5, respectively.

Table 8-4: Eigenvalues of the correlation matrix

	Eigenvalue	Difference	Proportion	Cumulative
1	4.6720	1.2777	0.3337	0.3337
2	3.3943	1.5273	0.2425	0.5762
3	1.8670	0.5356	0.1334	0.7095
4	1.3314	0.3441	0.0951	0.8046
5	0.9872	0.2249	0.0705	0.8751
6	0.7623	0.2846	0.0545	0.9296
7	0.4777	0.2005	0.0341	0.9637
8	0.2772	0.1291	0.0198	0.9835
9	0.1481	0.0927	0.0106	0.9941
10	0.0554	0.0386	0.0040	0.9980
11	0.0169	0.0063	0.0012	0.9992
12	0.0106	0.0106	0.0008	1.0000
13	0.0000	0.0000	0.0000	1.0000
14	0.0000	0.0000	0.0000	1.0000

[34] The different runs included direct multipliers 1994/95, direct multipliers 1997/98, total multipliers 1994/95, direct multipliers for both years combined, and pooled direct and indirect multipliers for both years combined. All of the variations revealed the similar five-component structure.

[35] It is important to note that PCA is a non-parametric method. Because eco-efficiency indicators are not normally distributed, statistical tests have not been used to test the significance of the results. Consequently, the conclusions from this PCA relate to this data set only. Given that this data set captures only some of the ecosystem service inputs into the economy, any attempt to make definitive statements about the principal components being the most important from a total system perspective should be avoided.

Table 8-5: Weights (eigenvectors) of the correlation matrix

	Prin1 Water pollutant intensity	– Prin2 Energy intensity	– Prin3 Material intensity	– Prin4 Land intensity	– Prin5 Water input intensity	– Prin6	Prin7	Prin8	Prin9	Prin10	Prin11	Prin12	Prin13	Prin14
Ecosystem goods:														
Water in	0.0487	0.0206	0.1584	0.1148	0.9477	-0.1857	0.1435	0.0206	-0.0353	-0.0379	0.0262	0.0450	0.0000	0.0000
Land	0.0511	0.0206	-0.1815	0.6386	0.1166	0.6679	-0.1663	-0.1951	0.1752	-0.0014	-0.0004	0.0007	0.0000	0.0000
Energy	-0.1147	0.5187	-0.0337	-0.0230	0.0329	-0.0308	-0.1244	0.0019	-0.0004	0.2148	-0.7626	0.2661	0.0000	0.0000
Minerals	0.0159	0.0659	0.6939	0.1892	-0.1654	0.0681	0.0202	0.0368	-0.0729	0.1099	0.2365	0.6091	0.0000	0.0000
Proxy for water regulation and water supply:														
Water discharge	0.1950	0.1216	0.6286	0.1191	-0.0875	0.0226	-0.0251	-0.0290	0.0627	-0.1279	-0.2479	-0.6682	0.0000	0.0000
Proxies for waste treatment:														
Water pollutant –														
Ammonia	0.4005	0.0779	-0.1262	0.1912	-0.0706	-0.1568	-0.0339	-0.3820	-0.7664	-0.0117	-0.0027	-0.0005	-0.0667	-0.1115
BOD_5	0.4501	0.0826	-0.0485	-0.1272	0.0054	0.0185	-0.0023	-0.0308	0.1617	0.0190	0.0277	0.0806	-0.4403	0.7370
DRP	0.4424	0.0763	-0.0301	-0.1733	0.0093	-0.0127	-0.0036	-0.2370	0.2374	0.0275	0.0342	0.0968	0.7970	0.0911
Nitrate	0.0887	0.0242	-0.1605	0.6483	-0.1870	-0.6193	0.0882	0.2195	0.2553	0.0034	-0.0021	0.0096	0.0586	0.0487
TKN	0.4429	0.0769	-0.0335	-0.1501	0.0020	-0.0453	0.0113	-0.1321	0.4094	0.0315	0.0374	0.1069	-0.3905	-0.6486
TPD	0.3889	0.0914	-0.0921	-0.0166	0.0200	0.2555	-0.0115	0.8285	-0.2350	-0.0216	-0.0050	-0.0050	0.1030	-0.1142
Proxies for gas and climate regulation:														
CO_2	-0.1138	0.5082	-0.0498	-0.0372	-0.0115	-0.0437	-0.1990	-0.0095	0.0259	-0.7944	0.2078	0.0911	0.0000	0.0000
CH_4	-0.0728	0.4117	-0.0785	0.0209	-0.0877	0.1689	0.8641	-0.0595	-0.0147	0.0770	0.1310	-0.0939	0.0000	0.0000
NO_2	-0.1069	0.4996	-0.0310	-0.0280	0.0628	-0.0836	-0.3737	0.0250	-0.0012	0.5332	0.4864	-0.2551	0.0000	0.0000

Five principal components retained

Appendix 6 discusses the issue of how many principal components (PCs) to retain. Cattel's Scree plot of the eigenvalues suggests retaining four PCs. On the other hand, the Jollife-amended Kaiser eigenvalue criterion suggests retaining five PCs. Similarly, examining the proportion of variance accounted for by the principal components also suggests retaining five PCs (which account for around 87% of the variation).

On balance, the first five principal components were selected, and account for 87.5% of the total variation (Table 8-4). Before a discussion of the principal components in more detail, it is important to note that the order in which the principal components are listed reflects the order in which are they are derived from the PCA. It does not necessarily reflect their relative importance in characterising eco-efficiency.

The five principal components described

The first principal component (Prin1), accounts for 33.4% of the total variation in the data (Table 8-4). Algebraically, Prin1 is shown as:

$$Prin1 = 0.048\varepsilon_1 + 0.051\varepsilon_2 - 0.115\varepsilon_3 + 0.016\varepsilon_4 + 0.195\varepsilon_5 + 0.400\varepsilon_6 + 0.450\varepsilon_7 + 0.442\varepsilon_8 + 0.088\varepsilon_9 + 0.443\varepsilon_{10} + 0.389\varepsilon_{11} - 0.114\varepsilon_{12} - 0.073\varepsilon_{13} - 0.107\varepsilon_{14}$$

Equation 8-16

Table 8-5 and the equation above show that Prin1 has high positive coefficients (weights) on ammonia water pollution (0.400), BOD_5 (0.405), DRP (0.442), TKN (0.443) and TPD (0.389). That is, on all water pollutant multipliers except nitrates[36]. Prin1 can be called water-pollutant intensity, with higher Prin1 scores indicating higher water pollutant intensity (m^3/\$). The prominence of water pollutants in this analysis is interesting since the issue of greatest concern to New Zealanders is also the pollution of New Zealand's freshwater resources (Ministry for the Environment, 2001).

The second principal component, Prin2, accounts for a further 24.25% of the total variation in the data, and is highly participated by energy (0.519) and air emission multipliers (0.508, 0.412, 0.499 for CO_2, CH_4 and NO_2 respectively). Prin2 can be interpreted as energy and energy-related air emission intensity, with higher scores indicating higher energy and energy-related air emission intensities.

[36] This appears to be because point source nitrate levels are closely linked to the *meat product's* sector, which has a significant level of 'embodied' (or indirect) land. Therefore, the PCA analysis traces land and nitrate pollutants in a separate principal component.

Prin3 accounts for a further 13% (Table 8-4) of total variation. Compared to the first two PCs, the interpretation of Prin3 is less intuitive. It has large positive coefficient loadings on mineral-input (0.694) and water-discharge (0.629) intensities. As was discussed in Chapter 7, *other mining* is a significant source of point-source water discharge in New Zealand. It is the dominance of the *other mining* (which includes iron sand mining) sector's water discharge intensity that helps to explain the prominence of water discharge in Prin3. Given that it is the mineral inputs that 'drive' this principal component, this component could be interpreted as 'material intensity,' with higher scores indicating greater mineral-input and water discharged intensities. An interesting characteristic of this 'material intensity' component is the dominance of negative coefficients on 11 out of the 14 variables. These negative factors are likely to have a dampening effect on this component's scores.

The fourth principal component accounts for a further 9.5% of the total variation. Prin4 is highly participated by land intensity (0.639) and water pollutant (nitrate) (0.648). The link between land and nitrate intensities is expected and an analysis of the *meat products* sector helps to explain this link. The *meat products* sector is a significant source of point-source discharge of nitrates and accounts for approximately 96% of measured point-source nitrate discharges. Furthermore, this sector's total land intensity is second only to *mixed livestock*. That is, the *meat products* sector has a relatively high indirect land intensity (see Figure 7-9), and its products contain a large degree of 'embodied' land. Given that the nitrates measured in this analysis derive from land, Prin4 can be interpreted to represent land intensities, with higher scores meaning higher land intensities.

The fifth principal component accounts for 7% of the total variation. Prin5 is dominated by water inputs[37] making the interpretation of this component straightforward. Prin5 can be interpreted as water-input intensity, with higher scores meaning higher water-input intensities.

These five principal components are useful for decision-makers. They represent the most important dimensions of eco-efficiency from an explained variance point of view given available data (the components explain almost 90% of the variation in all 14 variables). The five principal components also meet a priori expectations in that they summarise many of the important energy and material flows through the economy. The five components can be used to calculate overall scores over time to help track eco-efficiency progress in New Zealand. Also, individual sector scores can help identify those sectors that require policy intervention and monitoring focus.

The following sections put the principal components through their paces. The aim is to assess their usefulness in eco-efficiency analysis in New Zealand.

[37] To both water 'suppliers' and water 'consumers' (see below).

8.4.3 Overall scores for New Zealand

Individual sector scores for each principal component can be calculated by solving the principal component equations (such as Equation 8-16)[38]. Sector scores are shown in Appendix 7. Using the sectoral scores it is possible to calculate overall scores for New Zealand for each principal component for each year[39]. The overall scores are measured in units of Prin*i* per $ of value added and are shown in Table 8-6 and Figure 8-6.

How to interpret the scores

These scores (and particularly the negative scores) may at first appear counterintuitive. However, they are a result of the form of the principal component function (often with negative coefficients)[40]. The scores (both negative and positive) show relative magnitude, in terms of Prin*i*/$ at a point in time on the rational-number[41] scale. The higher the score, the higher the magnitude of the Prin*i*/$ for the sector or the economy.

An illustration helps to clarify how these scores are interpreted. Consider the *mixed livestock* sector. Figure 8-5 shows this sector's scorers for the five principal components in 1994/95 and 1997/98.

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[38] Note that SAS, by default, undertakes PCA using data that is standardised for unit variance and zero mean. While this is necessary for the PCA, it can make interpretation of PCA scores problematical. This is particularly the case with the zero-mean adjustment, which prevents calculation of percentage change in PCA scores and can lead to counterintuitive high negative scores. Consequently, the scores reported below have been adjusted to remove the zero-mean standardisation.

[39] The process of calculating the overall scores is as follows. First, sectoral scores are multiplied by final demand ($). These are summed and then divided by total New Zealand GDP to get a total score of Prin*i* per unit of value added.

[40] Remember that a condition imposed by PCA is that the squares of the components of each eigenvector (i.e. the weights) sum to one, so the sign is arbitrary (see section 8.3.1).

[41] From negative infinity to positive infinity.

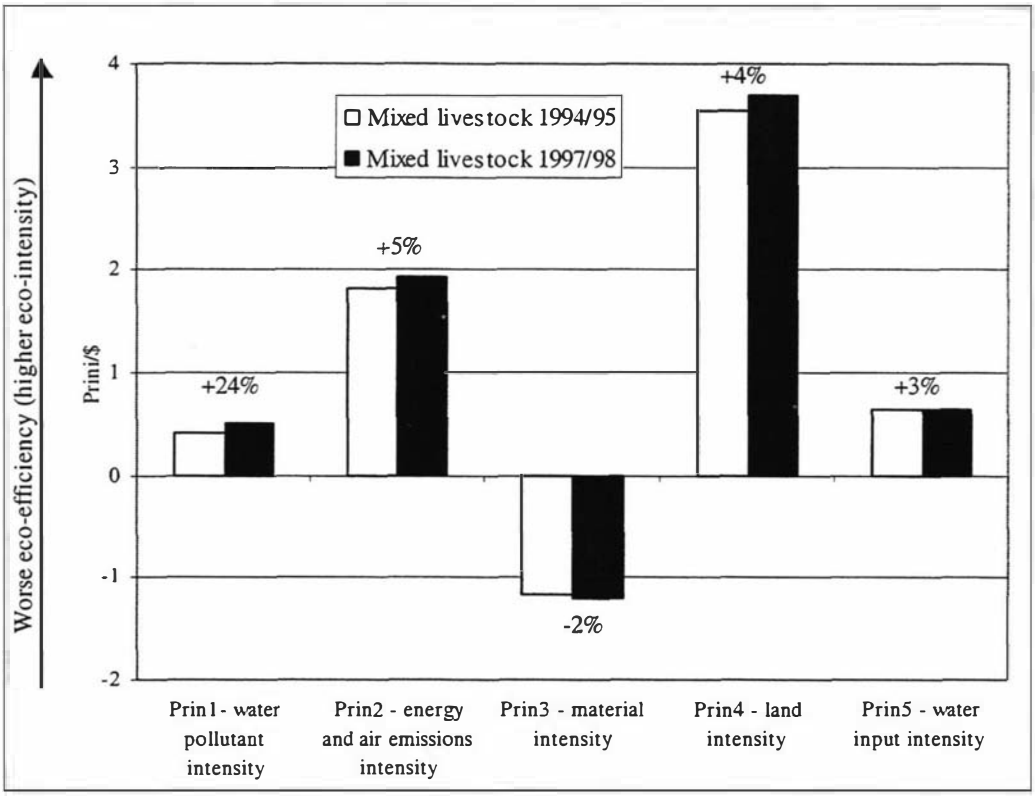

Figure 8-5: An illustration of how to interpret the principal component scores (and percentage changes) using the *mixed livestock* sector

Figure 8-5 shows that the scores for the *mixed livestock* sector changed slightly over the period. From Figure 8-5 it can be seen that the sector's intensities increased for all principal components except material intensity. For example, land and water-input intensities increased by 4% and 3% respectively. In contrast, the sector became less material intensive (the relative score decreased by 2%). Note that the negative score on Prin3 does not imply the sector uses a negative amount of material input for dollar of output.

Note also that no conclusions can be made about the relative magnitude of the different principal components. This is because each principal component (by definition) measures a different aspect of the sector's ecosystem service intensity. As such, each principal component is measured in different, incommensurable units.

Scores for New Zealand

The same reasoning can be used for understanding the economy-wide scores in Table 8-6 and Figure 8-6.

Table 8-6: Overall principal component scores for New Zealand, (Prin*i* /$), 1994/95 vs. 1997/98

	Prin1 - Water pollutant intensity	Prin2 - Energy and air emissions	Prin3 - Material intensity	Prin4 - Land intensity	Prin5 - Water input intensity
1994/95	0.432	1.443	-0.200	0.462	-0.027
1997/98	0.467	1.629	-0.230	0.518	-0.034
Change from 1994/95 to 1997/98	8%	13%	-15%	12%	-24%

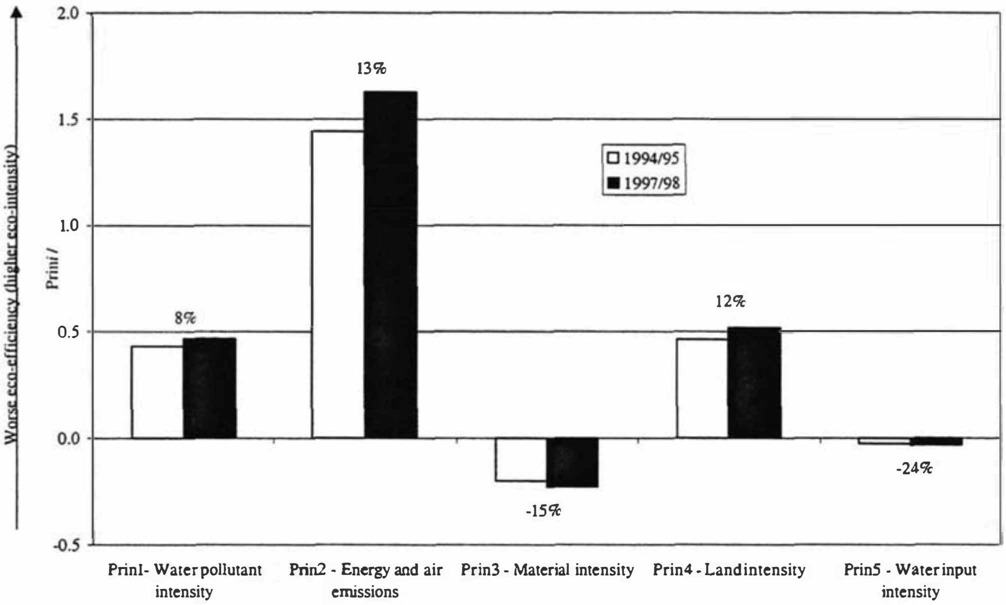

Figure 8-6: Graph of total principal component scores for New Zealand (and percentage changes), (Prin*i* /$), 1994/95 vs. 1997/98

These scores indicate that New Zealand's overall eco-efficiency improved (i.e. decreased relative score) for two out of the five principal components: material intensity (Prin3) and water input (Prin5). Over the period, New Zealand became less material intensive (the score decreased by about 15%) and less water input intensive (by about 24%)[42].

These results are generally consistent with other findings. The increase in water pollution intensity (Prin1) is consistent with the findings in Chapter 7, which estimated that water pollutants multipliers for all major sectors except *personal services* tended to increase over the period. The slight increase in the energy and air-emission intensity (Prin2) is also consistent with energy and air multiplier calculations in Chapter 7. For example, while sectoral energy

[42] Noted that while this PCA has reduced the number of variables to five principal components, it fails to provide the much-sought-after single overall index (whether this is a wise pursuit is another matter – see section 8.1.3). If a single index was considered useful, it could be calculated by multiplying the percentage change in each principal component by some 'importance' or 'impact' weighting. One way to determine these weights could be through a survey of expert opinion.

multipliers decreased on average by around 3%, air emission multipliers for CO_2, CH_4 and N_2O increased on average by 10%, 19% and 9% respectively[43].

The finding that the overall score for material intensity (Prin3) decreased slightly is not in line with findings in Chapter 7. Most mineral input and water discharge multipliers estimated in the eco-efficiency profile in Chapter 7 increased. Similarly, individual sector scores for material intensity increased over the period. The reason for the decreased New Zealand-wide score seems related to the combination of the method of calculating New Zealand-wide scores, and the formulation of Prin3's eigenvector. Many of the sectors with low material intensities receive negative scores on Prin3 as a result of the negative coefficients on Prin3's eigenvector (see Table 8-5). These sectors had relatively high and growing final demand (in dollars). Therefore, multiplying by final demand tends to increase these negative scores, and contributes to an overall decrease in New Zealand's Prin3 score.

The overall scores also indicate that New Zealand's performance with respect to land intensity (Prin4) has deteriorated. Over the period, it is estimated that New Zealand's land intensity increased by 12%. This is consistent with findings in Chapter 7 that land intensities tended to increase. This is especially the case in the most land-intensive sector (*mixed livestock*). It appears that growth in land-multipliers was exacerbated by stable or in some cases increasing nitrate multipliers. Prin5 (water-use intensity) shows a decrease over the period. Again, this is consistent with trends in the multipliers calculated in Chapter 7.

The ability of PCA to provide decision-makers with top-level indices over time is an important strength. Not only do these indices aid decision makers by providing a reduced number of indices, these PCA-estimated indices combine more information than any single original variable.

8.4.4 The principal components and sector clusters

It is instructive to look for 'groups' in sectoral scores for the principal components. Several groups, or 'clusters' can be confirmed using simple hierarchical cluster analysis[44]. Hierarchical cluster analysis was conducted on all five principal component scores using SAS/STAT

[43] These increases in energy-related air emission intensities in light of generally decreasing energy multipliers suggests a shift in energy shares to more emission-intensive energy types. This seems to be the case. Over the period, petrol and diesel (high CO_2, CH_4 and N_2O emission intensive fuels), for example, increased their share of total energy (in emjoule terms), at the expense of gas (less CO_2, CH_4 and N_2O emission intensive fuel than petrol and diesel).
[44] Cluster analysis is an unsupervised pattern recognition technique that aims to classify the objects of the system into categories or clusters based on their nearness or similarity. In this way, it uncovers the intrinsic structure or underlying behaviour of a data set without making a priori assumptions about the data. In hierarchical cluster analysis the distance between samples is used as a measure of similarity (Sharma, 1996).

CLUSTER procedure[45]. An examination of the statistics for evaluating the cluster solution[46] suggests six clusters (see Figure 8-7).

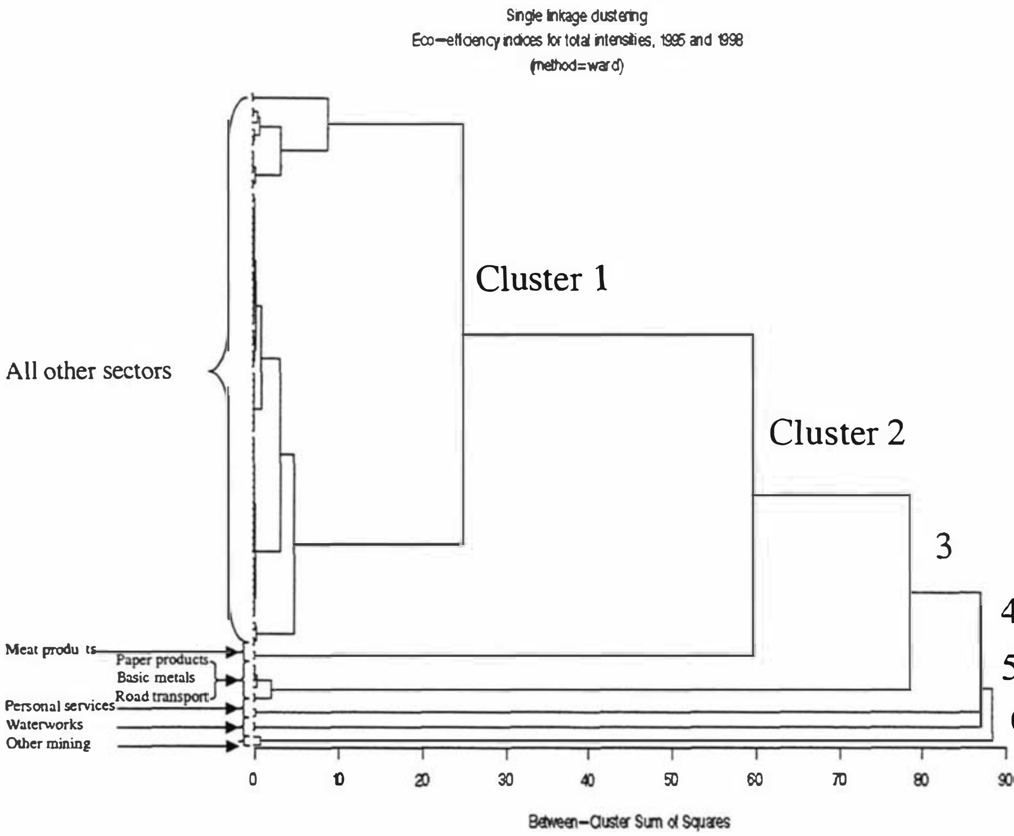

Figure 8-7: Cluster tree diagram showing the six sectoral clusters

The first cluster consists of those sectors with low scores for all five principal components. These sectors tend to be the agricultural, light manufacturing and service sectors[47]. Because of the low scores, these sectors can be regarded as relatively eco-efficient in all five dimensions.

The second cluster consists of the *meat products* sector. This sector has high scores[48] on water pollutants, energy and land intensity principal components. In particular, the *meat product's* score on land intensity is very high (due to the combined effect of land and nitrates on the score).

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[45] Specifying the Ward method.

[46] That is, the semipartial R-squared (SPRSQ) and R-squared (RSQ).

[47] These sectors are *Accommodation, Air Transport, Basic Chemicals, Beverage Manufacture, Business Services, Central Government, Communications, Community Services, Construction, Dairy farming, Dairy Products, Dwelling ownership, Education, Equipment Manufacture, Fabricated Metals, Finance, Finance services, Fishing and Hunting, Forestry & Logging, Horticulture, Insurance, Local Government, Manufacture of other food, Meat Products, Mixed livestock, Non-metallic Minerals, Oil and Gas Exploration, Other Chemicals, Other Manufacturing, Printing & Publishing, Real Estate, Recreation Services, Services to Agriculture, Services to Transport, Textile Manufacture, Trade, Transport Equipment, Water Transport, Wood & Wood Products.*

[48] That is, greater than 0.

The third cluster is made up of sectors with high scores on Prin2 (energy and energy-related air emission intensities) and low scores on the other principal components. These sectors are the energy intensive sectors identified in Chapter 7; *road transport*, *basic metals* and *paper products*.

The fourth cluster contains the sector with a high score on Prinl (water pollutant intensity) and low scores on the other principal components; *personal services*. The fifth cluster includes the *waterworks* sector[49], which has a high score on the water input intensity principal component (Prin5). The final cluster is that sector with the highest score on Prin3 (materials intensity); *other mining*.

This analysis of sectoral score groupings is useful because it helps to focus eco-efficiency policy attention and monitoring effort. In particular, several eco-intensive sectors are highlighted that should be the focus of attention for improving eco-efficiency. For Prinl (water-pollutant intensity), decision-makers should focus on trends in the *personal services* sector. For Prin2 (energy and energy-related air-emission intensity), sectors that should be scrutinised are *road transport*, *basic metal industries*, *paper manufacturing*. For Prin3 (material intensity), the *other mining* sector stands out for attention. In addition the *meat products* sector warrants attention from the perspective of several components, but particularly Prin4 (land intensity).

8.4.5 Sector eco-efficiency scores

Sectors showing poor eco-efficiency in multiple dimensions

PCA can also help identify those sectors that demonstrate poor eco-efficiency across all five important dimensions. An examination of the principal component scores reveals one sector as having relatively high scores[50] across all five principal components (*water works*) and one sector that scores highly on four principal components (the *other mining* sector has high scores on all components accept water input (Prin5)). In addition, four sectors show high scores on three principal components (Prin1, 2 and 4) simultaneously; *other farming, dairy farming, meat products* and *dairy products*. The component scores for these sectors are shown in Figure 8-8.

[49] Although it has been mentioned in Chapter 7 that this sector is not strictly a water 'use of' as such (see section 7.3.4).
[50] Defined in this instance as being 'greater than one.'

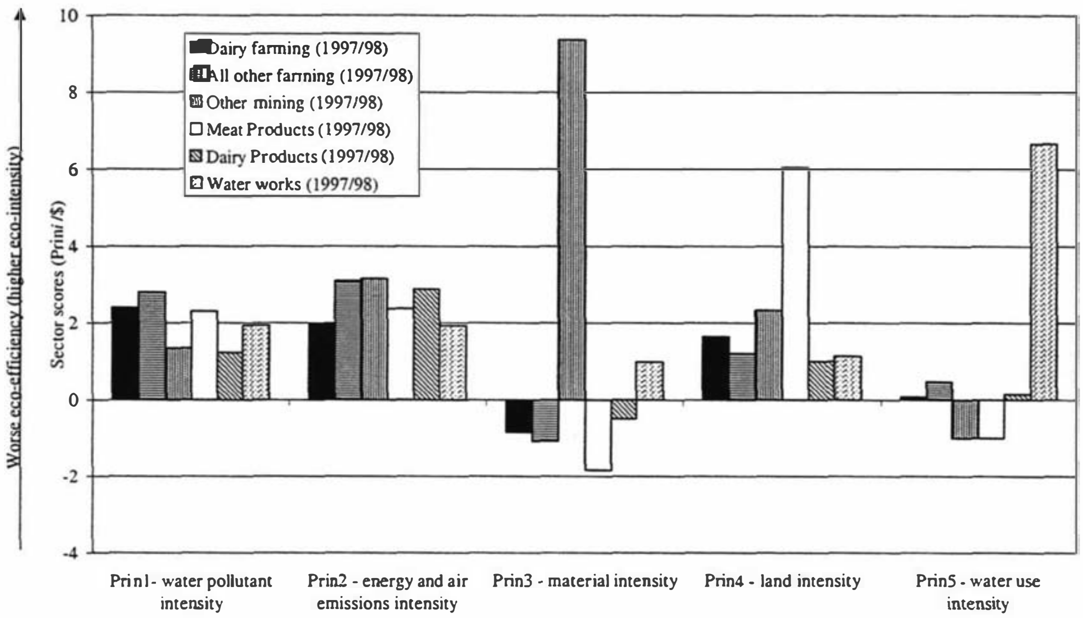

Figure 8-8: Diagram showing sectors with high scores[51] on three or more principal components

The high scores on these sectors indicate relatively 'poor' performance on an ecosystem service/dollar perspective. This analysis is useful, because it helps to identify those sectors that are relatively eco-intensive on several fronts. Consequently, these sectors may require broader policy attention than just a focus on one of the dimensions as is the trend in New Zealand (for example, EECA just focus on *energy* efficiency, whereas for the sectors mentioned in this section there is a need to extend this to eco-efficiency).

Further insights into New Zealand's eco-efficiency are possible from a more detailed analysis of each principal component in turn.

Prin1 – water-pollutant intensity

Prin1 by definition explains the greatest amount of variation in the eco-efficiency multiplier data of any of the principal components. The fact that the pollution of New Zealand's freshwater resources is an issue of concern to New Zealanders (Ministry for the Environment, 2001) gives this principal component added importance.

The overall score for Prin1 increased slightly (by 8%) over the analysis period. This suggests New Zealand as a whole is increasing the amount of water pollution discharged per dollar of output (see Table 8-6 and Figure 8-6).

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[51] Adjusted to remove the zero-mean standardisation.

The *personal services* sector has the highest score on Prin1[52]. This sector is plotted against other relatively high Prin1 sectoral scores for 1997/98 in Figure 8-9. The *personal services* sector scores are low on the other principal components. A graph of the *personal services* sector's scores shows the dominance of the Prin1 score compared with the relatively low scores for the other four principal components (see Figure 8-10).

The Prin1 scores for the *personal services* sector declined from 1994/95 to 1997/98 by 8% (Figure 8-9). This is consistent with the findings in Chapter 7 (see section 7.3.5) that suggested total water pollutant multipliers also declined by approximately 8% over the period, probably as a result of standard management practice to continually improve plant efficiency through capital replacement.

Other sectors warranting attention from a Prin1 (water pollutant) perspective are *all other farming*, *dairy farming*, *meat products*, *water works*, and *other mining*.

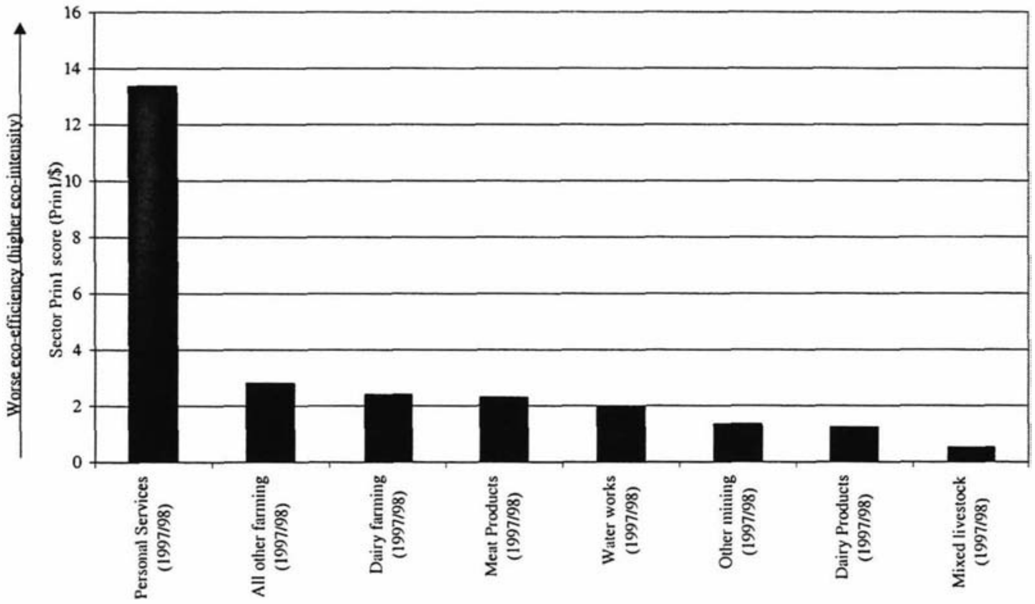

Figure 8-9: Sectoral scores on Prin1 (water pollutant intensity) for the most water-pollutant intensive sectors in New Zealand (1997/98)

[52] Chapter 7 noted that the reason for this was the inclusion in the *personal services* sector of the 'sewerage and urban drainage' (NZSIC 92012) sector.

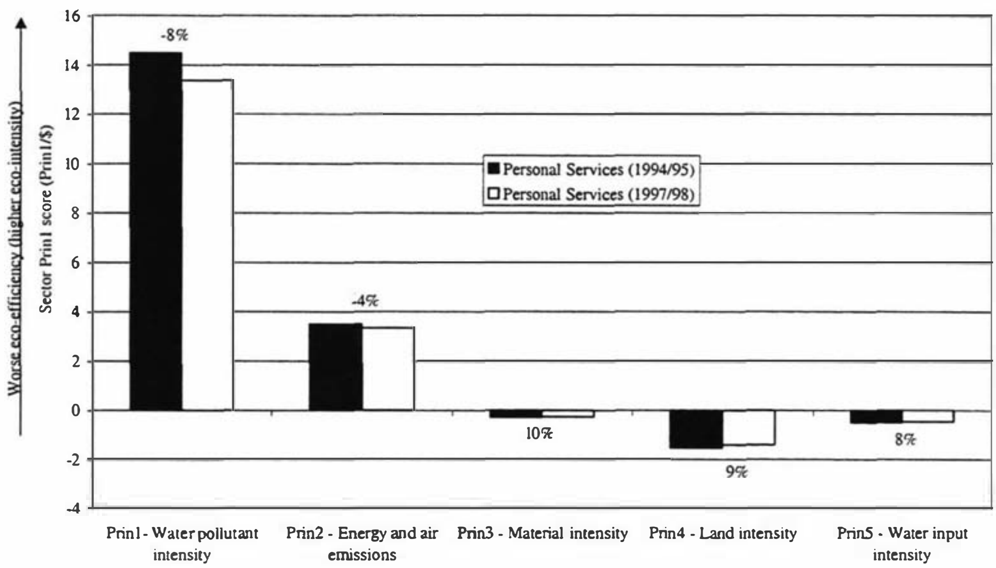

Figure 8-10: Diagram of five principal components (and percentage change) for the *personal services* sector in New Zealand (1994/95 vs. 1997/98)

Prin1 scores for these sectors tended to increase, in line with findings in Chapter 7. Of particular note is the more than doubling of the *all other farming* sector's score. This reflects a similar trend to this sector's original water-pollutant multipliers. The point-source water pollutant multiplier for this sector is almost entirely indirect. Therefore, this increase reflects the increased water pollutant intensities in those sectors with strong links to the *all other farming* sector as shown in the inverse Leontief matrix: *basic chemicals* and *trade*.

This analysis is useful for policy and monitoring purposes. It suggests that monitoring of Prin1 (water pollutants) should focus on several sectors: *personal services*, *all other farming* (and associated sectors), *dairy farming*, *meat products*, *water works* and *other mining*.

Prin2 – energy and energy-related air emission intensity

The second principal component explains 24% of the variation in the eco-efficiency data. Energy use and energy-related air emissions (CO_2, NH_4 and NO_2) are the focus of considerable policy attention at present. The prominence of Prin2 in this analysis adds further weight to the claim that this policy attention is well directed.

Those sectors scoring the highest on Prin2 are the usual energy-intensive suspects; *road transport*, *basic metal industries* and *paper manufacturing*. A plot of the scores for these sectors and other relatively high 'Prin2' scoring sectors is shown in Figure 8-11.

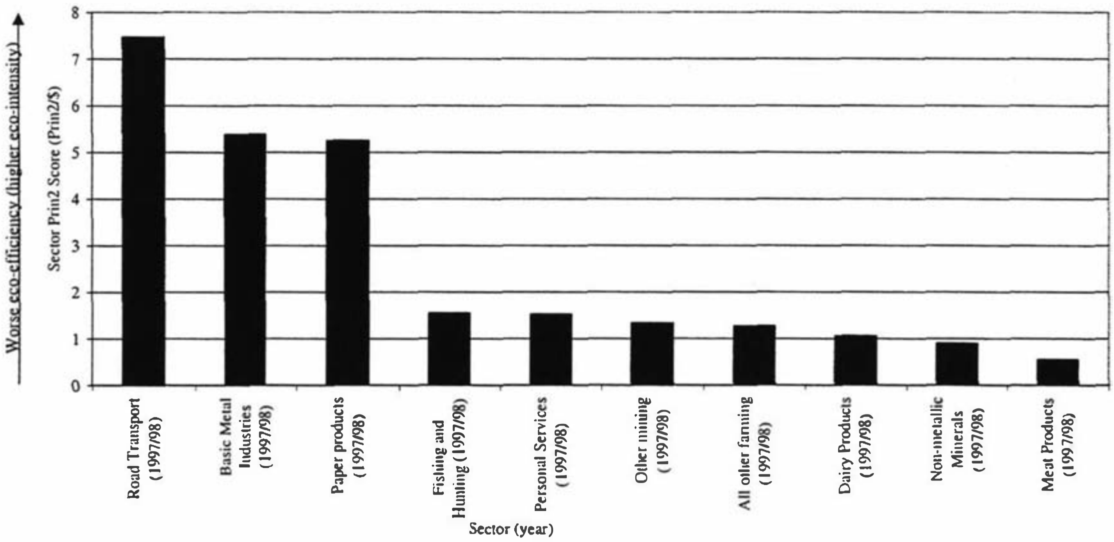

Figure 8-11: Highest sectoral scores on Prin2 – energy and energy-related air emission intensity (1997/98)

The change in the total Prin2 score from 1994/95 to 1997/98 increased by 13%. Changes in the scores of the energy-intensive sectors over the analysis period followed a similar trend to that identified in Chapter 7. The *road transport* sector showed an increase in Prin2 scores of around 5% (that is, declining, or 'worsening' eco-efficiency). In contrast, the *basic metal industries* and *paper manufacturing* sectors showed declining Prin2 scores (that is, 'improving' eco-efficiency).

It is encouraging to see that the agency with responsibility for monitoring energy efficiency in New Zealand (EECA) is focusing on these energy intensive sectors (see for example Energy Efficiency and Conservation Authority, 1995).

Prin3 – material intensity

The material intensity principal component explains 13.3% of the variation in the eco-efficiency data. Mineral inputs are an essential input into many aspects of the New Zealand economy. Specifically, an examination of the inverse Leontief matrix shows that there are important links between the *other mining* sector and *non-metallic minerals* and *basic metal industries*.

The sectors with the highest Prin3 scores are the *other mining*, *waterworks*[53] and *non-metallic minerals* sectors. A plot of the score for these sectors and other relatively high Prin3 scoring sectors is shown in Figure 8-12.

[53] Because of the high water discharge component of this sector.

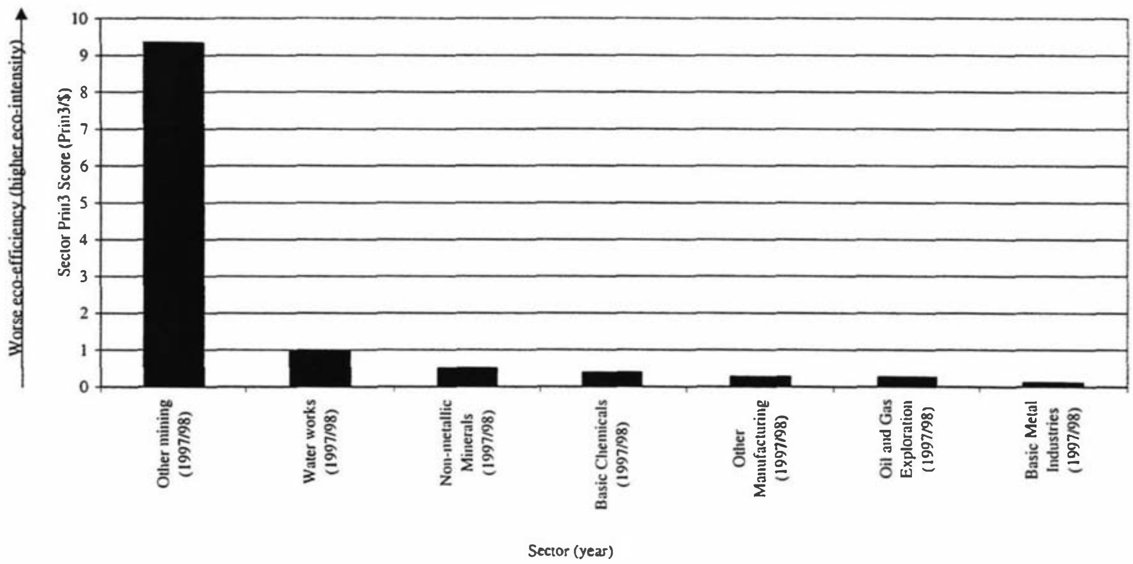

Figure 8-12: Highest sectoral scores on Prin3 – material intensity (1997/98)

Changes in these sectors' scores over the 1994/95 to 1997/98 period confirm findings in Chapter 7. The *other mining* sector recorded an increased Prin3 score of around 20%. This follows a similar trend outlined in section 7.3.7. In like manner, the *non-metallic minerals* sector recorded an increase in its Prin3 score of around 24 percent. Total water discharge multipliers for this sector also increased by 31%.

Prin3 is highly participated by water discharged multipliers. Consequently, it is not surprising to find that *waterworks* scores relatively highly on Prin3. The *waterworks* showed a decline in its Prin3 score (of around 20%). Again this follows a trend discussed in Chapter 7; water-discharge total-requirement multipliers declined by around 42 percent over the period.

Prin4 – land intensity

Prin4 – land intensity explains 9.5% of the variation in the eco-efficiency data. Land input is essential for all economic sectors. Furthermore, Prin4 is highly anticipated by the nitrate pollutant. Nitrate pollution in waterways is of concern because nitrate is a significant source of eutrophication (McDonald & Patterson, 1999).

The sectors with the three highest Prin4 scores are the *meat products*, *mixed livestock* and *other mining* sectors. A plot of the score for these sectors and other relatively high Prin4 scoring sectors is shown in Figure 8-13.

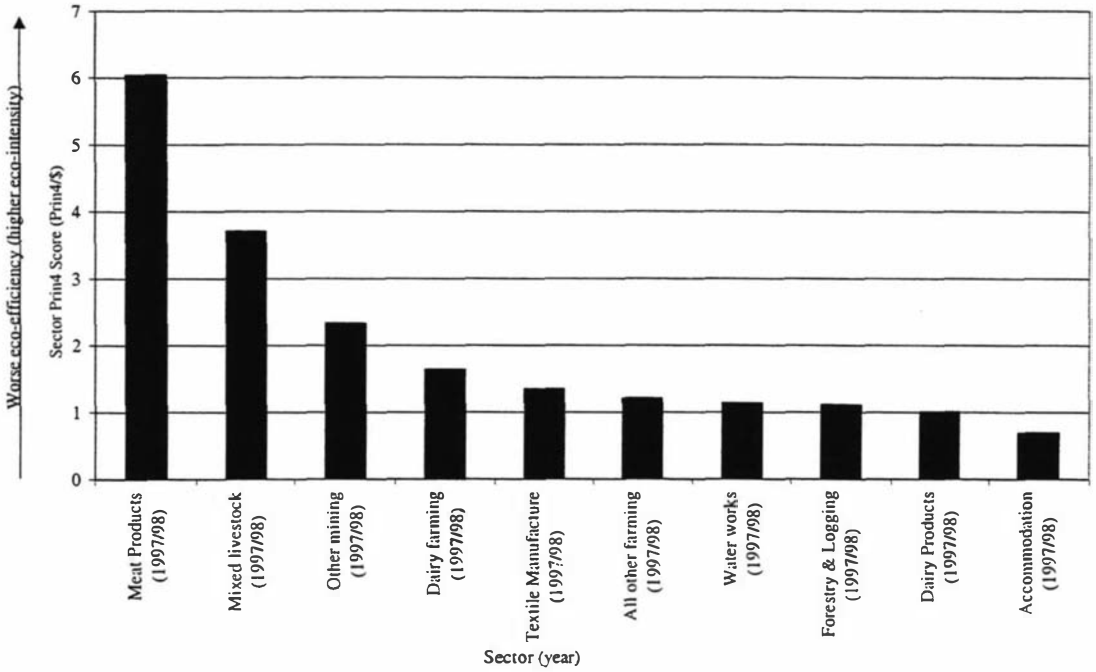

Figure 8-13: Highest sectoral scores on Prin4 – land intensity (1997/98)

The overall Prin4 score for New Zealand increased by 12% over the analysis period (see Figure 8-6). The increase is corroborated by an examination of both sectoral land and nitrate intensities (Chapter 7) and sectoral scores for the same period.

The five highest scoring Prin4 sectors recorded increased scores over the period, except *meat products*. The Prin4 score for the *meat products* sector decreased by 6%. This follows a decrease in nitrate multiplier of 4% and an increase in land intensity of 4% (see Chapter 7).

The Prin4 score for the *mixed livestock* sector increased by 4% over the period. This suggests that this sector is becoming more land and nitrate-pollutant intensive. Indeed, Chapter 7 estimates show this sector's land and nitrate multipliers (total requirements) grew by 4% and 23% respectively (see Appendix 5.3).

Similarly, the Prin4 score for the *dairy farming* sector increased by 7%. Chapter 7 reflects this and estimates this sector's land and nitrate multipliers increased by 5% and 9% respectively over the study period.

An analysis of Figure 8-13 suggests the two sectors warranting policy and monitoring attention are the *mixed livestock* and *meat products* sectors. These sectors are the most land and nitrate intensive, and the *meat products* sector in particular contributes a significant proportion of point-source nitrate pollutants.

Prin5 – water input intensity

Prin5 explains 7% of the variation in the eco-efficiency multiplier matrix used in this principal components analysis. This component is dominated by water inputs. Water is an essential ecosystem good and is required as an input (directly and indirectly) in all economics sectors.

The highest scores on Prin5 were for the *other mining* and *meat products* sectors[54] (see Figure 8-14).

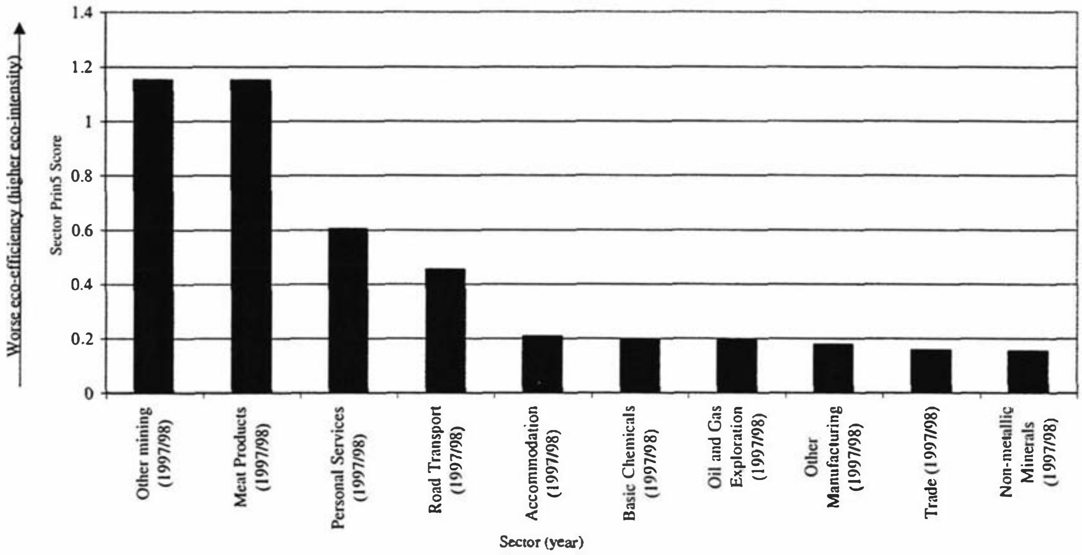

Figure 8-14: Highest sectoral scores on Prin5 – water-input intensities for water users (1997/98)

The dominance of the *other mining* sector is consistent with findings in Chapter 7. The *meat products* sector also has one of the highest water input multipliers. The changes in the Prin5 scores on these sectors are also consistent with the multiplier analysis in Chapter 7. In particular, the *other mining* sector's Prin5 score increased (by 16%) while its water-input multiplier increased by 18%. In contrast, the *meat products* sector's Prin5 score and multipliers decreased.

[54] Note that in this analysis it was decided to change the sign of the SAS-generated sectoral scores for the following reasons. *Waterworks* received the largest positive score in the SAS output while *other mining* received a high negative score. Chapter 7 has already noted that *waterworks* is not strictly a water 'user,' but rather a 'supplier.' In contrast, *other mining* is a water user.

The SAS-generated scores allocate positive signs in the eigenvector arbitrarily (remember that PCA is conducted under the condition that the square of the eigenvector elements must equal 1). Signs are, by default, allocated by SAS such that the largest scores are positive. While this is usually appropriate, in this case it would be useful for water 'users' (such as *other mining*) to have positive scores rather than water 'suppliers' (*waterworks*). Therefore, it was decided that it was appropriate to change the signs to improve the usefulness of the sectoral scores. Note that changing the signs does not affect the ranking of the sectoral scores, merely the interpretation.

8.5 Conclusion

The eco-efficiency multiplier matrix presented in Chapter 7 gives a multi-dimensional picture of eco-efficiency in New Zealand. In the context of decision-makers' preference for aggregate indices, the matrix can prove to be too cumbersome. What is needed is a framework for condensing information into aggregate indices (Dahl, 2000).

One aggregation function that has shown promise but had little attention in analysing eco-efficiency multipliers is PCA. Combining the aggregation process with a PCA of the eco-efficiency multipliers matrix has revealed several strengths of the technique. First, PCA consistently identified five important dimensions of the eco-efficiency data from an explained variance point of view: water pollutants, energy and energy-related air emissions, material input, land and water-use intensities. In doing so, the aggregation process using PCA is able to reduce redundancy in the eco-efficiency multiplier matrix while providing results that are consistent with the findings of Chapter 7.

Second, PCA is able to provide the much sought-after 'aggregate' scores for each dimension (principal component) for New Zealand. This supplies condensed information for decision-makers and provides an overall assessment of New Zealand's eco-efficiency trends.

Third, PCA helped to identify those sectors that are relatively 'eco-intensive' in several dimensions, thus providing a focus for policy and monitoring attention. In particular, the PCA conducted here identified the following sectors that merit special policy attention (see Table 8-7). This list of sectors bears a close resemblance to the sectors identified in Chapter 7 (see Table 7-6). One of the advantages of the PCA approach is that it is able to identify these sectors in a more 'parsimonious' manner than via the large multiplier matrix.

Table 8-7: Sectors that merit special eco-efficiency policy attention by virtue of their relatively high principal component scores

	Focus sector	Change in sector score from 1994/95 to 1997/98
All Principal components (Prin1-5)	Waterworks	
Across 4 Principal components (Prin1,2,3,4)	Other mining	
Across 3 Principal components (Prin1,2,4)	Other farming	
	Dairy farming	
	Meat products	
	Dairy products	
Prin1 – water pollutants intensity	Personal services	Decrease
	Other farming	Increase
	Meat products	Decrease
	Other mining	Increase
	Waterworks	
		Increase
Prin2 – energy and energy-related air emissions intensity	Road transport	Increase
	Basic metals	Decrease
	Paper products	Decrease
Prin3 – material intensity	Other mining	Increase
	Waterworks	Decrease
	Non-metallic minerals	Increase
Prin4 – land intensity	Meat products	Decrease
	Mixed livestock	Increase
	Other mining	Increase
Prin5 – water use intensity	Other mining	Increase
	Meat products	Decrease

Table 8-7 shows that many of the sectors requiring policy attention also recorded increases in their principal component scores (corresponding to a deterioration in eco-efficiency). Of particular concern from a policy perspective are the increases in two sectors. The *other mining* sector has high and increasing scores across four of the five principal components. This is of policy concern for two reasons. First, the *other mining* sector can impose significant pressure on the environment. Second, products from this sector are used throughout the New Zealand economy. Increasing intensity in the *other mining* sector will inevitably flow on to increasing total requirement intensities for the sectors that rely on material inputs. The other area of concern is the 6% growth in the *road transport's* Prin2 score. *Road transport* is a significant energy user and emitter of greenhouse gases. It is also proving to be a challenge for policymakers to reduce transport-derived greenhouse gas emissions. The increasing *road transport* multiplier (Chapter 7) and Prin2 score suggest that the challenge to reduce this sector's greenhouse gas emissions increased in the mid – to late 1990s.

Despite the merits of the PCA approach to aggregating eco-efficiency data, it can not be considered a panacea. The PCA has not produced the much sought-after single index. Another potential criticism is that the five principal components have not been developed on the basis of any measure of ecosystem impact. However, this may not be too damning a criticism, since there is certainly no consensus on how the relative impact of such diverse ecosystem service uses should be measured.

It is also important to remind the reader of the constraints imposed on this analysis by data limitations. The data only capture (in some instances imprecisely) a small set of ecosystem services. Water input, water pollutants and air emissions data are particularly limited. Water data only cover point-source abstraction and discharge. The area emissions data only cover energy-related emissions. Future research into the eco-efficiency area should focus on improving the quality and breadth of data in New Zealand.

In the final analysis, PCA has demonstrated its ability to provide robust aggregate indices for eco-efficiency. As such, this approach warrants further investigation as a legitimate aggregation approach.

In conclusion, it is useful to draw on the pertinent message from Costanza (2000, p. 342, brackets added). "Even given [the] advantage of aggregate indicators, no single one can possibly answer all questions and multiple indicators will always be needed ... as will intelligent and informed use of the ones we have."

9 Conclusions

Eco-efficiency has emerged as a popular concept in strategies for sustainable development. The concept has served to bring the business community into the sustainability debate and enabled businesses to demonstrate significant environmental improvement. It is also beginning to play a key role in national sustainable development policy. However, the recent interest in eco-efficiency has highlighted several unresolved and sometimes contentious issues. This thesis has addressed two of these issues – the meaning of the eco-efficiency concept and the measurement of eco-efficiency for national-policy purposes.

In order to address these issues, the thesis set four inter-related research objectives:

1. to evaluate the limitations of the dominant business-oriented perspective of eco-efficiency;
2. to develop a broad theoretical appreciation of the eco-efficiency concept based on ecological economics theory. This ecological economic perspective drew on its foundational disciplines of thermodynamics, economics and ecology. It also acknowledged the importance of scale, context-dependent problem solving, policy pragmatism and other such issues;
3. within the context of an ecological economic perspective of eco-efficiency, to develop and refine a selection of methods for analysing eco-efficiency trends and performance;
4. to apply these methods to the analysis of New Zealand-based case studies and to draw out their policy implications and messages for the practice of eco-efficiency.

The intention of this concluding chapter is to tie together the threads from the work in previous sections. It provides an opportunity to address the findings of the research questions outlined above and point towards future research directions. This thesis makes contributions in three main areas with respect to eco-efficiency: theoretical arguments, method development and empirical findings.

9.1 Theoretical arguments

9.1.1 Achievements of this thesis

In addressing research objectives 1 and 2, this thesis provides a unique discussion of eco-efficiency from an ecological economic perspective. Much of the current work on eco-efficiency appears to be dominated by a restrictive world view (see for example DeSimone, Popoff, & World Business Council for Sustainable Development, 2000; New Zealand Business Council for Sustainable Development, 2002). This world view is reflected in the narrow interpretations of eco-efficiency.

For example, a prominent interpretation of eco-efficiency has emerged from the WBCSD

> *"Eco-efficiency is reached by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing environmental impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity"* (DeSimone et al., 2000, p. 47).

At first glance, this interpretation may not appear particularly narrow. But behind the rhetoric, there is evidence that this interpretation was developed within the narrow confines of a world view that:

- is committed to a business-as-usual path;
- assumes controllability of production processes and sees technology as a fix for environmental problems;
- assumes independence of economic and environmental production processes.

This thesis argues that those involved with promoting and implementing eco-efficiency should avoid buying into a narrow conception of eco-efficiency. Interpretations of eco-efficiency based on inappropriate and questionable assumptions are limited. Such eco-efficiency interpretations undermine the credibility and restrict the wider adoption of the eco-efficiency concept. These interpretations also limit the ken of eco-efficiency (by ignoring the complex social and cultural milieu) and can lead to inappropriate policy prescriptions. Ultimately, these interpretations can limit the ability of resource users to address eco-efficiency in an 'holistic' sense.

The critique of the narrow interpretations of eco-efficiency is not a call to abandon the eco-efficiency concept. Rather, it lays down the challenge to take a broader perspective of eco-efficiency.

One way to broaden the conception of eco-efficiency is to apply an ecological economic framework. To date, ecological economic literature has not paid much attention to the issue of eco-efficiency interpretation. One of the few exceptions is Daly (1996) who perhaps makes the most comprehensive contribution to date with his formulation of 'overall ecological efficiency.'

Ecological economics is well placed to make a significant contribution to understanding eco-efficiency because it brings a number of relevant ideas and principles to bear on such an investigation. These include:

- the importance of a biophysical perspective;
- the need for a systems approach to eco-efficiency;
- the role and limitations of eco-efficiency in a sustainability context;

- the importance of an interdisciplinary, pluralistic approach;
- the need to draw on thermodynamic, economic and ecological theory.

The latter point is of particular interest. The efficiency concepts and world views of the foundational disciplines of ecological economics provide useful insights into eco-efficiency. For example, classical thermodynamics emphasises energy flows and limits in its conception of efficiency. In contrast, neoclassical economics focuses on the performance of the economic production process and the allocation of resources to enhance human welfare in its approach to efficiency. On the other hand, ecosystem ecology highlights energy and matter flows, the concept of ecosystem functions, goods and services and the notion of 'indirectness' in its perspective of efficiency.

These insights are not sufficient on their own to aid an understanding of eco-efficiency. A framework is needed that can highlight the limitations of eco-efficiency within the physico-socio-politico milieu. Such a framework is also necessary to highlight the interconnections, synergies and tensions between eco-efficiency perspectives. The lack of such a framework in the past studies of eco-efficiency that can accommodate this multi-dimensionality without losing the richness of different approaches through simplifying assumptions remains a significant lacuna in ecological economics' ability to understand and improve eco-efficiency.

This thesis proposes a nested hierarchy framework based on ecological economic theory. The thesis argues that eco-efficiency must be understood in a framework that embeds the concept within physical scale and social considerations. Consequently, the framework consists of a hierarchy of three tiers: scale, social values and decision criteria (eco-efficiency):

- *Scale* – consistent with Daly (1992), the first tier necessarily involves a consideration of biophysical scale;
- *Social values* – the second tier is subordinate to, but interacts with scale issues. Within the second tier, goal setting on other social issues such as equity takes place;
- *Third tier* – the eco-efficiency concept is regarded as a third-tier consideration. The eco-efficiency tier is used to generate guidance on how to pursue the goals in tiers one and two. Embedding eco-efficiency within the scale and social value tiers highlights the limitations of eco-efficiency as a decision tool, as well as the tradeoffs, the necessary hierarchy and the complexity of decision-making involving environment-economy interactions.

Following Norton et al. (1998), the framework is interactive and acknowledges the movement back and forth between all three tiers.

Because of the context-dependent nature of eco-efficiency, the third tier is not tied to one eco-efficiency concept. Rather, the interpretation of eco-efficiency can be described as interdisciplinary and pluralistic. This is appropriate for understanding eco-efficiency because it helps to avoid potential knowledge cul-de-sacs and encourages open-mindedness. Instead of defining eco-efficiency in the singular, the third tier can be considered a multi-dimensional space that accommodates a pantheon of interrelated perspectives of eco-efficiency. This plurality encourages a view that perspectives of eco-efficiency are intertwined and promotes tolerance and acceptance that all different perspectives provide important insights into eco-efficiency. In this way, the third tier manifests a core conclusion of this thesis: that a combined application of the eco-efficiency concepts from thermodynamic, economic and ecology disciplines can describe eco-efficiency more richly than is possible with methods borrowed from a single discipline.

The proposed nested hierarchy framework is an attempt to put to rest the notion that the eco-efficiency concept is necessarily analytically closed and unidimensional. The proposed ecological economic framework attempts to encourage open-mindedness and an acknowledgement of the interrelatedness and complementarity of different multiple perspectives – acknowledging that different perspectives of eco-efficiency are at once many and single, separate and interconnected.

9.1.2 Future research

There are several areas where further research is required into the theoretical aspects of eco-efficiency. First, there is a need for further critical examination of the eco-industrial épistémé approach to eco-efficiency from thermodynamic and ecological theory. This thesis has provided a critique of eco-efficiency from an ecological economic perspective. However, further critiques of eco-efficiency could be usefully conducted within the confines of ecological and thermodynamic disciplines. In particular, these critiques could attempt to address research questions such as the thermodynamic limits to eco-efficiency for specific processes and systems, issues of commensuration in measuring eco-efficiency and the relationship between eco-efficiency and evolutionary change. The hope is that such critiques will further enhance our understanding of eco-efficiency.

Second, this thesis has taken a pluralistic approach to eco-efficiency. A question remains as to what pluralism means in the context of the inevitable definitional and measurement tensions between different disciplinary perspectives of eco-efficiency. For example, a general policy of improving eco-efficiency is likely to be interpreted differently by different disciplines. In an interdisciplinary context, tensions are likely to arise as the different disciplines attempt to develop a shared definition of the policy goal and how success should be measured. Research is needed within ecological economics to identify ways of resolving these tensions that arise in interdisciplinary contexts.

Third, there is an urgent need for research into defining the role and interpretation of efficiency in general within ecological economics. Efficiency analyses within ecological economic literature tend to draw on neoclassical economic concepts (principally allocative efficiency). There is a need for ecological economists to debate whether this reliance on allocative efficiency is appropriate, whether ecological economics can contribute unique interpretations of the efficiency concept and what these unique perspectives might be. This thesis presents a framework within which this debate can take place.

Finally, this thesis highlighted the issue of the role of efficiency in complex evolutionary systems. The place of efficiency in such systems is not well understood. This is because there has been a lack of focus in research on the role of efficiency in complex systems. Furthermore, studies such as those by Bak (1996) and Papadopoulus et al. (2001) which supposedly examine efficiency in complex systems, seem to confuse efficiency with throughput. There is also a question about the relevance of the efficiency concept in complex systems. This is because the efficiency concept requires one to describe the 'purpose intended' of the system for which efficiency is being considered. Identifying this purpose, or 'goal' can be relatively straight forward for simple, deterministic systems. However, for complex systems, identifying such telos may be difficult or impossible. Without the ability to define a system's 'purpose intended' it is questionable whether the concept of efficiency is meaningful. The lack of understanding of the role and relevance of efficiency in complex systems is unfortunate since all real-world systems dealt with by ecological economics are complex systems. There is a need for an enquiry into the role of efficiency in complex systems.

9.2 Method development

9.2.1 Achievements of this thesis

This thesis makes several methodological contributions to measuring and analysing eco-efficiency (research objective 3). These contributions have extended the Divisia-index decomposition method, ecological multiplier analysis and the consequent principal components analysis.

Index decomposition analysis

This research has presented a complete revision of Ang and Choi's (1997) refined Divisia method to account for an energy quality effect. Most applications of Divisia decomposition only factorise the energy:GDP ratio into intensity and structural effects. However, additional factors such as energy quality also affect the ratio. Excluding these additional factors can lead to inaccuracies as the additional factors become subsumed within the intensity effect. This can lead to inaccurate and potentially misleading results.

Extending the method to include three factors required reworking the algebraic derivation of the factorisation. It also required the derivation of a new logarithmic-mean weighting function that would provide pure decomposition (i.e. zero residual).

The other main achievement of this thesis was to integrate index decomposition with the Quality Equivalent Method (QEM) to measure energy quality. This integration required incorporating the QEM coefficients into the Divisia algebra. The QEM was used as a measure of energy quality because it can accommodate system-wide quality effect. Implicit in the use of QEM for time-series decomposition was the need to calculate quality coefficients for New Zealand over time.

Ecological multiplier analysis and consequent principal components analysis

A contribution of this thesis was its integration of the ecosystem services concept into ecological multipliers analysis. This integration enabled all ecological multipliers calculated using the inverse Leontief matrix to be specified as measures of eco-efficiency. By building on the ecosystems services concept, this research was able to extend the analysis of eco-efficiency by way of ecological multipliers for New Zealand to a wide range of resources and pollutants. This analysis has also paid special attention to issues of double counting which has hitherto not received much attention in the literature.

In the pursuit of aggregate eco-efficiency indices for New Zealand, this thesis made a number of unique contributions to the indicators literature. First, the thesis formulated a generic process for developing aggregate indices. This generic process also integrated the work by Ott (1978) on the mathematics of aggregation functions. Prior to this research, guidance on calculating aggregate indices was limited. The thesis then applied the generic process to eco-efficiency subindices and found that the flow chart provided useful guidance.

Another achievement of this thesis relates to the incorporation of principal components analysis into the aggregation process. This research represents the first time principal components analysis has been explicitly incorporated as a weighting option in the generic aggregation process. This is also the first time principal components analysis has been applied to eco-efficiency indices.

9.2.2 Future research

Several areas stand out as warranting further research activity with respect to method development.

Index decomposition

Index decomposition methods need to be extended to account for a greater range of factors that affect eco-efficiency. While this thesis has attempted to incorporate energy quality issues, other factors such as energy-labour substitution need to be investigated. Work is also needed to investigate the drivers of the various decomposition factors. This would assist with understanding why decomposition factors change as they do. In particular, integrating price effects into the analysis would prove extremely useful for policymakers. EECA (unpublished) undertook such an analysis sometime ago using regression analysis. Unfortunately, their research was not conclusive. Research into these factor drivers needs to be reinvigorated.

There is also a need to further develop and apply stochastic decomposition methods as a complement to index decomposition. Although stochastic methods are not currently widely used, they do show promise for use in decomposition analysis (see for example Stern, 2002), particularly because the statistical significance of the decomposition factors can be tested.

Ecological multipliers and aggregate indices

The ecological multiples estimated in this thesis use proxies to attempt to quantify sectoral ecosystem service use. Future research could focus on more direct ways of measuring these ecosystem services. Also, the use of ecosystem services does not necessarily provide a measurement of the relative impact on the environment. Reformulating the quantity input data into impact equivalents such as eutrophication equivalents, global warming potentials, and acidification equivalents etc could usefully extend the work on ecological multipliers.

Work on calculating ecological multipliers could also be extended to accommodate multiple outputs, imports and endogenised capital into the input-output model. These issues have been addressed by other authors, but not in the context of eco-efficiency. Another way to improve the analysis in this thesis would be to expand the range of ecosystem services included in the **E** matrix.

With respect to the aggregate indices, future research could usefully test the effectiveness of the proposed aggregation process. This could be achieved by applying the process to the calculation of other indices.

One potential limitation of the current analysis is that it does not produce a single, 'all-encompassing' index. If such an index was desirable, research could usefully be conducted into determining a way of adding the five principal components together. Finally, the negative principal components scores could provide a challenge when trying to communicate the results to decision-makers. Research is needed into a method of conducting principal components analysis that does not produce negative values in the eigenvectors.

9.3 Empirical findings

9.3.1 Achievement of this thesis

Prior to the work of this thesis, there was limited understanding of the levels and trends in eco-efficiency at the national level in New Zealand. Certainly no attempt had been made to measure overall eco-efficiency in New Zealand across many ecosystem services. This current research aims to fill this information lacuna in New Zealand's policy makers' arsenal.

Through the application of the analytical methods this thesis made a number of important observations and conclusions about eco-efficiency and New Zealand.

Cross-cutting conclusions

Across the three empirical chapters, several sectors stand out as warranting policy attention in New Zealand. The transport sector features as a dominant sector with relatively low and decreasing energy and CO_2 efficiencies in all three empirical chapters. These characteristics are of concern in light of New Zealand's commitments under the Kyoto Protocol. The transport sector contributes around 45% of New Zealand's total CO_2 emissions (Ministry of Commerce, 1999). Also, the transport sector has proven to be one of the most difficult to influence in New Zealand from an environmental performance perspective. Therefore, this thesis concludes that significant resources should be devoted to enhancing the policy instruments (such as section 15 of the Resource Management Act, 1991) and other programmes that aim to improve the environmental performance of the transport sector.

Several other sectors warrant attention by virtue of their low (and often worsening) eco-efficiency measures. These sectors are often primary production and related processing sectors: *other mining*, *other farming*, *dairy farming*, *meat products*, *and dairy products*. This finding is of concern because it has the potential to undermine New Zealand's environmentally-friendly, eco-efficient image that is often relied on for marketing these primary products to international markets. As a result, urgent attention is required to improve the environmental behaviour of these sectors. The past information campaigns conducted by New Zealand's Ministry for the Environment are a useful start.

Index decomposition

The analysis found it instructive to break trends in New Zealand's energy:GDP ratio into two periods; restructuring period (1987 – 1992) and consolidation period (1993 – 2000). During the restructuring period the technical effect tended to increase the energy:GDP ratio by around 178 kJ/$ per annum. This indicates that the technical efficiency with which New Zealand used energy during this period actually worsened. In contrast, during the consolidation period, which was a period of economic growth in New Zealand, the technical efficiency of energy use improved.

It appears that this measure of technical efficiency is strongly influenced by economic performance. The challenge for New Zealand policymakers concerned with energy efficiency is to avoid the complacency that characterised New Zealand energy efficiency policy during the economic growth of the mid 1990s (Parliamentary Commissioner for the Environment, 2000). It is encouraging to see the New Zealand government's recent commitment to increase the resources of the Energy Efficiency and Conservation Authority in an attempt to improve New Zealand's energy efficiency.

The structure of New Zealand's economy also influences the energy:GDP ratio. During the restructuring period, there was a shift away from energy-intensive sectors towards service sectors. This was reversed somewhat in the consolidation period, particularly as a result of growth in energy-intensive transport activity.

The energy quality effect made a noticeable impact on the energy:GDP ratio. In both the restructuring and consolidation periods, the energy quality effect tended to decrease the energy:GDP ratio by 12 and 27 kJ/$ respectively. Given the potential for overall efficiency improvement from shifts in energy mix, it is unfortunate that the New Zealand government has in the past avoided promoting particular energy types over others to capture this energy quality effect. The government has taken this laissez-faire stance because it prefers, where possible, to leave energy mix decisions to market players (Ministry of Economic Development, 2000a). However, if the government is committed to improving energy efficiency in New Zealand, this author suggests it should consider developing and implementing policies that influence energy mix. The recent policy announcements regarding the possibility of an emissions charge applied to fossil fuels (New Zealand Climate Change Programme, 2002) may help to achieve such a change in energy mix.

Ecological multipliers and aggregate indices

The ecological multipliers and principal components analyses both identified several sectors that stand out as having relatively poor eco-efficiency (in a total-requirement sense):

- the most water-input intensive (m^3/$) sectors in New Zealand are the *other mining*, *horticulture* and *meat products* sectors;
- the most water-discharge intensive (m^3/$) sectors are the *other mining* and *personal services* sectors;
- *personal services*, *meat products*, *dairy farming* and *water works* sectors tend to have the highest water-pollutant multipliers;

- the *mixed livestock* sector is the most land-intensive sector in New Zealand;
- *basic metals, road transport* and *paper products* use the most energy per dollar of economic activity;
- sectors with the highest energy-related air emissions are the *basic metals, road transport* and *paper products* sectors.

Several sectors stand out by virtue of the trends in their eco-efficiency multipliers. It appears that many aspects of the eco-efficiency of the *dairy farming* sector have worsened over the period 1994/95 to 1997/98. Similarly, the *other mining* sector has shown a worsening in its eco-efficiencies with respect to water use and discharge. The *road transport* sector has also shown worsening energy efficiency over the same period.

This list of sectors with low eco-efficiency warrants particular policy attention by relevant government agencies. Efforts should be made to develop an appropriate mix of regulatory and nonregulatory (education and incentive programmes) to encourage these sectors to reduce their ecosystem service use per dollar of output.

This thesis also found that a consideration of direct eco-efficiency multipliers on their own can be misleading, particularly for the manufacturing and service sectors. These sectors often require significant indirect inputs into their economic activity. It is a matter of concern to find that government agencies tasked with monitoring eco-efficiencies in New Zealand (EECA, Ministry for the Environment, Statistics New Zealand) focus solely on direct inputs. In order to improve the information they provide to policymakers it is essential they augment their monitoring programmes to calculate total-requirement multipliers.

For the data set used in this thesis, principal components analysis identified five principal components explaining 87% of the total variation in the data: water pollutant intensity, energy and related air emission intensity, material intensity, land intensity and water-use intensity. These five components summarise many of the important energy and matter flows through the economy.

Principal components analysis enabled the calculation of overall eco-efficiency indices for New Zealand. This supplies condensed information for decision-makers and provides an overall assessment of New Zealand's eco-efficiency trends. The overall scores indicate that New Zealand's overall eco-efficiency worsened for three out of the five principal components: water pollutants, energy and related air emissions and land intensities. That is, over the period, New Zealand as a whole became less water-pollution efficient (by 8%), less energy efficient (by 13%) and less land efficient (by 12%).

It is encouraging to see that New Zealand now has in place policies and programmes to address all three of these aspects. Water pollutants are targeted in the Ministry for the Environment's work on water quality, energy efficiency is addressed through the Energy Efficiency and Conservation Act 2000, and land use is the focus of the Ministry of Agriculture and Forestry and a significant portion of the Foundation for Research Science and Technology funding. However, the findings from the principal components analysis suggest further resources could beneficially be allocated to these areas.

9.3.2 Future research

Several areas of future research could extend the empirical work of this thesis. All of the analyses could use more up-to-date data. This is particularly the case with the ecological multiplier analysis where the data are now almost five years out of date.

The index decomposition analysis has demonstrated its usefulness as applied to the energy:GDP ratio. Future work could apply the logarithmic-mean Divisia technique to other ecosystem service intensities. Obvious and timely candidates would include the water quality and CO_2 emission issues.

Future work on the multiplier and principal components analysis should focus on several areas. First, inclusion of imports into the ecological multipliers calculation would improve the accuracy of the multipliers. Second, the analysis should be extended to incorporate a broader range of ecosystem services. Third, it would be useful to conduct a comparative analysis with ecological multipliers in other countries. This would be useful for benchmarking New Zealand's eco-efficiency performance.

9.4 Concluding reflections

As the thesis draws to a close, it remains for the author to make a couple of concluding reflections. In Chapter 2, the thesis proposed ecological economics as an appropriate framework for examining eco-efficiency. This was because the key themes in ecological economic theory all provide important insights into eco-efficiency. At the end of this thesis the author finds no reason to resile from this proposition. Ecological economics has demonstrated its ability to guide and illuminate an analysis of eco-efficiency.

Finally, the thesis has commented in several places that eco-efficiency is a necessary, but not sufficient, strategy for moving towards sustainable development. Other strategies beyond eco-efficiency will be required. Nevertheless, by addressing the four research objectives this thesis has attempted to extend the understanding of eco-efficiency in New Zealand. Having done so, it is hoped that this thesis has helped to enhance policy makers' ability to use eco-efficiency to address the environmental challenges facing New Zealand in the 21^{st} century.

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Appendix 1 – What is an eco-efficiency indicator?

Introduction

The use of eco-efficiency indicators has been mooted as one approach for translating sustainable development goals into tangible measures (OECD, 1998, p. 7; Hukkinen, 2001). In fact, this interest in eco-efficiency indicators is a microcosm of a wider search for indicators of sustainable development. Indicators of sustainable development in general, and eco-efficiency in particular, are called for in several formative documents, including the OECD's (1998) *Eco-efficiency* and UNCED's *Agenda 21* (United Nations Conference on Environment and Development, 1992). For example, Chapter 40 ('Information for Decision Making') of *Agenda 21* poses the challenge "to develop a concept of indicators of sustainable development in order to identify such indicators (of sustainability)" (United Nations Conference on Environment and Development, 1992, paragraph 40.6).

The OECD (1998) advocates eco-efficiency indicators to measure one aspect of sustainable development. For example, the OECD (1998, p. 13) suggests work in a number of areas could support the development of policies to improve eco-efficiency. First among these is "the identification or development of transparent, comprehensive indicators of eco-efficiency as part of a broader set of sustainable development indicators."

The call of the OECD and the UNCED, inter alia, for indicators has led to a new wave of international action in the development of many kinds of indicators (Dahl, 2000). Indicators are now a pervasive feature of all aspects of sustainability policy.

Examples of eco-efficiency indicators developed on this 'new wave' are numerous but tend to focus on business-level eco-efficiency. These indicators include:

- The Roche Eco-efficiency Rate (EER) (Glauser & Muller, 1997). This divides expenditure on environment protection and environmental damage created (DeSimone, Popoff, & World Business Council for Sustainable Development, 2000, p. 202);
- The material, water and energy intensity indices referred to by Hilson (1999) and Metti (1999) for the nonferrous metal mining and food processing sectors respectively;
- The MIPS (material input per unit of service) indicator developed by the Wuppertal Institute (Hinterberger & Stiller, 1998);
- Novo Nordisk's eco-productivity indices (EPI) for raw materials, water, energy and packaging;
- Sony Europe's Resource Productivity Index (RPI);

$$RPI = \frac{(\text{Economic value added}) \times (\text{Product lifetime})}{(\text{Material consumed - recycled}) + (\text{energy consumed} + (\text{lifetime ener y use for production} + \text{recycling}))}$$

- Dow Europe's eco-compass (DeSimone et al., 2000) (see Figure A1-1).

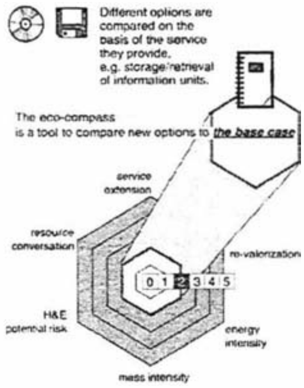

Figure A1-1: Dow Europe's eco-compass

However, the users of these indicators often neglect to address a number of important conceptual issues. In particular, a critical examination is required of:

- the definition of an eco-efficiency indicator;
- the characteristics of ideal eco-efficiency indicators;
- the limitations and strengths of eco-efficiency indicators.

Though not central to the argument of this thesis, these indicator-related issues are important to address because of the prominence of indicators in eco-efficiency literature, and because many of the measures presented in Part II of this thesis could be considered 'indicators' of eco-efficiency. Therefore, this appendix addresses each of these issues in turn.

What is an eco-efficiency indicator?

In order to define the term 'eco-efficiency indicator' it is first necessary to focus on the indicator concept in general.

Current definitions of indicators and the terminology used in this area are particularly confusing (Gallopín, 1997, p. 13). The indicators-related literature is full of sometimes contradicting and obtuse interpretations of what indicators are. For example, Adriaanse (1996, p. 2) defines an indicator as "a quantitative model and a form of information that makes a certain phenomenon perceptible that is not immediately detectable." McQueen and Noak (1988) define an indicator as a measure that summarises information relevant to a particular phenomenon, or a reasonable proxy for such a measure. Holling (1978, p. 106) defines an indicator as "a measure of system behaviour in terms of meaningful and perceptible attributes." These definitions all rest the concept of an indicator on quantification.

In contrast, the definition by Hammond et al (1995, p. 1) does not rely on quantification. They define an indicator as "something that provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable." Indicators imply a model or set of assumptions that relates the indicator to more complex phenomena (Hammond et al., 1995).

A wider survey of environmental indicator literature by Gallopín (1997) shows even more confusion with terminology. An indicator has been defined as a parameter, a statistical measure, a value, a fraction, an index or subindex, a piece of information or a sign. Clearly, there is a need to develop a more rigorous definition of the concept of an indicator that is grounded in theory.

Etymologically, the term 'indicator' traces back to the Latin verb *indicare*, meaning to disclose or point out, show, mention, or make known, or to act as a sign (Simpson & Weiner, 1989; Hammond et al., 1995). The use of the word 'indicator' has a long history in English, although its use in scientific endeavour is relatively recent. Simpson and Weiner (1989) present evidence of early use of the word 'indicator' in English dating back to 1666.

The use of the term 'indicator' in science was first recorded in 1842; "The substance we use as an indicator ..." (Grove 1842 cited in Simpson & Weiner, 1989, p. 861). In the area of environmental investigation, ecologists first used the term indicator in the early 1900s to mean "a group of plants or animals whose presence acts as a sign of particular environmental conditions" (Simpson & Weiner, 1989, p. 861). The term 'indicator' is now in common use in contemporary English language.

As noted above, in its most general sense, an indicator is a sign. In semiotics (the general theory of signs), a sign is defined "as something which stands for something to somebody in some respect or capacity" (Gallopín, 1997, p. 14). An indicator is clearly something that stands for something to someone else. Therefore, an indicator can be considered a particular form of sign.

The semiotics stemming from Pierce[1] provides both a useful classification of signs, and an insight into the core characteristics of those signs (and, therefore, eco-efficiency indicators as a particular form of sign). Clarke (1987) provides a three-tiered framework for classifying signs as shown in Figure A1-2 below.

[1] Semiotics, as defined by Pierce is a branch of logic and philosophy with the aim of "singling out necessary, as opposed to contingent, features of signs interpreted by creatures capable of learning" (Clarke, 1987, p. 25). Thus, the term 'semiotic' is used in this thesis to stand for the discipline delimited by Pierce, with its subject including linguistic and non-linguistic signs.

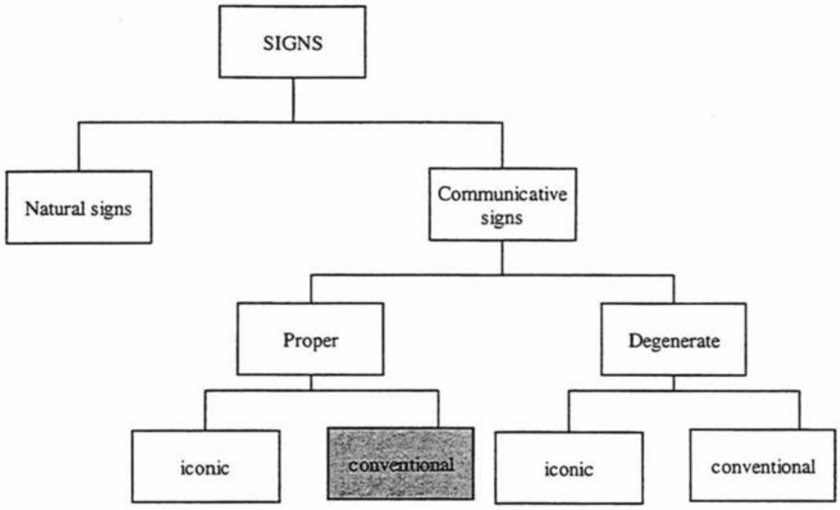

Figure A1-2: Semiotics and signs (Adapted from the classification by Clarke (1987))[2]

This framework is useful for defining eco-efficiency indicators. Eco-efficiency indicators can be considered a particular form of sign that belongs to what Clarke (1987) refers to as 'conventional proper communicative signs'[3] (shaded box in Figure A1-2).

The general group of communicative signs are those that are produced "with communicative intent and interpreted as such by their interpreters" (Clarke, 1987, p. 73). These are compared with what Clarke (1987) refers to as 'natural signs' (those that are not produced with communicative intent). There are several necessary conditions for a communicative sign. A sign X is a communicative sign if and only if[4]:

- X is produced by a communicator C with the intent of producing an effect E on some interpreter I; as
- C intends that I recognise the intention of (1); and
- I recognises this intention, and if E were produced on I, I's recognition of the intention of (2) would be the reason for E.

In other words, condition (1) requires that an effect on some interpreter be intended, and condition (2) adds that this effect be intended by the communicator to be recognised. Condition (3), in turn, requires that an interpreter perceive itself as the intended target of a display and that its response will not be a reflex response to a triggering stimulus (Clarke, 1987, p. 79).

[2] Note that Clarke further analyses the internal structure of communicative signs and breaks down communicative signs into signals and complete sentences. This more detailed discussion is not necessary for the main point of this section.
[3] Clarke uses the term 'comsigns' as an abbreviation of communicative signs. Clarke (1987) argues that 'comsign' is preferable to Grice's (1957) 'utterance' because of the former's more natural application to non-verbal communication (such as indicators).
[4] Note that this is based on the work of Grice (1968).

Degenerate communicative signs satisfy conditions (1) and (2) only. Proper communicative signs on the other hand, satisfy all three conditions. Eco-efficiency indicators can be regarded as a proper communicative signs because, in a normative sense, they satisfy all three conditions; they are produced with communicative intent; this intent is aimed at informing decisions/changing behaviour; they should be aimed at a clearly defined audience.

At the next level, iconic communicative signs are interpreted as representing objects by virtue of a similarity to those objects[5]. In contrast, conventional communicative signs rely on some convention for their interpretation[6]. The need to rely on some convention for interpretation is necessary because many communicative signs are essentially a model or abstraction of reality. Eco-efficiency indicators tend to adhere to both conceptual and scientific convention. Conceptually, eco-efficiency indicators are accepted as quantitative ratios of inputs and useful outputs (see Chapter 4). Scientifically, eco-efficiency indicators are quantified using conventional units such as Joules for energy, tonnes for weight, $ for value, etc.

In summary, drawing on semiotics, eco-efficiency indicators can be defined in abstract as *quantitative conventional proper communicative signs* of eco-efficiency. From a normative perspective, they, therefore, exhibit:

- communicative intent
- the aim of informing decisions/changing behaviour regarding eco-efficiency
- a clear audience definition
- adherence to conventions
- abstractions of the reality of eco-efficiency.

This abstract definition can be used to build an operational definition of eco-efficiency indicators. At an operational level, eco-efficiency indicators require quantification. This is achieved by measuring variables.

In mathematical sciences, the term 'variable' usually refers to some attribute of interest, which takes on different values. More specifically, a variable is "an operational representation of an attribute ... of a system" (Gallopín, 1997, p. 14). To avoid confusion this Appendix will use the

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[5] For example, a person A may perform a jogging motion to indicate that she or he wants B to jog (Clarke, 1987, p. 83).

[6] The classical view of a convention is as an historical agreement reached by decree or stipulation. however, many conventions exist without such agreement. A broader definition of convention is "an existing behavioural regularity based on the expectations and preferences of the members of a community" (Clarke, 1987, p. 85).

term 'ecosystem service[7] input[8] variable' to denote any physical, monetary, chemical or biological quantity intended as a measure of ecosystem service input to the economic system. Also, the term 'artifact services gained' is used to denote any physical, monetary, chemical or biological quantity intended as a measure of 'useful' output from economic processes.

Following from this, and building on the core definition of eco-efficiency outlined in Chapter 4, the term 'eco-efficiency indicator' can be defined as:

> *A measure of the performance of the interaction between the economy and the environment that: a) is quantified as the ratio of ecosystem-service input and artifact services gained variables; b) uses clear scientific and theoretical conventions; c) is produced with communicative intent with the aim of informing the decisions of a clearly defined audience.*

It is important to emphasise a couple of features of this definition. First, eco-efficiency indicators represent an empirical model of reality (or a sign), not reality itself. Indicators achieve this by performing three functions (Adriaanse, 1996):

- *Simplification.* They provide information about complex phenomena in a simple more readily understood form than complex statistics.
- *Quantification.* They quantify information so its significance is more readily apparent.
- *Communication.* Indicators are used to improve communication of the information to the user.

Indicators can be seen as occupying the top rungs of the 'information pyramid' (Figure A1-1), whose base is primary data[9] derived from monitoring (Ministry for the Environment, 1997). Data is increasingly condensed to cater for the needs of different audiences.

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[7] Following Costanza et al (1997) the term 'ecosystem service' is used to cover both ecosystem goods and services (see section 4.6.2).

[8] The term 'input' is used rather than Daly's 'ecosystem services sacrificed' to avoid relying on the economic concept of opportunity cost (though the term 'input' does not preclude one measuring ecosystem services in terms of the 'sacrificed benefit of the best alternative foregone'). In this way, ecosystem 'inputs' can, theoretically, be measured in either monetary *or* physical units. The 'input' term also covers all ecosystem services used as 'inputs' into economic processes, including detoxification and decomposition of waste.

[9] Data are actual measurements (or observations, in the case of qualitative indicators) of the values of the variables at different times, locations etc. A collection of quantitative data is usually referred to as statistics (Gallopín, 1997, p. 15). Analysed statistics provides information.

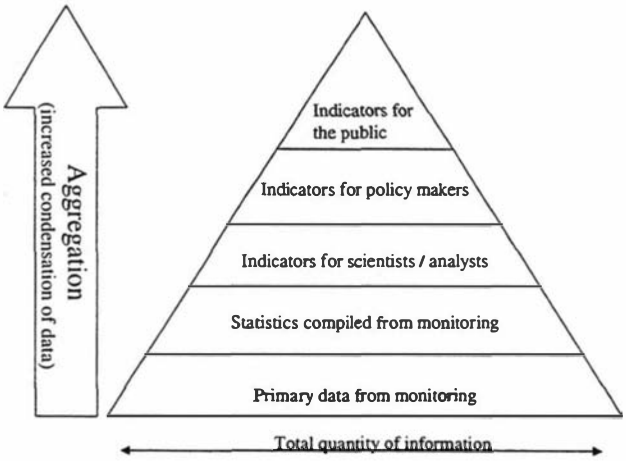

Figure A1-1: The information pyramid

Second, attaching the need for clear scientific and theoretical conventions to the definition of eco-efficiency indicators suggests the indicators must be based on a clear body of theory (Hammond et al., 1995). As was discussed in Chapter 4, eco-efficiency can draw on several bodies of theory. This definition of an eco-efficiency indicator is flexible enough to accommodate all three bodies of theory outlined in Chapter 4.

Third, this definition does not specify which of the input or output[10] variables will be the numerator. This flexibility is important because eco-efficiency indicators can take two forms. Eco-efficiency indicators can be calculated by dividing outputs by inputs ('true' eco-efficiency indicators) or the reciprocal (inputs divided by outputs) commonly referred to as 'intensities.' For example, the quantity of output of a production process divided by water input represents an indicator of the eco-efficiency of water use in production. The reciprocal, water input divided by process output could be referred to as water intensity. This difference is mathematically trivial. Both ratios measure essentially the same thing, and it is only the interpretation that differs[11]. Therefore, both ratios are considered useful indicators of eco-efficiency.

To avoid any further confusion, two other terms used in this thesis are also defined below. Eco-efficiency indicators can be presented individually or can be mathematically aggregated in to form an 'index.' An index is a scalar (a single number) derived from two or more eco-efficiency indicators (Ott, 1978, p. 8). In computing an index, the first step is often to compute the individual indicators, one for each input variable. Therefore, eco-efficiency indicators are also referred to as 'subindices.'

A number of eco-efficiency indicators presented at the same time (but not aggregated together) to give a picture of the state of eco-efficiency conditions is referred to as an 'eco-efficiency

[10] That is, 'artifact services gained.'
[11] Although it does affect the type of appropriate aggregation function (see Chapter 8).

profile.' An eco-efficiency profile is a matrix. The tensions between the use of a profile versus aggregated indices are investigated in Chapter 8.

Characteristics of ideal eco-efficiency indicators

Now that eco-efficiency indicators have been defined, the characteristics of ideal eco-efficiency indicators can be presented. Contemporary indicators literature is replete with discussions on characteristics or criteria for ideal indicators (see for example Gallopín, 1997; Mortensen, 1997; Adriaanse, 1996). Drawing on this literature suggests several ideal characteristics of eco-efficiency indicators. These ideal characteristics can be grouped into theoretical and pragmatic considerations.

Theoretical considerations

a) *Theoretical basis.* Eco-efficiency indicators must be grounded in theory (Mortensen, 1997, p. 48). Grounding indicators in theory is important because it helps the user to map empirical measurements (or indicators) onto their model of reality (Hardi & DeSouza-Huletey, 2000). Grounding in theory also helps to ensure eco-efficiency indicators are measuring the key aspects of the system in question.

Three important bodies of theory that the eco-efficiency indicators can draw on are discussed in Chapter 4. Ecological economics is a particularly important body of theory relevant to eco-efficiency indicators. Ecological economics accounts for the complex interaction between economic activity and the environment using a systems perspective (see Chapters 2 and 5). From a systems perspective, eco-efficiency indicators must account for the complex interlinkages between economic activity and the environment (Gallopín, 1997). As a consequence, eco-efficiency indicators should ideally measure both the direct environmental inputs to economic activity as well as the forward and backward linkages through the economic/environmental systems.

Often, an indicator is used to measure against some target or reference state. In this context, the correct specification of the target is crucial to an indicator's usefulness (Gilbert, 1996). Theory must play an important role in defining meaningful reference conditions.

b) Philosophical bias. Ideal eco-efficiency indicators should be formulated in terms of broad philosophical or ethical frameworks. This issue is particularly pertinent for eco-efficiency indicators as the audiences may include decisions-makers from diverse political and ethical convictions. Non-compliance with this requirement can lead to inappropriate indicators. For example, specifying eco-efficiency indicators solely based on neoclassical economic theory (see section 4.3) is likely to disenfranchise those with ecological interests. As Wright (1991) argues, few indicators are without such bias, which suggests an eco-efficiency profile may be preferable to aggregate indices. Because of the difficulty of removing bias, this criterion should be regarded as an ideal rather than an attainable goal.

c) *Appropriate data transformations.* Ideal eco-efficiency indicators are estimated using a sound methodology that employs appropriate data transformations (Ministry for the Environment, 1997). Raw data is rarely suitable for use as an indicator. That is, raw data nearly always needs to be transformed into a meaningful ratio, index or percentage. These data transformations must be scientifically credible, robust and standardised for the purpose intended. For example, consider an eco-efficiency indicator that is intended for measuring progress towards an eco-efficiency policy target. An appropriate data transformation could involve manipulating based data into an indicator measuring the percentage achievement of that goal.

d) *Analytical validity.* Analytical validity requires that the data transformations must be transparent and well documented (Ministry for the Environment, 1997; Gallopín, 1997). As well as providing users with the ability to determine how indicators have been estimated, transparency also allows others to reproduce the results.

e) *Appropriate scale.* Different indicators may be relevant at different scales and meaningless at other scales. According to Gallopín (1997) hierarchical systems theory shows that "different indicators of systems performance are usually required at different hierarchical levels of systems." In the context of eco-efficiency, this suggests "eco-efficiency indicators must be applied in the right context and at the appropriate scale" (Hukkinen, 2001, p. 313). That is, eco-efficiency indicators selected to measure the performance of a single production process could be different than indicators chosen to measure eco-efficiency at a national level. An ideal eco-efficiency indicator will be one that is chosen at a scale that is relevant to the purpose of inquiry.

f) *Efficient representation of a concept.* Ideal eco-efficiency indicators should convey the maximum possible information about a theoretical concept (Gustavson, Longeran, & Ruitenbeek, 2002). This involves the principle of parsimony – when many indicators are relevant to an aspect of interest, the simplest indicator is preferred over more complex indicators. Several statistical techniques are available for identifying those indicators that convey the most information including principal components analysis.

Pragmatic considerations

In addition to the theoretical considerations, there are a number of pragmatic characteristics of ideal eco-efficiency indicators; policy relevance, cost-effectiveness and clarity of message.

a) *Policy relevance.* The need for indicators (particularly national-level indicators) to be relevant to policy is a common theme throughout the indicators literature (Mortensen, 1997; Adriaanse, 1996; Walz et al., 1996). Gallopín (1997, p. 15) states "the most important feature of indicators compared to other forms of information is relevance to policy and decision-making." An ideal eco-efficiency indicator will be able to evaluate government policy in order to assist decision-makers to monitor progress towards policy objectives.

b) *Data availability and cost-effectiveness.* The eco-efficiency indicator, or set of indicators, must be based on available information and be cost effective (Alfsen & Saebo, 1993; Walz et al., 1996). This issue is often overlooked (Gallopín, 1997) and obviously creates a tension with other ideal characteristics. For example, indicators that are theoretically sound may not necessarily be cost-effective to monitor. From a pragmatic perspective, eco-efficiency indicators that are not cost-effective will not be implemented. Cost-effectiveness is a function of several aspects including data availability, data volume required, calculation complexity and data processing required.

c) Clarity of message. Finally, drawing on semiotics, ideal eco-efficiency indicators must be able to clearly communicate their message to their audience (Alfsen & Saebo, 1993). This requires that the audience must be accurately defined and the best means of communicating to them considered (Ott, 1978, p. 6). Hukkinen (2001, p. 313) suggests that the message of eco-efficiency indicators should be to ensure that "individual actors perceive their everyday activities to be materially grounded in bundles of ecosystem services." In general, eco-efficiency indicators should be easy to understand for the defined audience (Mortensen, 1997). The challenge of developing indicators that are easily understood should not be underestimated (Lindsey, Wittman, & Rummel, 1997).

It is unlikely that any one eco-efficiency indicator will satisfy all of these characteristics. Everyday use of indicators will inevitably involve trade-offs between these characteristics. For example, in pursuit of cost-effective indicators, it may be necessary to compromise on analytical validity or appropriate data transformations. In the final analysis, this list provides a benchmark for the development of high-quality eco-efficiency indicators rather than a list of characteristics that must be strictly adhered to.

A critique of eco-efficiency indicators

Despite the attractive features of ideal eco-efficiency indicators outlined above, indicators do have limitations. Eco-efficiency indicators can be used to reinforce narrow interpretations of eco-efficiency. By codifying eco-efficiency as indicators tied to a particular discipline, there is a tendency to fall into a *pars pro toto* trap; where the part is considered as the whole. That is, there is a tendency to consider only those dimensions of eco-efficiency that have been quantified as indicators. Those dimensions that are not quantified tend to be overlooked and the (implicit) assumption is that those dimensions that are quantified cover all dimensions of eco-efficiency. It is therefore important to constantly remind the user about the potential myopia inherent in using indicators.

Second, 'good' eco-efficiency indicators (and indicators in general) will be based on a strong theoretical foundation. Unfortunately, a lack of a theoretical basis for indicators is common and has led to a situation where "the use of environmental indicators continues to be *ad hoc* and sporadic" (Lindsey et al., 1997, p. 685). Without a strong theoretical context, indicators can miss key features or measure the wrong aspects of the system.

The lack of a theoretical foundation also makes interpretation of indicators difficult. As Waugh (1999, p. 200) points out, care is needed with numbers. "A number on its own (take seven) has no meaning unless it is related to things outside of itself, i.e. seven dogs, seven cats, seven dots, or whatever." That is, all numbers, including eco-efficiency indicators, need to be tied to a context to be meaningful. Theory is essential for mapping eco-efficiency to its relevant contexts.

Also, indicators are unavoidably biased. That is, most eco-efficiency indicators are constructed using information that is readily available, or can be obtained at a reasonable cost (Gallopín, 1997, p. 13). Therefore, it is important to be aware of this potential bias, and take care when interpreting indicators.

Perhaps the most vigorous critique of indicators comes from Bradbury (1996). According to Bradbury (1996), indicators are a legacy of an outmoded paradigm. That is, indicators emerge 'effortlessly' from a simplistic, linear, equilibrial, reductionistic view of the world with its "lust of lists - the desire to organise and codify" (Bradbury, 1996, p. 4). Scientists "fall for their seductive charms, to create a sad Cartesian parody: *indico, ergo sum*" (Bradbury, 1996, p. 2).

> *"Indicators, despite their popularity, are the consequence of an approach to understanding the complexity of the world which is fundamentally and fatally flawed. ... They are wrong, because they take reductionism, itself a suspect method... to a new pathological depth. They seek to reduce, to collapse, the dimensionality of some description of a complex system. ... Like throwing shadows on a wall, they can never capture reality. They remain caricatures" (Bradbury, 1996, p. 5).*

Bradbury (1996, p. 7) concludes by saying "it is time to learn to approach the complexity, the richness of the world with theory, data, models and tools which honour that richness instead of subverting it, which acknowledge that complexity instead of denying it."

Dahl (2000, p. 41) echoes Bradbury's sentiment and suggests that indicators are limited in their ability to assess 'the whole.' It is a characteristic of complex systems that they may show higher-order interactions that are not evident from a knowledge of the parts that are shown by indicators.

Bradbury's critique is itself limited. His argument comes from the point of view of normative 'objective, ideal' science. However, indicators are primarily tools of policy analysis rather than objective science.

The real-world policy process does not follow the normative, 'rational, scientific, comprehensive' approach of Bradbury's model (Etzioni, 1967; Dye, 1981; Ham & Hill, 1984). As Train (1972, p. 121) states:

> *"Policy-making neither can nor should become totally 'scientific.' Vital decisions will always depend ultimately on the values we hold and on the way we express these values through the political system. But we must strive to make maximum use of the scientific evidence available to us, and the development of environmental indices is one important way of doing this."*

The rational policy model suggests perfect information and a logical process of defining goals, identifying alternatives, conducting benefit-cost analysis, decision-making, implementation and evaluation (Dye, 1981). In contrast, actual policy development is commonly disjointed and incremental, can involve mixed scanning[12] (Etzioni, 1967) and is more akin to 'muddling through' (Lindblom, 1959). In this context of imperfect information and limited resources, often a reductionistic approach is all that can be achieved. From a pragmatic perspective, indicators are a practical tool for informing 'messy' policy debates.

Furthermore, it is possible to reduce the 'indicators myopia' of the *pars pro toto* problem by acknowledging that indicators are not sufficient on their own for managing eco-efficiency. As Ott (1978, p. 3) states about environmental indicators in general: "environmental indices, of course, are not the only source of information that is bought to bear on environmental decisions. Decision-making will be based on many other considerations besides indices and the monitoring data on which they are based."

Indicators have an important place in an ecological economics milieu. Eco-efficiency indicators are one of a range of useful analytical tools useful for addressing complex problems. In particular, eco-efficiency indicators are useful in this context because:

- in the presence of such complex problems it is often not possible to develop reliable, comprehensive models of eco-efficiency because of the lack of knowledge of many parts of the system. Instead, one must rely on more piece-meal information such as departure from

[12] A view of the policy development process that combines Lindblom's disjointed incrementalism and the rational policy process. It acknowledges that the important issues can proceed in a rational, linear way, while lower-priority policies usually proceed in an incremental fashion.

benchmarks or time series of key variables over time (Cartwright, 1975). Indicators are particularly suited to this measurement;

- they can accommodate an open system of information. That is, they are flexible and can accommodate new information as it becomes available;
- they can accommodate the 'less-than-comprehensive analysis' aspects of difficult problems by tracking those aspects of the system that are amenable to measurement. For example, as was shown in Chapter 7, relatively reliable data is available on some ecosystem service inputs (such as energy consumption, water abstraction and water discharges) but not for others (such as biodiversity or climate regulation).
- they can potentially provide information useful for understanding the complex interactions of a system.

The use of indicators is also consistent with ecological economics' pragmatic approach. Rather than being overwhelmed by the dynamic and uncertain nature of economic-environmental interactions, ecological economics suggests that action must be taken on a case-by-case basis (see Chapter 2). Indicators are an important tool for informing such a pragmatic approach.

Eco-efficiency indicators are, therefore, one way of analysing those parts of the 'messy' problem of managing New Zealand's eco-efficiency that are amenable to analysis. The caveat of course is that eco-efficiency indicators must be created carefully to account for the critical dimensions of the system of interest. They must also be used carefully as one of several simultaneous views of a system. If this is followed, eco-efficiency indicators may help rather than hinder our understanding of eco-efficiency in New Zealand.

One might conclude this discussion of indicators by citing the famous actor Maurice Chevalier. Upon being asked about the fate of being old, he replied it was so much better than the alternative! (Doelman, 1976). This conclusion goes without saying. Indicators, with all of their limitations, are bound to prepare the ground for decision making so much better than its alternative of relatively uniformed action.

Appendix 2 – Data used in the decomposition analysis

The data used for this analysis were drawn from two sources: the economic data are produces by Statistics New Zealand, and the energy data came from the Ministry of Economic Development. GDP data are measured in New Zealand dollars at constant 1991/92 prices. The GDP data were aggregated to conform to the Ministry of Commerce sectoral aggregation standards. The sectoral aggregation used in this analysis and the ANZSIC groups are shown in the table below.

Table A2- 1: Sectoral aggregation used in the decomposition analysis in Chapter 6

Sector heading for energy analysis	NZSIC group
Agriculture, hunting and fishing	1+2
Other primary	3+4
Food, Beverages and Tobacco	5
Textiles	6
Wood, pulp paper & printing	7+8
Chemicals	9
Non-metallic mineral products	10
Basic metals	11
Building and construction	15
Non-specified	12+13+14
Total Commercial	16+18+19+21+24+25+22+23
Total Transport	17
Residential	20

Appendix 3 – Assumptions behind the Energy Quality Coefficients

The following outlines the assumptions behind the calculation of the energy quality coefficients mentioned in Chapter 6.

Delivered **electricity** to:

Light: Increased efficiency of 1% per annum from 1987 to present to allow for introduction of new generation compact fluorescent lamps and 26mm tubes.

Electronics: Increased efficiency of 2% per annum from 1987 to present to account for vast improvements in computer technology.

***Cooking*:** Increased efficiency due to microwave ovens (2% per annum increase from 1987 to 1989 and 3% per annum to 1997).

***Pumping*:** Increased efficiency at 0.5% per annum from 1987 to account for general technological improvement.

Reduction of aluminium oxides: Increased efficiency at 0.5% per annum to account for general technological improvement.

***Refrigeration*:** Increased efficiency at 0.5% per annum from to account for general technological improvement.

***Space heating*:** Increased efficiency at 0.5% per annum from 1987 to 1990 to account for increased use of heating ventilation and air conditioning (HVAC) units.

***Stationary motive power*:** Increased efficiency at 0.5% per annum to account for general technological improvement.

***Water Heating*:** Energy efficiency improves at 1% per annum from 1991 to present due to penetration of A-grade cylinders.

Delivered **gas** to:

***Land transport*:** Increased by 0.5% per annum from 1987 to 1990 to account for major energy efficiency improvements in gas vehicles.

***Process heat*:** Increased efficiency at 1% per annum from 1987 to 1990 to account for general technological improvement.

***Water heating*:** Increased efficiency at 0.5% per annum from 1990 to account for general technological improvement.

Delivered **geothermal** to:

***Process heat*:** Increased efficiency at 1% per annum from 1987 to account for energy efficiency promoted by increasing scarcity of geothermal energy.

Delivered **oil** to:

***Land transport*:** Increased efficiency at 1% per annum to account for general technological improvement in vehicle fleet.

Rail transport: Increased efficiency at 0.5% per annum from 1990 to account for general technological improvement doe to new locomotive purchases.

Delivered **wood** to:

***Process heat*:** Increased efficiency at 0.5% per annum to account for general technological improvement.

***Domestic space heating*:** Increased efficiency by 7% per annum from 1991 to account for instillation of slow-burning wood heaters.

Appendix 4: A description of input-output matrices and mathematics

4.1 Structure and mathematics of input-output matrices

An input-output (IO) matrix is both a descriptive framework and an analytical tool. An IO matrix describes the relationships between sectors for a given period. These relationships are established by a representation in which one sector's outputs are the inputs to other sectors (Duchin, 1996, p. 290).

Originally, the IO table provided an analytical tool for measuring the impact of autonomous disturbances on an economy's output and income. Indeed, one of the main analytical purposes of conventional IO analysis was to determine the effects of specified changes in final demand (which is regarded as autonomous) upon gross output, given the direct-input coefficients matrix[13].

Conventionally, an IO table is presented as a matrix. Each sector in the economy is assigned a row and a column. Each cell in the table represents the flow of goods from the row sector to the column sector. Thus, the element x_{ij} in row i column j indicates the volume of goods sold from (or outputs of) sector i as inputs to sector j. For instance, row 1 in the table below shows the sales of sector 1 to all other sectors (intermediate demand) and to consumption, private investment, government spending and exports (final demand). Conversely, column 1 indicates the purchasing pattern of sector 1 from all other sectors (intermediate inputs) and primary inputs (labour, capital etc), which are value, added entries taking the form of wages, profit, depreciation, interest and taxes, and from imports.

IO analysis describes the interaction of three elements of an economic system: the input requirements of each sector (intermediate demand and primary inputs), final demand and gross output. The design of a standard IO matrix reflects these elements by dividing the economic structure of the economy into quadrants (see Figure A4-1). Vertically the matrix is divided into the inputs into the production process of the productive industries, and the sales to the final demand sectors. Horizontally, each part may the further subdivided into two sections so as to distinguish between intermediate inputs and primary inputs.

[13] However, aspects of final demand could be endogenised, in which case, these aspects of final demand would no longer be autonomous.

	Sector 1	... Sector j ...	Sector n	Sub Total	Household	Govt Expenditure	Other Final Demand	Exports	Sub Total	Total Gross Output
Sector 1	x_{11}	x_{1j}	x_{1n}		C_1	G_1	I_1	E_1		X_1
⋮ Sector i ⋮	⋮	**Quadrant 1**	⋮		⋮	**Quadrant 2**		⋮		⋮ X_i ⋮
Sector n	x_{n1}	x_{nj}	x_{nn}		C_n	G_n	I_n	E_n		X_n
Subtotal										
Labour	L_1 ...	L_j ...	L_n		L_c	L_g	L_I	L_E		L
Other value added	V_1	... **Quadrant 3** ...	V_n		V_c	**Quadrant 4**		V_E		V
Imports	M_1 ...	M_j ...	M_n		M_c	M_g	M_I	M_E		M
Sub Total										
Total Gross Input	X_1 ...	X_j ...	X_n		C	G	I	E		X

Figure A4-1: A simplified input-output matrix

Quadrant 1 is commonly referred to as the intermediate or inter-industry demand quadrant (Leontief, 1986, p. 23). This quadrant depicts the flows of commodities produced and used in the intermediate stages of production. In a standard Leontief IO table, Quadrant 1 is a square matrix with the same number of rows and columns. An important characteristic of this matrix is that the total value of output of each intermediate sector must always equal its total expenditure on inputs.

The matrix of intermediate demand sectors by final demand (Quadrant 2) records the delivery of the products of each sector to the various types of final demand. As such, this quadrant describes consumer behaviour in a number of important markets. Quadrant 2 is of special importance because it is regarded as autonomous, from which changes occur that are transmitted throughout the rest of the model (Miernyk, 1965, p. 13; Schaffer, 1976).

The matrix of primary input sectors by intermediate demand sectors (Quadrant 3) shows the contribution to intermediate production of primary inputs, which (excluding imports) correspond to the national accounting concept of value added. These inputs are described as 'primary' because they do not form part of the output as defined by rows forming quadrants 1 and 2. The total of the primary inputs for each sector less imports represents the value added to commodities consumed in the production process.

Quadrant 4 describes the primary inputs that are used directly by final demand sectors.

As will be discussed below, one of the strengths of IO matrices is that they allow several consistency checks. Two accounting identities that are particularly important are calculated by summing across the rows and down the columns. Summing across row 1[14]:

[14] Row 1 is used for demonstration purposes. This accounting identity can be applied to all sectors in the transaction matrix (Quadrant 1).

$$X_1=\sum_{1}^{n} x_{1j} + (C_1+G_1+I_1+E_1)$$ **Equation A4-1**[15]

Where:

X_1 = total gross output from row 1

$\sum_{1}^{n} x_{1j}$ = sum of sales of sector 1 to all sectors

C_1 = household consumption of sector 1 goods
G_1 = government consumption of sector 1 goods
I_1 = other final demand of sector 1 goods
E_1 = exports of sector one goods
n = number of sectors.

A frequent convention with IO matrices is to aggregate the final demand components into a single vector, $Y_1=(C_1+I_1+G_1+E_1)$ (Ferrer & Ayres, 2000, p. 21), and, therefore:

$$X_1=\sum_{1}^{n} x_{1j} + Y_1$$ **Equation A4-2**

Where Y_1 = final demand for sector 1 goods.

In other words, Equation A4-2 shows that gross output (X_1)= intermediate demand ($\sum_{1}^{n} x_{1j}$) + final demand (Y_1).

Also, summing down column 1[16]:

$$X_1=\sum_{1}^{n} x_{i1} + (L_1+V_1+M_1)$$ **Equation A4-3**

Where:

$\sum_{1}^{n} x_{i1}$ = sum of purchases (inputs) by sector 1 from all sectors

L_1 = labour inputs to sector 1
V_1 = other value added inputs to sector 1
M_1 = imports to sector 1.

---

[15] The algebra used throughout this thesis uses the following conventions: matrices are in upper case boldface letters (e.g. **X**). Vectors are represented by lower case boldface letters (e.g. **x**) and the matrix and vector elements are designated by lower case italic letters with the appropriate subscripts (e.g. x_{ij}).
[16] Column 1 is used for demonstration purposes. This accounting identity can be applied to all sectors in the transaction matrix (Quadrant 1).

However, since the value of inputs to sectors must equal outputs, total gross input to a sector must equal total gross output. Hence, X_1 (column total) equals X_1 (row total). A similar accounting identity can be shown for the economy as a whole (Ferrer & Ayres, 2000, p. 20).

Direct-input coefficients and direct effects

From an IO matrix, direct-input (or technical) coefficients (a_{ij}) can be estimated. Direct-input coefficients show "the amount of inputs required from each sector to produce one dollar's worth of the output of a given sector" (Miernyk, 1965, p. 21). For example, from appendix 1.1.2 it can be seen that, in 1994/95, the sheep, beef & mixed livestock sector requires approximately \$0.09 worth of inputs directly from the Dairy sector per \$1 of output.

A direct-input coefficient a_{11} is calculated as:

$$a_{11} = \frac{x_{11}}{X_1}$$
$$x_{11} = a_{11} X_1$$

Equation A4-4

Repeating the calculation in Equation A4-4 for all a_{ij} and substituting Equation A4-4 into Equation A4-2 gives

$$X_1 = a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + \ldots a_{1n}X_n + Y_1$$

Equation A4-5

A complete set of input coefficients of all sectors of a given economy arranged in the form of a square table is called the direct-input coefficient (or **A**) matrix of that economy (Leontief, 1986, p. 22).

4.2 Calculating system-wide effects using multipliers from input-output matrices

It is important to note that the direct-input coefficients **A** matrix only shows the *direct* purchases that will be made by a given sector from all other sectors within Quadrant 1 for each dollar's worth of current output. It does not represent the *total* addition to output resulting from additional sales to final demand. An increase in the final demand for the products of a sector will lead to both direct and indirect increases in the output of all sectors in Quadrant 1.

One of the main analytical purposes of conventional IO analysis is to determine the total effects of specified changes in final demand upon gross output, given the direct-input coefficients matrix. The multipliers in the inverse Leontief matrix capture these direct and indirect (or multiplier) effects (Bicknell, Ball, Cullen, & Bigsby, 1998). To capture the flow on effects in the IO system, Equation A4-5 for row 1 can be rewritten as:

$$X_1 - \sum_{1}^{n} a_{1j}X_{1j} = Y_1$$ **Equation A4-6**

The entire set of equations for all rows in quadrant 1 can expressed in a matrix form:

$$\mathbf{x} - \mathbf{Ax} = \mathbf{y}$$ **Equation A4-7**

Where:

x = $n \times 1$ vector of total gross output

A = $n \times n$ matrix of direct-input coefficients

y = $n \times 1$ vector of total final demand.

Calculation of the multipliers (total addition[17] to output) resulting from additional sales to the final demand sector, requires calculation of the inverse Leontief matrix. Initially this involves taking the difference between an identity matrix **I** and the direct-input coefficients matrix (see Equation A4-8). Thus Equation A4-7 becomes:

$$\mathbf{(I-A)x} = \mathbf{y}$$ **Equation A4-8**

Where **I** is an $n \times n$ identity matrix and **(I-A)** is the Leontief matrix of order $n \times n$.

Under the condition that **(I-A)** has an inverse[18] the inverse Leontief matrix can be used to express gross output as a function of (exogenous) final demand (Miernyk, 1965; Richardson, 1972):

$$\mathbf{x} = \mathbf{(I-A)}^{-1}\mathbf{y}$$ **Equation A4-9**

Where $\mathbf{(I-A)}^{-1}$ is the inverse Leontief matrix[19].

The inverse Leontief matrix[20] shows the "total dollar production directly and indirectly required from the industry at the top (of the table) for each dollar of delivery to final demand by the

[17] That is, the first, second, third and higher-order flow on requirements.

[18] In practical circumstances this condition will be met if the **y** vector contains at least one non-zero element.

[19] Essentially, the $\mathbf{(I-A)}^{-1}$ matrix captures the direct and second, third-level and so on requirements of commodity production. It can be shown that $\mathbf{(I-A)}^{-1} = \mathbf{I+A+A^2+A^3+} \ldots$
where **I** gives the direct effect and $\mathbf{A+A^2+A^3+} \ldots \mathbf{A^n+} \ldots$ gives the second, third, etc order indirect effects. The proof of this equation is as follows. Multiply each side by the Leontief matrix **(I-A)**.

$$
\begin{aligned}
(I-A)(I-A)^{-1} &= [I+A+A^2+A^3+\ldots](I-A) \\
I &= I(I-A)+A(I-A)+A^2(I-A)+A^3(I-A)+\ldots \\
&= I^2-AI+AI-A^2+A^2I-A^3+A^3I-\ldots \\
I &= I
\end{aligned}
$$

[20] There is a fundamental condition that must be met by the inverse Leontief matrix. This condition is known as the "Hawkins-Simon condition." Basically, this condition states that *there can be no negative entries in the table of direct and indirect requirements* (Miernyk, 1965 p. 27). What would a negative value mean? In essence, it would mean that each time the sector with a negative entry expanded its sales to final demand, its direct and indirect input requirements would decline (an economic absurdity).

industry at the left (of the table)" (comments in brackets added, Miernyk, 1965, p. 26). The elements of the inverse Leontief matrix are referred to as multipliers and are expressed in dollars per dollar. In this way, the inverse Leontief matrix maps the economic system-wide requirements to meet one dollar of final demand in a sector.

Appendix 5 – Details of input-output data and calculations used in estimating ecological multipliers

5.1 Economic input-output matrices

5.1.1 48 sector input-output matrices

	A	B	C	D	E	F	G	H	I	J	K	L
1	**1994-95 New Zealand Input-Output Matrix (48 sector transaction matrix)**											
2		Nominal dollars										
3			1	2	3	4	5	6	7	8	9	10
4			Mixed livestock	Dairy farming	Horticulture	Services to Agriculture	All other farming	Fishing and Hunting	Forestry & Logging	Oil and Gas Exploration	Other mining	Meat Products
5		***Intermediate Inputs***										
6		1 Mixed livestock	479,158,520	268,402,000	16,076,232	1,852,083	62,874,990	81,770	4,941,666	14,652	22,835	1,793,917,920
7		2 Dairy farming	82,059,500	50,511,700	8,144,260	7,208,821	13,402,700	50,876	1,123,038	7,990	11,873	206,194,390
8		3 Horticulture	18,998,860	10,421,530	26,613,290	8,700,463	4,440,721	78,459	927,727	13,625	23,772	11,014,658
9		4 Services to Agriculture	262,867,130	97,248,395	180,709,940	18,995,342	43,879,641	892,474	13,500,424	0	0	1,497,658
10		5 All other farming	72,935,250	30,483,800	6,619,833	1,035,342	103,808,000	37,657	2,127,182	6,606	10,299	235,719,100
11		6 Fishing and Hunting	7,872,548	1,920,352	1,935,713	3,958,926	5,479,012	147,526	13,415	8,736	9,132	348,794
12		7 Forestry & Logging	1,584,963	580,551	1,000,280	1,038,136	732,182	10,257	880,689,075	15,964	41,010	1,012,967
13		8 Oil and Gas Exploration	258,702	210,240	55,142	553	27,871	2,449	14,261	178,766,767	123,607	100
14		9 Other mining	3,042,701	1,956,964	1,138,820	1,354,118	451,810	33,923	7,025,881	18,039,829	30,838,936	13,293,033
15		10 Meat Products	2,096,530	2,887,441	363,727	546,783	7,276,720	307,975	1,126,120	113,000	131,319	940,233,030
16		11 Dairy Products	938,309	520,516	240,412	259,131	192,340	70,848	350,476	61,414	173,332	1,504,291
17		12 Manufacture of other food	10,004,545	37,528,151	618,887	1,332,184	17,891,919	4,309,207	7,733,150	314,372	213,549	34,381,528
18		13 Beverage Manufacture	187,666	298,251	42,909	96,383	211,598	36,567	88,569	9,618	26,999	572,247
19		14 Textile Manufacture	15,912,363	2,295,126	2,216,891	3,324,068	498,646	6,403,023	736,685	115,231	534,418	15,498,928
20		15 Wood & Wood Products	4,737,835	1,722,726	18,784,159	406,126	268,241	194,043	2,520,140	141,432	1,072,128	5,248,165
21		16 Paper Manufacturing	406,607	144,101	46,849,993	8,957,774	345,649	839,718	1,399,561	385,232	1,450,188	69,516,952
22		17 Printing & Publishing	1,022,712	209,296	8,741,370	2,046,547	85,909	643,502	1,544,881	352,106	1,762,762	41,880,400
23		18 Other Chemicals	22,250,223	29,712,799	16,394,096	4,666,634	2,503,998	1,351,069	6,041,112	631,191	6,000,307	97,766,517
24		19 Basic Chemicals	255,168,315	182,571,391	94,706,776	30,765,100	38,426,818	6,408,338	52,171,076	2,044,960	13,604,984	30,634,214
25		20 Non-metallic Minerals	286,514	190,536	2,168,770	5,404,767	100,564	95,826	247,358	397,435	498,557	1,141,609
26		21 Basic Metal Industries	192,944	152,062	37,495	30,042	26,398	114,000	39,319	10,285	356,096	194,715
27		22 Fabricated Metals	42,562,594	40,641,740	3,866,055	4,585,217	4,358,689	2,722,661	8,840,307	3,140,015	11,526,292	15,190,206
28		23 Equipment Manufacture	2,390,941	2,587,708	1,200,868	6,565,538	405,608	2,373,892	16,689,864	2,071,947	21,563,799	33,457,405
29		24 Transport Equipment	1,107,280	1,041,012	446,828	963,397	181,925	14,295,300	313,424	41,234	312,986	843,050
30		25 Other Manufacturing	317,461	181,241	156,359	77,262	23,911	36,048	99,589	20,599	61,005	985,896
31		26 Electricity Generation &	24,539,150	43,638,800	8,343,070	2,520,074	5,137,130	424,513	1,736,382	1,580,373	18,523,190	63,658,750
32		27 Gas Treatment & Distributioı	188,070	75,474	229,757	85,990	35,861	67,811	222,590	69,009	95,642	9,115,068
33		28 Water works	7,940	11,169	4,563	43,569	2,457	4,365	18,750	272	58,462	40,440,270
34		29 Construction	196,977,142	101,955,190	52,656,184	9,700,536	19,748,776	2,120,741	8,922,626	10,678,041	50,980,001	49,141,055
35		30 Trade	207,438,400	123,584,000	62,875,900	28,863,170	37,676,100	14,106,677	46,652,611	3,796,168	32,828,110	291,260,700
36		31 Accommodation	9,856,279	2,811,070	1,284,109	3,329,955	1,961,361	1,556,938	1,754,321	459,620	5,192,417	15,597,787
37		32 Road Transport	125,474,305	18,271,700	16,418,108	6,979,426	9,380,016	6,105,779	120,259,267	16,818,605	45,104,128	106,431,282
38		33 Services to Transport	15,767,203	10,829,692	3,763,079	3,521,854	3,881,382	2,147,937	27,390,994	5,537,515	5,764,531	49,225,675
39		34 Water Transport	2,937,099	1,452,070	4,409,828	156,977	2,311,328	166,123,703	1,522,882	2,115,305	4,010,603	16,691,228
40		35 Air Transport	1,326,519	1,025,827	1,472,174	1,195,337	949,227	997,884	2,174,446	465,966	1,368,206	9,317,745
41		36 Communications	20,537,380	10,961,100	7,335,820	3,653,824	6,071,730	1,360,634	5,252,869	1,523,751	5,467,250	42,530,000
42		37 Finance	88,848,120	73,196,400	36,500,680	17,785,775	22,152,120	10,887,280	46,592,277	21,416,527	10,121,319	114,962,420

	A B	C	D	E	F	G	H	I	J	K	L
43	38 Finance services	173,277	2,779,799	513,701	1,595,971	1,465,261	66,718	149,622	94,282	87,502	5,220,797
44	39 Insurance	16,860,762	10,327,982	3,827,800	2,265,314	3,458,082	1,805,178	2,492,748	2,874,828	1,091,705	11,362,924
45	40 Real Estate	39,457,236	55,113,810	20,971,754	516,550	12,013,020	439,790	3,332,734	638,172	958,106	40,272,145
46	41 Business Services	80,592,040	21,314,060	29,893,614	42,974,841	21,508,340	12,136,054	38,072,178	38,792,865	28,003,248	225,123,047
47	42 Dwelling ownership	0	0	0	0	0	0	0	0	0	0
48	43 Education	1,837,103	1,160,088	276,286	108,964	348,659	9,114	39,841	25,823	71,020	1,940,680
49	44 Community Services	6,083,471	5,465,782	403,596	126,597	1,392,443	43,264	193,799	61,812	375,881	1,115,481
50	45 Recreation Services	10,474,273	21,014,552	11,173,084	767,417	7,556,853	282,147	450,131	254,839	256,757	24,226,363
51	46 Personal Services	70,424,653	82,410,034	26,709,635	3,696,996	11,355,773	974,035	13,060,875	1,126,853	2,959,846	17,345,831
52	47 Central Government	5,854,864	6,076,370	2,375,274	630,333	2,056,180	416,999	1,426,352	1,002,937	2,208,269	8,763,487
53	48 Local Government	2,074,127	824,791	715,678	941,480	1,678,010	101,948	763,041	22,907	32,259	944,248
54	*Total*	2,216,090,426	1,358,719,387	731,282,798	245,631,687	480,035,967	263,716,915	1,332,785,634	316,080,712	305,928,638	4,696,734,757
55											
56	49 Compensation of Employees	296,705,300	193,845,000	281,320,700	179,075,400	62,091,500	55,880,300	167,922,950	68,947,110	130,074,300	782,583,300
57	50 Operating Surplus	944,337,000	1,018,220,000	307,867,700	163,636,600	235,069,000	157,731,450	1,033,502,670	356,212,500	129,379,600	77,563,300
58	51 Commodity Indirect Taxes	62,137,860	33,260,900	11,556,650	8,791,150	7,312,830	6,005,960	22,216,336	15,631,792	12,526,080	20,292,280
59	52 Non-Commodity Indirect Ta›	162,924,000	77,719,400	32,428,100	9,568,120	17,914,300	18,000,426	17,352,077	8,172,000	13,398,300	14,682,170
60	53 Commodity Subsidies	-1,028,200	-976,500	0	0	0	-100	0	0	0	-200
61	54 Non-Commodity Subsidies	-3,741,800	-3,049,500	-4,383,000	-3,354,900	-1,132,000	-5,050,400	-4,575,800	0	0	-4,917,100
62	55 Consumption of Fixed Capita	267,484,600	189,265,000	106,629,400	50,208,490	60,122,200	45,772,087	35,787,486	176,810,060	74,573,900	98,981,500
63	56 Second Hand Assets	0	0	0	0	0	0	0	0	0	0
64	57 Interregional Imports	0	0	0	0	0	0	0	0	0	0
65	58 International Imports	204,731,969	145,195,180	86,165,390	48,686,626	61,088,560	159,190,223	68,709,955	19,389,388	63,690,524	325,075,784
66	*Total primary inputs*	1,933,550,729	1,653,479,480	821,584,940	456,611,486	442,466,390	437,529,946	1,340,915,674	645,162,850	423,642,704	1,314,261,034
67	***Total***	4,149,641,155	3,012,198,867	1,552,867,738	702,243,173	922,502,357	701,246,861	2,673,701,309	961,243,562	729,571,342	6,010,995,791

	M	N	O	P	Q	R	S	T	U	V	W	X
1												
2												
3	11	12	13	14	15	16	17	18	19	20	21	22
4	Dairy Products	Manufacture of other food	Beverage Manufacture	Textile Manufacture	Wood & Wood Products	Paper Manufacturing	Printing & Publishing	Other Chemicals	Basic Chemicals	Non-metallic Minerals	Basic Metal Industries	Fabricated Metals
5												
6	78,321,318	65,618,678	14,983,325	766,457,199	3,410,007	1,221,709	599,828	5,695,295	332,936	290,349	97,772	948,260
7	2,261,408,500	19,722,209	5,719,999	75,787,225	893,388	294,790	323,109	1,488,140	159,347	162,483	69,357	512,490
8	6,518,959	126,565,733	63,665,809	4,516,059	1,166,905	238,275	276,612	491,979	206,050	181,442	41,751	429,216
9	1,008,284	615,546	243,854	1,034,383	44,155	15,093	0	20,628	96	101	0	0
10	21,007,002	141,038,706	29,179,595	24,859,211	1,259,388	442,794	235,142	11,411,437	138,622	113,098	37,712	369,396
11	9,435	431,808,685	64,098	3,502,275	25,354	28,914	28,912	892,086	28,994	19,169	9,471	34,796
12	2,728,186	594,845	138,443	79,412	485,703,417	186,824,613	70,290	188,658	81,110	37,302	29,346	65,464
13	0	0	0	0	36,862	0	631	0	315,349,713	0	0	0
14	18,338,505	4,270,672	1,203,955	1,680,717	651,212	546,204	234,812	6,022,950	110,865,548	131,539,552	111,807,622	1,735,646
15	5,637,797	86,344,863	3,148,527	143,176,197	1,892,191	960,879	509,226	2,730,297	15,713,708	365,281	270,626	1,029,611
16	100,738,399	32,010,502	3,159,104	799,573	912,032	650,943	400,357	1,779,967	1,025,134	343,264	318,909	580,372
17	134,018,006	608,457,438	49,029,313	3,605,013	2,062,510	1,554,273	688,962	10,369,660	3,883,000	523,200	217,355	3,726,965
18	879,686	4,203,479	81,071,289	175,891	218,284	132,252	74,593	181,962	244,673	63,167	60,494	131,958
19	1,153,881	19,822,098	9,771,755	953,527,965	39,218,446	3,432,453	2,504,955	10,175,121	6,944,563	1,573,323	1,492,567	10,019,516
20	6,096,488	6,299,125	4,952,041	4,134,105	603,031,061	49,481,451	9,353,031	9,776,415	4,004,200	10,666,719	3,026,663	35,259,493
21	46,959,780	82,790,403	33,403,087	19,849,480	43,251,615	452,387,090	285,239,800	47,452,738	15,639,941	16,791,692	2,644,763	14,705,811
22	54,282,070	41,589,468	16,011,190	6,524,805	8,170,004	72,428,500	309,748,000	20,523,628	4,662,486	5,456,827	519,220	11,427,791
23	56,570,697	90,731,688	33,903,104	39,935,288	43,374,625	25,087,048	52,713,288	145,689,062	46,868,270	8,935,380	3,511,522	39,947,344
24	28,147,639	31,071,944	14,487,863	40,332,802	57,162,958	29,344,857	8,882,100	230,443,507	467,620,999	17,829,286	27,291,534	21,118,501
25	16,329,762	15,775,052	67,672,804	432,339	18,693,122	404,214	145,640	5,705,098	3,671,294	198,311,210	2,350,876	23,015,303
26	98,899	324,915	286,212	812,005	3,476,074	1,339,733	747,232	2,542,449	6,620,066	3,232,436	111,786,110	208,501,720
27	13,797,992	46,928,507	39,589,610	4,619,104	76,029,825	7,382,998	2,932,093	30,487,398	6,391,653	26,364,483	34,113,308	206,257,403
28	23,363,454	27,079,825	5,226,062	10,419,708	29,834,737	45,002,265	8,401,177	9,047,212	18,179,434	9,848,832	11,313,660	39,487,244
29	725,585	1,313,046	1,007,307	343,141	2,731,570	787,444	211,889	766,949	482,172	1,217,213	1,685,145	3,869,072
30	536,337	870,350	478,998	7,857,417	487,659	201,688	4,315,693	710,236	237,857	298,865	56,054	480,380
31	28,308,560	37,238,280	7,359,853	20,095,635	50,174,185	132,274,800	10,918,200	21,871,197	27,185,819	20,503,518	198,281,000	21,065,250
32	39,548,550	10,334,189	2,305,056	3,917,416	1,327,162	31,401,171	1,290,630	1,449,230	41,865,102	6,114,069	10,969,210	5,475,883
33	5,577,448	12,847,478	7,853,410	6,903,813	990,141	15,622,569	7,095	1,958,761	2,872,825	6,099,618	926,122	2,923,858
34	13,803,775	37,600,050	4,924,325	33,469,015	68,978,276	8,510,300	12,041,353	23,505,608	55,304,544	60,413,239	44,682,498	22,144,415
35	106,508,630	275,012,200	206,346,200	204,798,534	215,327,970	120,518,400	72,972,100	158,203,290	307,049,300	85,367,360	169,320,200	273,967,100
36	10,923,627	17,781,245	10,890,992	12,030,680	18,006,437	12,051,908	11,395,570	18,587,142	9,538,231	6,260,696	6,809,005	13,698,334
37	95,500,639	131,896,061	39,502,775	33.272,535	109,598,263	94,723,125	48,670,260	46,223,345	26,560,670	27,509,356	11,851,133	38,863,276
38	26,635,987	33,647,185	13,771,893	12,013,915	45,336,939	28,344,020	8,098,049	21,592,087	7,566,196	12,747,821	10,185,736	25,288,000
39	22,016,664	67,177,210	3,537,595	8,287,784	17,305,777	66,116,383	5,237,442	11,301,971	15,588,402	14,177,966	13,818,073	8,986,392
40	3,358,641	8,707,882	2,500,055	7,584,102	7,999,604	9,894,668	4,166,067	6,933,805	2,509,099	2,348,496	1,701,844	5,916,121
41	17,406,340	36,374,025	11,141,880	27,388,207	30,553,426	14,776,600	45,680,800	25,099,600	11,253,591	9,880,495	5,923,110	26,504,490
42	95,018,611	155,888,997	58,367,777	88,435,502	85,480,896	83,414,870	75,225,100	97,416,953	56,940,802	34,566,624	39,199,300	90,726,919

	M	N	O	P	Q	R	S	T	U	V	W	X
43	852,368	13,313,460	1,114,264	1,591,582	1,065,501	4,969,188	4,726,970	9,757,947	4,675,089	337,431	33,566	5,825,447
44	4,969,260	8,182,568	1,588,816	4,648,083	8,478,217	6,271,112	5,188,457	5,544,750	6,111,948	2,625,839	2,115,786	5,040,287
45	5,527,578	19,850,467	3,259,169	30,289,124	35,482,977	11,422,857	26,297,030	28,890,660	11,331,481	11,562,036	4,973,735	36,787,628
46	48,464,818	124,273,901	26,345,109	88,474,943	79,666,871	3,710,026	109,291,979	127,187,021	59,347,345	57,035,491	43,803,841	92,347,713
47	0	0	0	0	0	0	0	0	0	0	0	0
48	84,773	1,466,809	696,209	372,585	314,983	87,188	1,659,595	941,107	480,212	155,679	527,449	304,829
49	345,763	530,523	175,355	508,502	481,502	308,221	716,499	684,383	262,157	157,508	420,867	381,770
50	560,929	10,303,879	3,988,414	1,848,432	2,854,376	1,922,116	2,759,943	10,769,622	1,918,950	1,540,993	501,478	2,021,804
51	18,901,261	12,637,711	9,509,071	8,871,713	11,439,932	9,588,041	13,615,473	9,185,217	8,073,704	6,871,031	5,420,409	8,052,342
52	1,241,909	3,958,709	1,096,605	5,190,703	5,088,826	1,161,649	5,788,390	4,717,525	2,258,471	1,942,748	1,216,885	3,996,376
53	896,488	757,237	230,536	936,564	262,080	678,437	2,586,940	389,747	198,791	137,977	87,855	305,326
54	3,425,129,279	2,905,627,843	894,902,700	2,715,390,682	2,219,951,742	1,537,958,130	1,156,971,314	1,186,803,840	1,688,244,592	802,520,667	885,520,936	1,314,277,309
55												
56	414,534,200	719,264,000	170,378,500	607,212,370	714,550,700	447,404,700	753,224,000	628,293,600	276,594,900	268,318,310	345,873,000	675,138,500
57	80,494,780	440,271,460	153,434,900	190,567,260	259,690,670	322,918,700	277,840,000	333,737,600	427,129,700	189,413,900	108,687,700	353,693,700
58	18,544,560	21,224,489	40,871,250	6,628,753	21,703,762	16,605,680	8,991,520	14,629,153	55,670,870	7,501,800	4,963,200	9,142,007
59	29,142,500	31,428,015	10,478,390	14,616,251	17,591,080	14,598,060	16,719,900	20,987,136	13,343,700	16,434,622	10,444,550	17,522,460
60	0	-100	0	0	0	0	0	0	0	0	0	0
61	0	-4,942,400	-328,600	-7,958,000	0	-2,053,700	-11,700	0	0	0	0	-447,500
62	236,374,660	146,942,560	60,624,230	63,764,154	117,837,020	185,052,500	111,462,000	113,643,130	258,031,000	74,066,420	162,861,900	81,338,980
63	0	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0
65	150,342,423	453,517,009	139,292,662	628,826,897	345,618,234	281,554,160	224,793,020	768,642,019	1,335,278,421	172,435,349	257,244,001	506,449,264
66	929,433,123	1,807,705,033	574,751,332	1,503,657,685	1,476,991,466	1,266,080,100	1,393,018,740	1,879,932,638	2,366,048,591	728,170,401	890,074,351	1,642,837,411
67	4,354,562,402	4,713,332,875	1,469,654,032	4,219,048,368	3,696,943,208	2,804,038,230	2,549,990,054	3,066,736,478	4,054,293,183	1,530,691,068	1,775,595,287	2,957,114,720

	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1												
2												
3	23	24	25	26	27	28	29	30	31	32	33	34
4	Equipment Manufacture	Transport Equipment	Other Manufacturing	Electricity Gener:	Gas Treatment &	Water works	Construction	Trade	Accommodation	Road Transport	Services to Transport	Water Transport
5												
6	1,304,484	407,012	170,752	102,792	44,499	38,265	610,773	18,612,460	10,182,034	658,037	935,630	558,578
7	686,637	229,850	99,246	55,498	24,116	21,131	335,651	11,497,000	5,891,430	349,088	490,451	297,372
8	615,092	262,786	333,430	52,522	26,589	53,731	812,082	26,980,950	65,246,550	311,335	399,347	1,627,960
9	238	0	1,003	0	0	87	34,669	560,742	229,158	0	0	6,098
10	527,562	141,897	72,423	41,179	17,320	19,586	288,759	7,604,010	13,613,600	255,645	370,004	430,055
11	59,597	25,929	1,501,200	10,613	3,003	18,005	267,645	415,852	13,587,857	40,009	37,378	570,789
12	147,082	59,758	14,152	30,691	4,679	42,772	363,184	19,213,534	222,866	72,818	99,408	53,339
13	3,299	95	0	129,900,331	97,260,145	1,183	1,302,880	37,624,955	405	983	115	227,812
14	814,302	358,691	23,158,164	35,466,040	3,859,215	32,485	15,247,744	3,157,370	537,517	987,040	363,179	566,791
15	1,374,819	769,463	1,633,034	114,104	26,256	155,384	3,300,078	12,359,140	411,730,600	1,486,160	792,245	4,809,500
16	936,870	1,028,806	112,491	148,757	22,363	77,423	3,320,935	144,094,000	68,327,130	929,447	159,021	2,481,200
17	5,185,392	1,106,271	193,283	136,512	47,198	217,488	5,156,549	12,409,426	404,810,960	875,575	475,433	12,072,037
18	369,641	235,770	21,212	30,789	6,303	30,001	947,724	23,809,630	342,430,300	113,794	27,002	1,150,825
19	10,090,898	2,673,005	2,613,432	280,602	246,819	233,615	28,164,706	65,458,518	7,077,136	4,287,678	835,614	1,086,491
20	84,409,217	49,533,465	2,883,677	3,895,170	1,785,049	254,075	846,325,553	50,783,370	9,897,959	802,129	1,979,309	839,719
21	39,984,141	5,252,571	7,603,447	4,952,268	681,734	1,169,620	60,250,132	306,326,500	8,149,040	3,858,947	5,713,034	1,464,816
22	39,819,550	6,659,172	789,123	3,917,190	635,167	1,711,230	58,344,400	222,932,000	30,316,600	7,272,432	16,695,560	837,044
23	65,494,582	34,726,868	13,498,582	1,523,280	506,057	533,815	218,424,722	260,188,450	14,817,789	52,554,742	5,544,412	3,860,350
24	58,014,837	9,086,526	6,506,654	6,568,007	2,298,688	1,695,854	271,472,174	179,317,341	11,526,543	156,620,888	8,387,269	23,100,862
25	9,507,065	18,227,469	1,059,247	5,252,340	3,011,063	8,490,413	835,077,600	12,367,114	10,112,869	365,396	168,566	151,257
26	98,600,238	40,212,077	10,071,817	53,455	334,525	482,295	37,605,887	556,921,000	148,361	94,364	14,388	45,940
27	149,638,975	36,821,673	4,253,756	11,928,050	4,332,737	5,045,614	895,313,620	54,255,130	14,403,072	1,275,127	1,288,332	2,133,195
28	294,647,981	26,998,002	1,588;121	23,686,997	339,478	866,133	218,437,329	108,768,914	9,472,387	19,532,879	4,707,042	7,461,283
29	8,006,848	597,048,176	153,614	237,364	84,229	73,780	7,737,187	151,635,414	893,085	97,222,024	371,002	16,099,795
30	803,729	274,161	4,445,267	126,391	13,481	45,893	2,913,581	6,956,099	242,298	486,265	273,362	42,199
31	31,216,846	13,411,175	1,861,827	2,025,490,000	3,128,250	26,190,600	39,600,680	207,554,000	100,005,700	14,865,620	25,244,735	8,755,964
32	4,117,651	2,088,098	127,325	617,471	98,555,900	90,945	4,552,040	11,339,300	12,509,410	4,988,956	1,031,939	701,044
33	1,522,308	849,493	10,818	1,030,180	7,196,310	100,108,000	2,102,259	7,407,120	5,031,140	4,461,404	1,474,221	80,748
34	38,715,618	6,932,974	5,525,960	48,317,210	1,766,749	7,322,218	2,585,329,300	179,071,970	93,469,351	24,899,296	505,631,730	74,327,845
35	332,066,130	264,460,590	35,408,434	39,773,000	6,438,760	6,856,300	853,223,000	1,401,160,000	205,525,000	250,067,900	35,691,700	45,736,925
36	37,566,798	7,925,634	2,729,286	4,481,540	540,908	1,602,269	53,121,020	146,266,700	51,900,620	16,550,690	11,978,849	9,044,223
37	49,719,977	9,999,206	5,185,311	22,360,162	170,965	1,326,390	54,174,041	493,579,700	6,143,060	299,939,763	15,673,798	43,043,359
38	27,739,643	10,128,620	2,590,061	3,573,977	165,210	1,558,093	22,870,491	252,176,859	5,970,316	75,377,702	54,694,234	25,321,254
39	12,727,629	5,940,942	1,365,131	19,374,230	81,280	344,340	7,529,266	194,152,508	4,138,695	27,123,290	2,291,030	168,136,370
40	14,025,501	7,670,345	1,359,294	1,740,884	90,005	294,067	12,045,179	95,594,161	2,965,447	18,166,398	50,785,721	7,105,000
41	67,169,705	15,227,974	3,704,481	27,699,400	4,558,060	975,971	114,677,800	532,432,000	74,592,100	49,204,950	101,127,960	9,135,246
42	122,511,736	67,332,527	9,850,395	9,110,106	6,380,130	462,413	429,247,500	992,870,000	121,609,420	86,787,220	23,851,090	29,914,935

	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
43	8,088,609	5,295,520	28,183	139,963	121,899	396,137	43,334,265	92,598,270	2,686,812	2,454,516	6,126,235	120,823
44	8,089,897	3,305,994	963,275	2,449,618	1,662,049	501,092	18,466,126	66,887,200	11,241,829	13,982,959	5,370,808	1,981,230
45	49,110,787	16,144,958	6,312,337	4,105,979	1,698,012	1,631,511	35,583,862	576,667,300	122,579,380	25,704,869	35,651,342	15,786,726
46	188,312,191	67,701,822	18,262,716	31,819,297	5,918,036	9,657,960	479,306,059	836,271,937	161,394,187	101,190,734	171,059,447	79,377,382
47	0	0	0	0	0	0	0	0	0	0	0	0
48	1,683,381	169,687	189,759	399,021	27,583	625,038	1,578,529	4,354,750	656,603	137,449	1,712,697	518,048
49	1,058,813	171,488	70,506	750,046	24,681	596,181	2,086,945	5,731,270	1,045,591	315,652	972,094	334,593
50	15,337,801	2,203,533	359,505	610,740	108,868	1,046,960	12,207,787	46,434,342	10,778,108	2,415,602	7,591,262	1,345,700
51	21,443,006	11,671,482	1,892,297	4,982,365	803,441	5,832,080	95,136,245	143,861,043	59,719,812	60,399,288	9,944,807	4,567,326
52	7,475,594	2,454,660	786,120	864,948	374,846	619,605	36,082,840	49,213,200	9,601,550	4,031,474	33,487,463	6,489,421
53	595,310	160,392	33,214	22,003,800	22,921	44,502,100	156,880,630	4,110,420	1,196,636	5,633,759	1,608,242	159,622
54	1,911,338,005	1,353,386,606	181,393,363	2,500,204,877	255,445,575	233,850,149	8,571,191,431	8,633,982,969	2,518,628,310	1,439,152,291	1,153,128,506	613,959,092
55												
56	789,958,010	404,856,270	83,405,935	401,801,000	46,195,000	42,200,000	1,766,642,000	5,880,950,000	1,007,675,000	668,281,000	359,417,300	506,711,040
57	614,052,260	87,947,200	63,186,189	1,302,410,000	96,549,100	45,700,100	675,419,400	3,520,180,000	635,949,000	325,718,100	283,650,000	224,187,000
58	14,255,020	3,163,481	1,276,174	18,762,300	10,634,800	705,450	63,025,650	144,533,000	139,883,200	115,455,790	7,952,211	21,207,264
59	18,539,774	8,803,186	2,294,081	14,345,500	3,045,120	357,850	65,829,200	375,862,000	74,116,800	21,558,150	25,964,240	27,043,146
60	-100	0	0	0	0	0	-600	-1,800	-11,300	0	0	0
61	-12,470,600	-40,700	0	0	0	0	-8,288,500	-33,733,500	-2,765,000	-74,254,700	-6,701,200	-357,700
62	121,927,420	55,502,818	11,261,529	321,409,000	27,285,800	12,594,700	307,395,500	854,168,000	173,211,300	252,515,800	225,071,240	103,277,510
63	0	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0
65	855,973,016	981,365,791	67,305,890	69,681,700	6,387,930	13,037,883	1,256,998,140	1,361,084,000	336,672,290	187,852,450	98,109,777	162,920,128
66	2,402,234,800	1,541,598,046	228,729,797	2,128,409,500	190,097,750	114,595,983	4,127,020,790	12,103,041,700	2,364,731,290	1,497,126,590	993,463,568	1,044,988,388
67	4,313,572,805	2,894,984,652	410,123,160	4,628,614,377	445,543,325	348,446,132	12,698,212,221	20,737,024,669	4,883,359,600	2,936,278,881	2,146,592,075	1,658,947,480

	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
1												
2												
3	35	36	37	38	39	40	41	42	43	44	45	46
4	Air Transport	Communications	Finance	Finance services	Insurance	Real Estate	Business Services	Dwelling ownership	Education	Community Services	Recreation Services	Personal Services
5												
6	558,176	7,446,360	2,980,818	451,044	554,404	1,436,904	3,552,944	0	1,300,344	3,828,094	2,850,742	1,368,194
7	344,837	3,998,390	1,615,146	250,461	299,856	763,604	1,825,109	0	420,411	1,348,806	1,546,180	731,166
8	4,729,951	2,961,285	1,538,066	181,411	287,135	595,527	2,288,000	0	460,699	5,250,208	6,222,555	649,959
9	22,770	0	1,468	0	111	546,415	15,800	0	3,323,360	3,320,772	23,723,477	59,327
10	744,817	2,871,840	1,176,695	169,762	222,288	542,280	1,551,191	0	1,906,896	1,161,047	4,822,002	559,845
11	2,001,097	44,268	156,928	10,952	32,426	48,929	164,284	3,873	120,249	1,291,922	227,573	53,904
12	137,809	195,693	236,263	37,407	36,407	135,475	404,417	22,596	228,279	5,259,133	1,778,093	123,304
13	1,216	0	3,752	0	1,736	1,394	5,287	0	178,939	225,242	477,084	267,883
14	109,987	3,654,555	189,031	28,883	36,183	745,505	487,230	183,224	50,289	7,506,568	404,438	437,628
15	19,945,298	416,213	1,109,784	98,185	328,623	359,486	1,754,598	1,005,450	981,403	12,868,730	3,889,733	910,957
16	8,176,176	470,606	675,361	48,184	173,482	258,570	1,157,387	520,631	341,675	6,421,656	1,807,632	560,882
17	32,912,796	118,834	1,936,418	48,236	366,360	211,751	8,284,475	424,745	3,866,135	30,731,789	21,087,104	1,254,950
18	6,396,216	23,889	153,609	1,932	43,014	27,607	240,529	110,191	138,325	2,292,474	6,240,760	176,872
19	1,942,189	2,068,080	2,231,098	200,541	567,500	3,888,175	10,693,083	53,245,342	1,569,926	34,630,229	24,174,608	3,993,038
20	203,618	1,572,359	2,664,586	277,724	570,135	2,713,976	13,191,297	70,349,335	18,114,508	3,090,729	5,881,213	18,065,902
21	2,210,073	1,701,760	25,990,127	7,314,623	7,760,289	10,325,273	62,564,573	24,958,840	24,609,616	28,573,008	16,977,716	14,158,949
22	19,022,297	15,523,200	34,266,120	33,308,690	9,929,936	63,282,100	538,250,410	792,947	83,596,920	58,818,000	65,042,190	28,377,720
23	11,091,441	15,912,751	3,399,197	927,780	840,550	4,811,175	55,518,818	22,267,794	19,133,609	86,760,154	28,713,442	103,726,672
24	53,564,013	31,497,844	2,285,962	1,697,497	3,092,963	8,399,689	32,090,221	7,736,820	24,603,097	38,625,795	40,178,595	44,027,872
25	490,395	509,023	260,151	20,198	51,665	8,079,634	5,617,486	34,762,001	2,934,863	1,930,227	1,209,357	3,341,434
26	1,051,415	84,403	52,395	8,622	7,648	347,205	186,635	356,331	418,200	297,900	114,467	453,204
27	946,674	1,366,329	1,282,920	87,557	344,691	22,433,999	18,016,554	98,957,220	9,190,973	2,883,973	20,257,206	20,591,404
28	7,595,464	17,487,893	6,508,142	622,549	686,786	7,111,358	47,875,074	7,705,650	6,281,805	44,983,819	6,979,302	37,610,614
29	65,125,601	1,337,339	461,800	63,743	59,333	384,323	4,775,242	954,750	277,014	1,057,814	2,248,732	53,071,686
30	167,942	279,966	739,358	275,018	245,736	250,516	10,422,335	196,004	3,657,174	3,505,658	7,381,519	2,281,324
31	9,482,380	89,042,500	1,675,028	7,247,764	3,464,289	9,217,270	34,192,910	59,090	35,119,970	99,840,000	43,349,300	28,764,440
32	331,589	2,675,300	690,383	518,200	395,178	1,191,268	3,276,793	41,785	2,306,443	10,520,240	3,046,485	2,928,366
33	32,657	4,495,740	51,772	241,692	6,817	897,504	273,352	78,239,600	5,680,011	8,269,218	820,167	6,442,517
34	19,600,013	25,153,960	52,850,473	11,123,140	20,534,205	284,538,280	80,194,901	383,507,500	116,967,239	125,434,610	121,575,428	51,112,473
35	129,589,860	109,195,000	46,872,280	7,158,616	15,734,157	37,388,900	195,492,000	157,305,000	43,770,170	146,628,300	99,825,460	138,001,810
36	73,438,963	22,284,920	34,530,596	6,279,802	7,572,755	22,213,290	68,185,282	1,980,877	20,294,360	93,076,400	58,839,120	25,289,764
37	25,738,906	33,251,927	17,784,105	3,967,759	4,640,326	9,388,126	70,119,989	1,473,852	58,922,053	10,509,766	23,812,429	5,294,630
38	204,721,173	8,715,396	14,373,647	1,621,768	5,819,438	3,489,203	38,434,283	349,674	12,386,245	28,044,377	20,432,737	9,815,171
39	12,588,320	23,313,421	4,301,527	852,371	1,157,432	3,345,930	16,720,821	18,454	913,167	3,659,599	2,526,286	3,161,664
40	209,050,465	20,220,733	12,432,010	1,185,280	2,665,884	7,440,716	28,121,007	96,691	3,747,785	20,900,811	13,890,978	5,279,294
41	27,423,540	175,483,000	144,846,000	52,101,800	40,283,422	46,507,420	231,775,910	91,170	29,318,300	87,121,700	80,249,900	87,382,040
42	68,118,207	110,950,700	1,100,085,700	120,545,368	239,200,345	142,324,280	265,491,375	246,652,300	4,840,599	57,729,840	40,732,790	56,941,761

	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
43	1,610,542	971,622	205,647,654	50,761,630	284,159,024	41,631,760	139,027,647	1,077,608	2,478,725	4,425,066	2,747,346	1,928,002
44	9,674,826	25,893,358	25,020,524	4,012,276	32,665,654	7,706,489	25,193,653	47,268,540	2,661,703	11,159,406	7,217,087	6,161,137
45	13,508,320	285,518,500	116,659,920	17,902,654	22,012,078	514,880,600	127,092,348	36,275	7,610,946	53,319,040	63,514,770	52,588,996
46	254,997,003	126,598,520	395,827,144	76,216,033	60,270,467	255,593,105	660,840,648	13,422,984	53,553,691	200,393,844	213,092,513	127,939,698
47	0	0	0	0	0	0	0	0	0	0	0	0
48	9,557,153	2,316,731	486,137	126,489	207,837	640,400	2,735,921	34,483	14,445,051	6,992,653	1,113,325	519,866
49	33,466,732	2,307,382	1,031,161	180,956	2,962,874	780,738	1,858,789	7,616	3,930,706	111,701,440	7,260,776	411,117
50	14,421,299	9,621,513	154,839,735	802,106	2,496,068	30,113,957	85,533,041	439,926	3,269,002	12,323,265	362,294,504	6,341,356
51	15,004,354	65,183,587	15,266,948	3,463,280	12,222,255	29,978,963	66,387,576	4,852,849	35,636,791	138,931,252	80,090,306	81,272,174
52	53,320,060	21,487,100	14,709,580	2,533,018	3,041,320	15,189,950	21,949,675	1,039,880	10,997,340	22,400,200	11,158,530	7,508,133
53	3,762,153	1,152,120	933,385	317,280	346,487	11,810,570	4,640,806	94,872	489,738	1,524,847	26,414,217	31,426,809
54	1,428,930,783	1,277,375,909	2,452,830,905	415,290,280	788,397,570	1,613,969,590	2,988,471,703	1,262,644,768	677,044,743	1,641,569,620	1,578,240,174	1,073,365,907
55												
56	571,326,000	957,095,000	1,526,506,000	294,831,100	399,880,550	293,031,700	2,106,943,000	0	2,872,404,000	3,425,837,000	713,944,500	884,517,000
57	382,802,600	1,012,080,000	1,304,684,600	259,061,500	95,144,710	2,435,750,000	1,409,158,800	5,052,060,000	-9,869,800	830,285,000	581,670,700	344,990,700
58	30,070,860	26,909,200	187,238,800	55,280,800	56,586,050	119,406,300	25,621,410	191,382,000	9,071,260	24,811,360	36,905,290	14,711,470
59	17,420,300	16,784,100	85,572,200	10,490,783	24,830,214	365,629,000	83,420,350	838,826,000	43,326,070	109,644,300	70,482,690	33,136,920
60	0	0	-100	0	0	0	-400	0	-100	-19,700	-33,700	0
61	-130,400	0	-2,900	0	0	0	-6,862,800	0	-8,832,900	-24,897,200	-97,703,400	0
62	163,854,190	572,310,000	391,058,400	34,699,730	55,376,270	597,642,300	317,861,600	544,595,000	12,531,820	103,567,000	126,929,400	86,281,080
63	0	0	0	0	0	0	0	0	0	0	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0
65	565,713,674	119,110,680	105,615,123	24,154,604	39,877,662	95,536,760	536,021,891	175,372,530	42,608,719	396,763,891	211,120,400	346,671,241
66	1,731,057,224	2,704,288,980	3,600,672,123	678,518,517	671,695,456	3,906,996,060	4,472,163,851	6,802,235,530	2,961,239,069	4,865,991,651	1,643,315,880	1,710,308,411
67	3,159,988,007	3,981,664,889	6,053,503,028	1,093,808,797	1,460,093,026	5,520,965,650	7,460,635,554	8,064,880,298	3,638,283,812	6,507,561,271	3,221,556,054	2,783,674,318

	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH
1												
2												
3	47	48		49	50	51	52	53	54	55		
4	Central Government	Local Government	***Total intermediate outputs***	Household Consı	Consumption of (	Consumption of l	Interregional Exp	International Exp	Net Increases in ;	Capital Formatioı	***Total Final demanı***	Total Gross Outp
5												
6	3,083,883	96,840	3,628,453,405	27,969,429	0	0	0	383,819,530	107,479,158	1,919,634	521,187,750	4,149,641,155
7	1,675,340	50,029	2,770,102,991	17,061,100	0	0	0	95,148,400	128,646,785	1,239,590	242,095,875	3,012,198,867
8	1,320,353	422,113	409,161,530	272,921,000	0	0	0	860,886,000	7,865,812	2,033,396	1,143,706,208	1,552,867,738
9	1,007,939	105,168	655,531,746	5,125,799	0	0	0	4,431,625	33,016	37,120,988	46,711,427	702,243,173
10	1,834,860	72,809	723,893,544	49,983,300	0	0	0	148,371,000	-725,997	980,510	198,608,813	922,502,357
11	2,940,810	287,946	482,069,376	3,462,055	0	0	0	198,522,076	17,058,312	135,042	219,177,485	701,246,861
12	2,847,528	112,801	1,595,125,957	31,254,420	0	0	0	625,571,370	418,519,291	3,230,271	1,078,575,352	2,673,701,309
13	247,821	653,305	763,232,761	1,133,079	0	0	0	193,065,800	-189,864	4,001,786	198,010,801	961,243,562
14	3,194,928	1,109,450	568,759,847	10,983,583	0	0	0	136,807,300	6,794,389	6,226,223	160,811,495	729,571,342
15	946,619	1,075,878	1,701,103,587	743,933,000	0	0	0	3,358,223,000	204,769,668	2,966,536	4,309,892,204	6,010,995,791
16	1,824,601	636,903	391,741,819	1,390,404,000	0	0	0	3,171,457,900	-604,478,509	5,437,192	3,962,820,583	4,354,562,402
17	7,076,686	1,814,392	1,485,283,982	1,670,330,700	0	0	0	1,473,258,980	73,120,996	11,338,218	3,228,048,894	4,713,332,875
18	264,887	235,930	474,527,764	847,713,000	0	0	0	89,982,680	55,449,605	1,980,983	995,126,268	1,469,654,032
19	12,606,420	369,456	1,382,400,219	929,412,840	0	0	0	1,774,444,330	125,727,825	7,063,154	2,836,648,149	4,219,048,368
20	7,083,937	149,029	1,978,492,823	480,540,910	0	0	0	939,035,920	52,627,264	246,246,290	1,718,450,384	3,696,943,208
21	16,569,357	2,874,892	1,883,407,320	140,258,100	0	0	0	720,513,900	32,604,390	27,254,520	920,630,910	2,804,038,230
22	70,410,400	6,289,810	2,026,473,681	384,712,000	0	0	0	89,986,700	46,744,093	2,073,580	523,516,373	2,549,990,054
23	44,165,974	1,955,839	1,845,484,107	588,064,400	0	0	0	534,319,300	77,144,462	21,724,209	1,221,252,371	3,066,736,478
24	32,563,636	14,250,304	2,749,445,912	636,566,610	0	0	0	592,232,000	66,671,473	9,377,189	1,304,847,271	4,054,293,183
25	2,938,036	46,144	1,329,019,662	82,924,460	0	0	0	83,410,630	17,010,499	18,325,817	201,671,406	1,530,691,068
26	1,372,768	14,047	1,090,270,794	10,174,490	0	0	0	648,928,000	-1,959,798	28,181,800	685,324,492	1,775,595,287
27	26,816,150	2,185,409	2,038,378,488	152,198,700	0	0	0	370,685,700	44,379,932	351,471,900	918,736,232	2,957,114,720
28	23,718,690	5,036,318	1,263,221,185	381,372,940	0	0	0	1,185,379,660	104,806,669	1,378,792,350	3,050,351,619	4,313,572,805
29	96,734,033	104,591	1,140,905,488	474,734,475	0	0	0	294,359,640	102,817,087	882,167,962	1,754,079,164	2,894,984,652
30	504,686	82,049	65,102,918	65,621,736	0	0	0	234,869,560	38,368,438	6,160,509	345,020,243	410,123,160
31	22,170,600	10,663,700	3,636,992,366	975,644,000	0	0	0	6,809,340	545,761	8,622,910	991,622,011	4,628,614,377
32	816,240	524,628	336,165,914	105,899,000	0	0	0	936,014	13,396	2,529,000	109,377,410	445,543,325
33	3,106,920	3,103,350	348,110,272	1,595	0	0	0	273,740	2,401	58,124	335,859	348,446,132
34	264,380,000	37,521,984	6,054,062,119	113,220,100	0	0	0	36,544,210	2,575,092	6,491,810,700	6,644,150,102	12,698,212,221
35	116,175,000	17,482,700	7,781,500,112	7,990,870,000	0	0	0	3,012,190,000	-8,805,443	1,961,270,000	12,955,524,557	20,737,024,669
36	27,746,060	7,608,650	1,004,827,098	2,601,430,000	0	0	0	1,246,804,000	5,289,303	25,009,200	3,878,532,503	4,883,359,600
37	20,141,430	2,287,065	2,464,062,150	252,466,900	0	0	0	213,443,860	494,557	5,811,414	472,216,731	2,936,278,881
38	10,530,006	1,797,610	1,215,754,876	89,882,658	0	605,882,000	0	231,551,847	1,197,538	2,323,156	930,837,199	2,146,592,075
39	15,410,655	224,479	986,681,519	48,206,370	0	0	0	616,585,500	630,914	6,843,178	672,265,962	1,658,947,480
40	26,213,303	1,946,645	648,947,320	480,553,410	0	0	0	2,016,753,900	1,184,966	12,548,411	2,511,040,687	3,159,988,007
41	108,229,000	12,207,700	2,490,203,470	1,062,530,000	0	0	0	298,238,000	8,274,419	122,419,000	1,491,461,419	3,981,664,889
42	93,084,790	10,224,717	5,859,995,512	149,777,900	0	0	0	37,887,965	311,363	5,530,287	193,507,516	6,053,503,028

	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH
43	86,081,800	327,062	1,044,676,463	9,692,539	0	0	0	38,534,320	302,018	603,458	49,132,334	1,093,808,797
44	9,762,413	4,469,857	470,901,443	975,605,600	0	0	0	10,610,381	231,911	2,743,691	989,191,582	1,460,093,026
45	148,607,600	11,219,540	2,724,836,709	2,117,575,000	0	0	0	40,654,700	1,702,665	636,196,576	2,796,128,941	5,520,965,650
46	312,083,950	90,248,480	6,389,709,192	185,584,030	0	0	0	323,214,065	13,857,845	548,270,422	1,070,926,362	7,460,635,554
47	0	0	0	8,064,880,298	0	0	0	0	0	0	8,064,880,298	8,064,880,298
48	21,256,620	1,095,807	86,490,015	633,982,800	2,860,919,000	0	0	44,396,100	764,667	11,731,230	3,551,793,797	3,638,283,812
49	73,638,230	230,246	273,161,796	3,035,000,000	3,137,084,000	0	0	31,002,800	231,275	31,081,400	6,234,399,475	6,507,561,271
50	23,976,379	2,365,889	926,725,599	1,528,453,000	102,680,000	429,942,400	0	224,670,930	1,384,168	7,699,956	2,294,830,454	3,221,556,054
51	47,633,034	8,943,938	1,377,350,937	1,200,145,880	0	231,204,000	0	36,869,864	-70,591,233	8,694,870	1,406,323,381	2,783,674,318
52	43,125,300	1,668,440	450,080,108	158,968,000	4,660,340,000	0	0	47,268,900	575,253	43,982,300	4,911,134,453	5,361,214,562
53	2,455,090	172,400,000	510,241,886	32,658,500	0	506,627,000	0	1,713,250	297,802	335,001	541,631,553	1,051,873,439
54	1,840,374,762	438,593,939	81,523,067,782	41,211,883,706	10,761,023,000	1,773,655,400	0	26,724,664,686	1,081,755,635	12,993,563,931	94,546,546,357	176,069,614,139
55												
56	2,712,970,000	531,497,000	37,488,108,045	0	0	0	0	0	0	0	0	37,488,108,045
57	0	0	29,134,167,349	0	0	0	0	0	0	0	0	29,134,167,349
58	19,670,200	11,705,300	1,776,433,522	5,431,130,000	0	0	0	397,602,000	28,856,700	610,795,000	6,468,383,700	8,244,817,222
59	181,772,000	11,019,800	3,115,579,330	0	0	0	0	0	0	106,685,000	106,685,000	3,222,264,330
60	0	0	-2,072,900	0	0	0	0	0	0	0	0	-2,072,900
61	0	0	-322,987,900	0	0	0	0	0	0	0	0	-322,987,900
62	0	0	8,189,960,684	0	0	0	0	0	0	0	0	8,189,960,684
63	0	0	0	201,820,000	0	0	0	43,162,000	0	-244,982,000	0	0
64	0	0	0	0	0	0	0	0	0	0	0	0
65	606,427,600	59,057,400	15,167,358,227	6,083,096,000	0	0	0	0	467,418,800	4,143,615,000	10,694,129,800	25,861,488,027
66	3,520,839,800	613,279,500	94,546,546,357	11,716,046,000	0	0	0	440,764,000	496,275,500	4,616,113,000	17,269,198,500	111,815,744,857
67	5,361,214,562	1,051,873,439	176,069,614,139	52,927,929,706	10,761,023,000	1,773,655,400	0	27,165,428,686	1,578,031,135	17,609,676,931	111,815,744,857	287,885,358,996

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**1997-98 New Zealand Input-Output Matrix (48 sector transaction matrix)**												
2		Nominal dollars	1	2	3	4	5	6	7	8	9	10	11
3			Mixed livestock	Dairy farming	Horticulture	Services to Agriculture	All other farming	Fishing and Hunting	Forestry & Logging	Oil and Gas Exploration	Other mining	Meat Products	Dairy Products
4		***Intermediate Inputs***											
5		1 Mixed livestock	533,474,680	318,236,600	16,891,638	2,424,934	67,670,910	77,767	4,953,163	27,935	24,650	1,859,758,520	55,232,793
6		2 Dairy farming	132,336,900	98,937,000	12,351,080	14,324,271	20,661,400	71,491	1,477,868	23,525	19,976	312,515,500	2,792,323,500
7		3 Horticulture	38,450,210	21,690,920	44,655,740	14,239,561	10,454,730	152,226	1,529,265	61,708	60,894	22,558,272	14,052,205
8		4 Services to Agriculture	278,409,970	124,176,331	213,965,936	28,547,638	54,886,043	1,015,740	12,029,668	0	0	1,610,406	861,873
9		5 All other farming	88,093,500	48,084,600	7,877,340	1,750,067	128,875,000	43,257	2,264,791	15,653	13,754	289,654,400	20,149,919
10		6 Fishing and Hunting	10,427,907	2,840,253	2,240,235	6,397,553	6,379,407	148,206	13,099	19,213	11,424	424,389	8,522
11		7 Forestry & Logging	2,218,715	1,023,829	1,349,053	1,789,203	1,020,963	14,878	1,040,470,951	41,301	61,306	1,444,015	2,868,947
12		8 Oil and Gas Exploration	95,514	96,295	19,876	266	10,045	793	4,001	105,689,529	29,136	35	0
13		9 Other mining	2,989,683	2,368,398	1,090,365	1,628,366	431,139	31,098	5,623,946	32,729,121	30,383,265	13,952,118	15,747,329
14		10 Meat Products	2,425,472	3,474,600	461,263	999,579	9,374,960	348,039	1,415,514	329,456	190,181	1,405,751,180	5,761,244
15		11 Dairy Products	2,582,929	1,809,765	650,918	1,118,734	540,424	195,786	855,416	355,990	515,052	4,668,374	202,271,234
16		12 Manufacture of other food	6,521,297	25,953,240	628,394	1,703,385	25,061,490	3,942,901	6,822,395	586,271	208,774	29,449,154	87,527,705
17		13 Beverage Manufacture	189,356	361,283	41,634	141,840	206,683	36,295	79,665	20,007	30,160	610,872	834,723
18		14 Textile Manufacture	11,408,528	1,909,777	1,544,352	2,323,588	350,014	4,238,739	282,096	96,949	223,617	6,827,101	404,927
19		15 Wood & Wood Products	4,819,707	2,176,286	21,124,368	621,225	296,978	192,567	2,103,772	281,800	1,165,461	5,733,945	5,539,229
20		16 Paper Manufacturing	395,706	178,070	45,715,396	12,330,621	335,093	770,201	1,166,747	718,171	1,409,904	69,569,551	37,879,058
21		17 Printing & Publishing	1,100,653	277,601	8,715,880	2,843,979	89,683	635,466	1,387,348	702,680	1,869,801	43,794,700	44,688,790
22		18 Other Chemicals	17,028,971	30,743,215	16,966,992	5,544,757	2,197,716	1,281,457	5,330,359	1,053,404	6,298,603	103,560,306	47,473,781
23		19 Basic Chemicals	270,753,185	241,586,472	99,115,824	38,332,170	39,239,356	4,397,111	42,276,537	2,850,036	10,107,020	26,051,523	16,805,241
24		20 Non-metallic Minerals	285,798	237,152	2,092,963	6,594,838	98,341	81,630	206,096	746,151	506,537	1,102,878	12,623,014
25		21 Basic Metal Industries	174,458	173,721	32,677	35,633	23,249	88,105	29,043	17,915	342,661	181,852	67,393
26		22 Fabricated Metals	44,162,085	52,866,011	4,002,303	6,848,168	4,119,309	2,815,829	8,381,682	5,905,669	11,867,701	16,827,012	12,798,171
27		23 Equipment Manufacture	4,249,491	4,839,830	2,379,908	3,774,471	1,095,074	2,099,261	11,024,018	5,042,845	20,412,393	30,524,587	18,076,719
28		24 Transport Equipment	1,237,950	1,345,990	374,915	1,024,670	157,281	11,388,728	246,212	74,170	288,252	834,547	587,919
29		25 Other Manufacturing	193,969	143,950	101,697	64,722	18,822	22,470	52,790	23,327	35,462	638,500	278,258
30		26 Electricity Generation &	21,361,630	47,472,500	7,032,840	2,922,138	4,398,350	339,296	1,262,863	2,581,526	15,293,490	53,860,690	19,204,250
31		27 Gas Treatment & Distribution	168,216	85,041	205,397	103,145	31,806	55,181	168,392	116,781	85,432	7,963,429	27,876,848
32		28 Water works	10,794	18,733	5,944	72,416	3,247	5,756	20,878	672	76,695	52,633,270	6,005,099
33		29 Construction	245,066,498	159,144,610	62,195,687	15,636,796	24,040,737	2,430,882	9,266,049	24,937,694	61,323,820	57,244,546	13,148,260
34		30 Trade	230,844,500	170,911,000	67,002,300	42,125,570	41,008,600	13,765,641	43,188,749	7,885,890	35,633,760	315,413,800	90,856,870
35		31 Accommodation	11,492,298	3,860,040	1,367,708	4,919,455	2,350,433	1,570,643	1,588,779	928,414	5,728,043	16,316,031	10,100,092
36		32 Road Transport	140,643,311	25,116,930	18,217,518	10,499,158	10,326,251	6,013,089	111,180,305	34,828,636	47,051,047	115,483,299	78,453,943
37		33 Services to Transport	19,185,447	16,570,253	4,436,360	6,423,531	5,010,146	2,591,516	28,522,365	13,801,318	7,035,339	61,416,826	25,647,100
38		34 Water Transport	3,600,425	2,517,261	5,313,904	288,348	2,793,010	214,866,188	1,750,645	4,875,750	5,307,242	21,265,694	21,807,228
39		35 Air Transport	1,518,924	1,615,123	1,755,960	1,954,425	1,120,636	1,062,493	2,268,318	1,045,299	1,729,205	10,943,852	3,104,243
40		36 Communications	31,612,070	21,384,400	11,169,980	7,657,958	9,322,990	1,985,819	6,880,564	4,467,504	8,482,350	66,329,700	21,054,000
41		37 Finance	112,742,340	115,614,400	44,012,110	29,735,816	27,536,230	12,017,300	49,517,072	51,006,587	13,123,018	144,625,030	94,342,066
42		38 Finance services	143,102	2,931,929	416,612	1,754,403	1,216,200	50,420	108,155	152,635	77,010	4,473,943	589,786

	A	B	C	D	E	F	G	H	I	J	K	L	M
43	39	Insurance	18,675,460	14,160,368	4,017,059	3,354,971	3,637,473	1,798,871	2,344,852	6,046,325	1,200,535	12,028,357	4,302,844
44	40	Real Estate	41,763,910	74,520,300	22,032,380	742,229	12,773,420	429,003	3,036,222	1,277,385	1,043,223	42,339,793	4,527,006
45	41	Business Services	93,409,073	31,438,500	33,381,685	66,591,015	24,856,088	12,853,397	38,420,068	85,221,158	32,327,075	261,082,558	44,693,444
46	42	Dwelling ownership	0	0	0	0	0	0	0	0	0	0	0
47	43	Education	3,312,756	3,343,845	310,697	314,607	343,457	11,412	22,117	120,447	104,156	4,140,562	84,413
48	44	Community Services	22,691,999	25,159,380	6,395,822	2,221,176	5,836,810	389,176	2,447,483	1,953,318	3,613,363	15,635,782	4,174,365
49	45	Recreation Services	13,221,097	31,375,682	12,745,044	1,234,468	9,092,018	310,196	494,632	578,375	346,676	31,722,348	676,323
50	46	Personal Services	71,306,635	103,957,614	26,177,421	5,817,596	11,102,577	1,035,432	12,486,697	2,635,884	3,512,775	19,916,384	17,107,723
51	47	Central Government	705,631	925,137	281,893	102,364	246,390	44,987	146,712	229,412	263,516	1,036,856	115,821
52	48	Local Government	1,923,530	976,464	651,701	1,201,328	1,563,530	98,372	600,176	40,709	33,257	870,860	695,528
53		*Total Intermediate Inputs*	2,539,426,279	1,838,630,698	833,516,766	361,077,151	572,204,508	307,815,110	1,465,748,534	402,144,549	329,467,011	5,564,787,346	3,883,429,747
54													
55	49	Compensation of Employees	286,397,861	237,790,018	427,189,548	176,755,909	78,012,270	58,023,532	188,194,592	25,802,679	143,810,057	995,838,914	544,754,247
56	50	Operating Surplus	845,474,479	1,157,059,520	441,093,390	155,588,105	273,590,337	145,424,265	1,073,652,825	134,723,727	135,135,619	93,834,396	98,112,583
57	51	Commodity Indirect Taxes	62,829,625	41,530,454	17,023,060	9,234,989	9,352,116	6,205,006	25,105,051	6,796,904	13,365,401	25,047,352	24,581,980
58	52	Non-Commodity Indirect Tax	169,183,933	98,084,981	48,971,893	9,987,922	23,156,058	18,349,638	20,036,019	3,427,348	15,203,266	19,490,628	40,154,185
59	53	Commodity Subsidies	-954,189	-1,011,352	0	0	0	-83	0	0	0	-220	0
60	54	Non-Commodity Subsidies	-3,043,994	-2,995,451	-5,738,382	-2,965,363	-1,138,718	-4,027,125	-4,112,275	0	0	-5,057,102	0
61	55	Consumption of Fixed Capital	259,981,360	230,401,376	157,742,678	51,964,218	74,962,018	45,830,031	39,617,212	75,152,313	78,014,488	124,122,361	308,330,231
62	56	Second Hand Assets	1,594,535	1,629,900	804,506	5,100,998	335,178	5,371,945	3,126,956	1,480,493	14,829,298	7,918,813	25,625,454
63	57	Interregional Imports	0	0	0	0	0	0	0	0	0	0	0
64	58	International Imports	149,407,383	172,302,157	128,758,865	45,049,816	75,422,686	153,591,120	73,449,730	5,871,315	64,723,130	407,203,936	191,820,670
65		*Total Primary inputs*	1,770,870,993	1,934,791,602	1,215,845,559	450,716,595	533,691,946	428,768,329	1,419,070,109	253,254,778	465,081,259	1,668,399,078	1,233,379,350
66		**Total**	4,310,297,272	3,773,422,300	2,049,362,325	811,793,746	1,105,896,454	736,583,439	2,884,818,643	655,399,326	794,548,270	7,233,186,424	5,116,809,097

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1													
2	12	13	14	15	16	17	18	19	20	21	22	23	24
3	Manufacture of other food	Beverage Manufacture	Textile Manufacture	Wood & Wood Products	Paper Manufacturing	Printing & Publishing	Other Chemicals	Basic Chemicals	Non-metallic Minerals	Basic Metal Industries	Fabricated Metals	Equipment Manufacture	Transport Equipment
4													
5	62,918,841	15,853,564	802,174,191	4,065,997	1,350,442	697,386	6,727,189	427,823	352,711	113,131	1,110,647	1,351,175	472,157
6	28,850,740	10,160,071	105,573,738	1,400,228	428,151	569,062	2,631,901	285,981	295,463	119,387	899,568	1,087,424	434,202
7	231,264,997	145,514,373	7,789,972	1,836,889	519,482	726,849	1,412,033	655,072	467,685	116,250	1,101,047	1,441,974	543,696
8	668,442	290,171	1,570,355	50,504	17,202	0	25,691	191	121	0	0	345	0
9	160,294,569	36,562,476	28,600,405	1,697,692	567,921	333,510	16,371,768	220,480	168,560	54,029	527,378	657,458	205,578
10	457,096,629	83,025	3,792,363	31,081	31,716	37,424	1,226,809	51,780	27,953	12,469	44,393	72,623	27,828
11	821,182	199,729	155,434	653,192,268	232,788,269	116,663	300,463	141,128	60,714	46,230	100,869	329,388	113,370
12	0	0	0	13,914	0	260	0	213,874,880	0	0	0	1,175	68
13	4,331,145	1,414,108	1,933,599	664,457	572,140	258,654	6,825,750	101,868,707	154,045,574	115,692,093	1,919,115	845,555	396,852
14	127,297,617	4,677,490	194,222,394	2,681,487	1,274,568	803,359	4,574,223	24,203,386	628,159	425,578	1,666,458	1,986,558	1,133,565
15	96,025,025	8,040,760	3,258,682	2,654,451	1,879,503	1,311,545	5,628,698	4,630,436	1,144,578	968,726	1,911,738	2,815,967	3,753,800
16	580,944,688	56,557,207	3,341,760	2,178,628	1,573,419	752,762	12,048,162	4,696,395	547,499	257,397	4,360,006	5,767,079	1,199,950
17	5,369,174	82,912,130	259,326	267,599	145,586	87,192	214,807	400,528	77,766	72,545	154,552	372,783	305,937
18	8,610,785	4,726,477	585,290,445	26,743,435	2,156,677	1,283,289	6,834,860	5,174,893	960,946	774,740	6,057,876	6,431,334	1,880,830
19	6,759,731	6,488,723	6,209,002	628,519,341	47,586,345	10,508,011	10,836,621	5,310,959	14,228,308	3,932,934	40,893,099	76,423,739	61,228,576
20	82,230,276	37,779,070	29,261,442	46,093,438	509,603,740	316,872,300	55,611,554	18,093,707	19,854,132	3,122,417	16,427,589	37,654,846	5,615,858
21	46,367,487	19,136,070	9,764,542	9,172,770	86,587,400	369,419,000	24,573,988	6,850,729	6,968,088	616,588	13,223,340	37,121,989	7,507,656
22	99,126,525	41,263,542	63,680,837	48,069,508	30,551,270	65,719,911	167,733,036	64,673,929	10,543,555	3,985,436	44,840,995	69,832,119	49,558,775
23	24,857,705	12,775,753	52,732,387	50,411,026	24,536,113	8,425,671	230,963,478	631,888,582	17,252,298	26,546,729	19,744,337	50,157,024	8,791,102
24	14,613,682	68,809,297	574,168	19,590,030	451,440	161,286	6,486,687	4,071,757	225,090,872	2,569,419	24,581,368	9,671,352	23,249,244
25	297,208	283,762	882,428	3,359,008	1,409,565	716,832	2,411,424	6,214,010	4,150,123	112,801,760	218,597,580	99,134,171	36,010,935
26	49,480,316	53,517,034	6,641,183	85,274,911	7,995,458	3,451,148	39,103,369	10,025,783	34,654,227	40,892,655	230,034,486	167,319,444	50,388,554
27	27,423,327	7,270,475	15,981,688	35,320,720	42,053,505	10,560,965	11,788,229	29,568,757	11,537,728	12,418,363	49,210,636	470,512,194	38,379,940
28	1,332,664	1,359,181	432,855	2,971,198	700,109	214,490	983,835	706,339	1,265,403	2,128,833	5,265,263	7,801,436	511,928,106
29	606,109	345,024	6,548,569	316,682	143,752	2,916,907	478,086	214,742	201,923	41,147	344,305	665,656	206,305
30	31,280,620	6,941,095	23,668,727	44,410,314	107,877,850	10,679,800	20,887,039	30,517,943	20,685,927	193,990,100	20,538,950	27,982,450	14,748,818
31	9,392,038	2,354,168	4,586,107	1,256,574	26,746,852	1,307,680	1,464,935	37,349,564	6,121,463	10,752,780	5,421,631	3,580,638	2,246,975
32	17,126,118	12,016,029	10,221,484	1,331,920	19,432,721	10,705	3,043,717	5,946,057	8,910,469	1,442,806	4,448,260	2,490,668	1,766,200
33	43,190,318	6,588,572	53,479,571	85,211,756	10,215,464	16,312,638	31,414,092	90,063,077	85,553,275	59,288,251	29,796,857	53,255,216	8,797,986
34	295,895,500	251,566,100	310,345,120	247,589,110	136,824,900	90,741,900	198,934,820	521,065,600	112,305,960	209,368,000	340,490,900	360,114,250	473,424,430
35	18,494,672	12,820,783	18,560,134	21,475,144	13,933,546	13,856,150	23,965,017	15,239,014	8,449,518	8,699,621	17,446,102	39,838,855	10,418,942
36	142,975,468	46,860,674	49,032,333	124,940,747	104,106,302	60,735,600	58,601,976	32,888,076	36,219,417	15,063,079	48,527,247	54,737,521	12,634,511
37	41,331,444	18,490,341	22,162,044	56,347,075	33,399,421	12,019,042	32,737,462	12,820,000	19,077,810	13,530,487	34,474,022	37,097,775	15,171,383
38	79,489,374	4,960,711	12,603,320	21,879,935	78,754,634	7,290,192	16,188,927	20,347,274	19,994,484	18,044,519	12,360,029	14,450,686	11,080,345
39	9,998,306	3,178,319	12,716,998	10,016,075	11,461,919	5,610,594	9,424,202	3,878,160	3,317,777	2,295,121	7,853,581	15,706,051	8,761,676
40	56,899,024	18,759,780	58,790,969	49,549,603	24,907,310	80,134,400	44,650,420	21,714,510	18,152,991	10,167,680	46,356,540	97,505,220	27,941,447
41	198,854,243	81,961,824	143,254,995	111,094,063	104,577,410	107,501,600	137,355,833	92,299,960	51,927,136	55,301,220	128,547,242	156,907,371	141,372,192
42	11,305,895	1,141,991	1,826,157	980,303	4,402,262	4,646,258	9,905,640	5,243,512	338,118	31,661	5,742,278	7,485,721	8,252,059

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
43	8,691,950	1,896,939	6,740,123	9,535,148	6,770,665	6,279,714	6,688,430	9,379,039	3,334,268	2,563,231	5,950,630	8,938,653	4,530,905
44	21,837,702	3,752,043	46,127,523	41,084,772	14,040,278	31,978,240	35,194,763	14,038,344	14,514,172	5,901,289	44,610,345	53,687,754	21,324,719
45	146,214,716	32,994,490	143,096,761	98,263,512	4,737,066	145,787,856	172,523,587	91,851,843	79,739,449	58,197,144	123,574,180	216,070,698	114,678,172
46	0	0	0	0	0	0	0	0	0	0	0	0	0
47	4,417,778	2,829,299	1,404,485	1,184,195	100,478	2,875,383	2,663,615	992,995	568,625	1,261,512	1,298,724	4,011,257	626,024
48	5,376,772	4,296,198	9,947,554	4,141,796	2,465,898	17,644,420	10,574,919	5,518,301	2,504,424	5,137,567	4,697,201	12,181,336	2,224,394
49	14,671,767	5,590,532	3,838,032	4,385,698	2,763,832	4,136,819	15,726,750	3,838,434	2,606,724	897,094	3,280,672	17,022,438	4,172,570
50	14,557,203	11,256,799	13,911,112	13,573,672	12,217,537	17,036,461	12,162,346	13,550,708	9,436,206	7,352,428	10,686,826	27,975,829	17,462,660
51	473,518	142,776	861,845	652,835	152,714	792,433	652,215	349,659	278,144	164,441	545,277	896,358	376,279
52	723,645	236,960	1,246,714	261,761	696,065	2,753,850	419,501	241,645	155,015	93,938	324,051	543,587	221,644
53	3,290,786,934	1,146,655,933	2,879,093,872	2,575,743,267	1,715,508,896	1,436,076,210	1,460,972,866	2,163,384,686	1,008,715,757	1,007,252,824	1,579,988,191	2,261,935,139	1,705,567,212
54													
55	747,815,414	197,453,588	509,041,054	794,642,513	459,596,862	796,285,558	676,368,778	268,556,236	298,060,017	329,037,101	783,742,337	900,432,327	412,981,926
56	432,564,159	160,490,271	147,915,104	267,187,299	284,849,709	272,090,454	331,538,582	389,858,168	198,951,476	85,616,775	357,387,141	654,128,428	102,545,557
57	22,403,685	48,897,188	5,642,349	24,607,670	17,605,100	9,675,441	16,073,213	56,034,379	8,619,652	4,689,272	10,519,359	17,284,832	3,025,138
58	33,621,920	12,573,660	12,637,050	20,170,963	15,096,585	18,184,922	23,092,151	13,561,403	19,006,669	10,325,855	20,940,804	22,894,967	8,539,141
59	-75	0	0	0	0	0	0	0	0	0	0	-86	0
60	-4,178,703	-378,018	-5,340,922	0	-1,772,198	-9,903	0	0	0	0	-373,880	-11,168,264	-27,345
61	150,418,959	70,977,505	53,227,854	130,805,755	193,685,308	116,935,216	122,274,747	253,815,605	80,469,317	151,069,560	93,979,165	139,556,553	50,007,335
62	24,136,409	4,295,934	3,582,042	9,138,601	48,330,983	6,789,022	8,630,339	16,863,474	4,401,212	1,738,088	12,242,535	107,184,510	19,050,397
63	0	0	0	0	0	0	0	0	0	0	0	0	0
64	477,583,976	159,144,973	510,945,406	373,931,455	290,751,827	236,680,697	814,015,346	1,325,675,698	192,662,313	240,450,577	606,927,301	1,030,624,159	885,932,462
65	1,884,365,743	653,455,102	1,237,649,935	1,620,484,257	1,308,144,176	1,456,631,407	1,991,993,155	2,324,364,964	802,170,656	822,927,228	1,885,364,761	2,860,937,425	1,482,054,611
66	5,175,152,677	1,800,111,035	4,116,743,807	4,196,227,524	3,023,653,072	2,892,707,618	3,452,966,021	4,487,749,651	1,810,886,413	1,830,180,052	3,465,352,952	5,122,872,563	3,187,621,823

	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL
1												
2	25	26	27	28	29	30	31	32	33	34	35	36
3	Other Manufacturing	Electricity Gene	Gas Treatment &	Water works	Construction	Trade	Accommodation	Road Transport	Services to Transport	Water Transport	Air Transport	Communications
4												
5	208,829	141,551	64,443	41,523	694,918	19,364,580	9,895,562	743,255	926,063	496,643	483,203	7,184,560
6	182,950	117,104	53,039	36,135	604,249	17,954,000	9,945,040	597,017	735,852	425,022	497,007	5,770,130
7	457,367	167,407	89,505	116,517	1,738,244	69,479,790	107,967,200	766,165	912,631	3,035,092	7,739,733	6,379,378
8	1,255	0	0	112	42,495	660,155	262,023	0	0	5,793	22,611	0
9	110,649	69,983	30,665	26,962	404,676	9,562,850	18,409,770	351,889	447,520	481,985	870,051	3,337,570
10	1,820,747	16,586	4,908	22,716	352,489	476,936	16,595,211	50,432	41,556	606,020	2,158,847	47,432
11	23,176	58,393	9,313	68,157	560,486	25,761,351	328,935	110,611	131,646	65,349	187,127	247,619
12	0	64,229,672	50,115,702	473	535,301	13,746,767	159	388	40	79,604	419	0
13	23,605,469	52,270,075	5,905,436	34,306	18,255,065	3,090,258	595,422	1,044,177	341,653	499,018	109,603	3,625,583
14	2,842,641	219,837	52,846	250,343	5,208,542	18,179,860	534,499,500	2,260,788	1,236,917	6,143,844	24,909,590	513,095
15	372,803	718,684	129,549	330,943	12,283,257	450,250,900	232,864,200	2,957,875	508,835	7,976,562	26,262,095	1,318,013
16	286,348	175,345	67,064	207,074	5,826,222	12,103,735	419,832,867	898,284	412,945	10,232,442	24,598,920	100,301
17	25,616	45,268	9,047	37,645	1,279,555	22,949,830	373,885,900	113,090	25,365	1,227,902	7,736,681	20,241
18	2,039,018	167,352	290,164	119,172	28,284,839	34,121,832	4,950,327	2,848,630	406,591	633,793	830,405	1,129,393
19	3,732,516	5,236,866	2,482,822	279,586	1,163,109,554	55,249,540	12,018,677	906,129	1,820,127	892,215	214,014	1,478,382
20	8,952,704	6,616,775	948,939	1,255,627	81,725,245	312,094,300	8,933,742	4,158,159	5,437,098	1,330,012	1,935,313	1,525,567
21	983,239	5,597,280	945,811	1,981,160	76,034,100	235,748,000	34,287,100	8,416,512	17,019,132	850,361	18,616,987	15,169,900
22	20,340,309	2,223,251	717,675	537,544	285,622,946	275,836,794	13,804,774	63,206,174	5,590,157	3,431,832	9,390,284	16,207,327
23	7,969,240	6,387,188	2,374,732	1,571,589	257,644,497	148,575,045	9,213,094	122,076,907	5,853,741	16,910,417	36,823,904	20,963,350
24	1,137,242	6,945,666	4,217,370	8,779,423	1,054,119,230	11,969,452	10,182,751	396,836	155,556	160,696	449,524	467,937
25	10,109,989	62,799	490,459	550,765	48,963,896	561,465,700	141,615	105,939	12,291	49,719	860,492	80,430
26	5,012,519	17,395,690	6,809,110	5,796,082	1,183,431,620	62,825,210	12,553,332	1,474,813	1,333,170	2,216,026	975,889	1,435,581
27	3,844,846	38,556,916	520,918	1,134,307	268,644,005	128,120,141	11,016,357	19,657,864	3,753,970	6,552,828	20,262,256	27,339,769
28	191,408	360,542	144,034	88,536	9,587,728	117,434,022	949,079	120,766,974	279,202	13,200,231	66,872,814	961,274
29	4,953,459	101,419	12,363	30,178	2,270,096	4,403,266	171,397	368,743	160,426	26,898	106,034	161,949
30	1,984,871	2,373,750,000	3,820,480	24,868,900	39,182,330	180,015,000	93,341,500	13,944,340	21,072,603	8,422,221	7,895,490	71,367,400
31	126,307	749,558	124,678,000	89,451	4,787,902	10,187,100	11,850,430	4,905,258	903,405	565,757	280,827	2,221,070
32	15,459	1,861,110	13,548,100	146,532,000	3,071,802	9,903,270	7,179,940	6,524,785	1,937,107	112,168	44,280	5,554,640
33	7,805,879	77,400,570	2,949,735	9,600,688	3,818,315,710	213,382,840	117,338,860	29,106,799	632,547,859	85,964,139	21,994,151	27,545,110
34	45,876,185	59,255,800	9,996,740	8,276,380	1,174,183,000	1,544,920,000	244,223,000	300,103,700	37,605,520	46,954,254	132,204,040	111,262,000
35	3,404,454	6,560,570	829,397	1,874,062	70,736,350	160,922,700	57,826,200	18,661,270	12,170,118	9,576,775	71,927,857	22,735,350
36	7,263,718	34,540,350	304,879	1,728,606	72,070,979	551,980,200	7,526,597	361,927,970	17,478,314	42,564,630	28,598,637	35,379,563
37	4,290,675	7,211,343	600,998	2,612,964	37,704,976	312,476,800	8,830,029	102,426,323	65,516,042	28,413,949	243,960,787	10,621,540
38	2,176,992	38,970,620	167,136	512,332	10,817,546	240,048,700	6,270,170	36,733,206	2,967,841	229,578,127	16,532,394	26,799,680
39	1,914,315	2,840,565	169,272	406,983	16,892,606	114,150,952	3,813,015	23,753,661	60,765,248	7,723,919	236,524,026	22,308,003
40	6,643,351	58,216,600	9,983,210	1,661,970	215,138,800	828,160,000	122,994,800	83,713,890	151,507,100	12,670,620	39,410,979	252,238,000
41	13,645,086	16,586,702	11,303,900	676,304	678,914,100	1,254,895,000	163,165,130	119,914,403	26,666,175	34,442,547	80,318,213	134,139,200
42	27,375	164,009	144,314	387,120	47,003,152	81,376,570	2,527,260	2,273,178	4,965,923	92,947	1,258,303	757,047

	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL
43	1,198,195	3,658,254	2,579,427	600,400	24,261,893	69,173,940	12,180,556	16,782,255	5,119,447	1,975,214	10,000,003	24,654,124
44	8,144,870	5,975,960	2,576,181	1,927,150	49,063,450	622,130,000	141,316,130	30,373,599	36,918,140	15,406,792	13,500,695	284,491,200
45	25,875,296	49,592,453	9,319,786	12,457,666	690,700,018	986,804,275	199,634,175	131,664,231	191,970,438	84,559,132	275,272,036	134,845,490
46	0	0	0	0	0	0	0	0	0	0	0	0
47	846,267	573,891	83,545	281,190	3,092,677	12,356,886	2,368,485	384,801	6,347,593	2,144,979	35,289,542	8,371,506
48	1,255,062	13,758,010	445,860	12,622,680	38,770,184	52,255,700	10,879,669	6,534,005	18,925,336	3,807,692	127,658,297	20,967,770
49	619,805	1,029,211	214,686	1,367,830	18,604,641	59,961,547	15,002,391	3,382,660	8,876,467	1,739,771	16,015,770	13,827,538
50	2,453,543	7,766,943	1,383,768	8,185,771	130,678,254	164,259,029	79,859,549	74,002,595	9,186,482	5,504,073	16,614,921	68,531,341
51	113,639	141,868	64,071	82,342	5,127,954	5,973,800	1,245,821	524,197	3,894,224	723,869	5,990,434	2,410,300
52	37,367	28,063,500	30,470	45,986,900	160,590,830	3,879,760	1,206,048	5,824,969	1,479,424	134,879	3,724,150	1,004,940
53	234,923,050	2,996,549,536	271,679,868	306,036,566	11,816,932,408	10,090,638,382	3,153,883,790	1,727,739,745	1,366,363,289	700,608,757	1,637,929,632	1,397,497,592
54												
55	76,896,259	412,192,848	40,701,378	52,511,198	2,262,901,306	6,803,895,858	1,185,533,176	797,567,089	442,201,644	619,165,541	641,384,997	1,578,424,773
56	54,191,139	1,237,691,312	78,802,085	52,678,224	747,766,894	3,772,680,399	683,240,796	327,913,579	350,391,843	269,850,247	399,947,413	1,546,179,481
57	1,167,590	19,591,586	9,537,583	893,509	80,208,278	170,203,853	167,661,809	134,717,235	10,214,876	24,914,924	34,485,032	45,171,378
58	2,163,531	15,140,479	2,760,276	458,114	85,074,359	447,375,522	90,115,543	25,127,929	33,758,542	32,284,117	20,287,047	28,477,417
59	0	0	0	0	-647	-1,758	-11,163	0	0	0	0	0
60	0	0	0	0	-8,342,029	-31,248,389	-2,648,121	-75,008,859	-6,663,172	-322,407	-117,862	0
61	10,176,314	327,207,354	23,857,611	15,552,560	386,815,445	980,683,491	202,672,031	289,401,245	289,703,464	121,797,480	182,708,769	936,645,903
62	832,431	5,480,461	15,977	492,565	183,882,141	70,068,683	7,321,488	7,001,538	2,652,304	16,787,902	18,292,133	5,678,296
63	0	0	0	0	0	0	0	0	0	0	0	0
64	70,141,609	71,314,313	5,612,499	15,945,062	1,547,524,228	1,532,719,556	383,067,152	196,544,137	114,290,445	177,657,550	630,312,491	190,654,665
65	215,568,874	2,088,618,353	161,287,409	138,531,232	5,285,829,975	13,746,377,214	2,716,952,710	1,703,263,894	1,236,549,947	1,262,135,355	1,927,300,020	4,331,231,914
66	450,491,925	5,085,167,888	432,967,276	444,567,798	17,102,762,383	23,837,015,596	5,870,836,500	3,431,003,639	2,602,913,236	1,962,744,112	3,565,229,652	5,728,729,506

	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX
1												
2	37	38	39	40	41	42	43	44	45	46	47	48
3	Finance	Finance services	Insurance	Real Estate	Business Services	Dwelling ownership	Education	Community Services	Recreation Services	Personal Services	Central Government	Local Government
4												
5	3,170,533	453,354	667,840	1,627,528	3,862,024	0	1,334,643	2,306,810	2,155,806	1,769,904	3,016,638	104,129
6	2,600,535	378,560	544,117	1,422,115	3,074,665	0	689,951	1,317,748	2,271,253	1,272,848	2,526,350	85,236
7	3,663,792	373,409	724,502	1,423,604	3,889,780	0	658,370	6,096,856	8,399,519	1,950,650	2,081,494	947,208
8	1,605	0	116	411,577	18,680	0	3,310,904	2,180,815	28,475,234	79,045	1,051,623	126,240
9	1,515,312	210,200	323,621	680,058	2,074,031	0	2,535,387	890,388	5,939,219	933,261	2,228,250	99,892
10	183,565	10,971	38,682	58,435	202,585	2,823	145,672	952,282	271,716	79,073	3,343,637	361,404
11	338,541	53,076	54,833	164,262	584,713	19,829	389,329	4,715,030	2,488,033	209,300	3,904,485	174,331
12	1,393	0	541	386	2,078	0	58,068	50,669	179,210	113,880	83,892	260,741
13	193,200	28,802	40,496	979,689	493,760	111,397	44,807	5,316,908	391,200	480,183	3,241,465	1,167,729
14	1,598,051	119,994	504,297	598,094	2,567,355	774,073	1,176,685	10,965,298	4,558,515	1,571,081	1,264,423	1,662,693
15	2,312,409	143,182	618,849	946,734	3,850,306	867,603	1,008,623	13,245,548	7,009,303	2,068,236	5,112,930	2,681,523
16	1,809,591	39,689	346,007	211,472	7,912,337	287,037	3,091,768	17,256,889	13,042,871	1,409,041	6,755,015	1,717,105
17	155,500	1,792	48,747	28,573	260,163	78,824	132,311	1,712,976	6,986,349	291,653	254,313	296,504
18	1,189,156	100,110	305,453	5,757,481	5,323,212	36,674,889	755,215	13,433,595	12,746,986	2,419,201	6,190,715	187,301
19	2,795,523	312,755	672,422	3,372,574	15,781,933	44,614,525	16,269,838	1,906,457	6,285,001	22,087,034	7,441,768	178,195
20	25,712,685	8,646,117	9,347,084	11,832,793	60,479,497	14,250,012	19,488,867	17,414,091	18,153,576	17,547,138	15,479,111	3,025,422
21	37,011,630	42,484,170	12,759,014	83,379,370	594,537,950	528,086	74,101,800	38,689,300	69,047,020	39,403,250	71,900,000	7,256,510
22	3,660,883	1,257,735	1,037,292	7,175,826	59,351,288	13,087,622	14,061,522	40,543,336	31,047,185	99,979,447	45,064,499	1,841,711
23	1,758,820	1,475,571	2,697,184	7,636,049	25,936,794	4,024,420	16,180,580	17,918,759	32,170,097	38,441,891	23,857,833	11,175,304
24	269,820	20,274	55,555	10,702,461	5,705,237	20,854,250	2,515,719	1,197,145	1,135,943	3,475,044	2,797,288	49,684
25	48,484	7,572	8,087	375,373	168,043	199,509	344,479	166,483	104,574	518,951	1,151,084	13,323
26	1,241,397	79,079	334,599	33,104,407	19,509,205	66,060,636	6,369,126	1,826,251	22,422,007	23,834,251	28,767,740	2,748,481
27	9,433,145	640,271	1,927,661	9,390,034	80,698,361	5,512,011	16,472,307	70,611,882	27,647,919	54,832,488	54,482,971	10,193,480
28	411,657	55,744	54,422	424,436	5,105,108	662,075	262,610	582,445	2,608,469	44,847,842	82,845,384	115,259
29	458,084	203,466	178,307	122,670	6,269,632	78,142	2,051,151	1,316,248	5,434,403	1,551,602	303,591	53,479
30	1,492,534	8,155,660	3,785,656	9,539,080	30,363,470	32,277	25,828,690	54,600,900	39,079,350	27,772,539	18,568,200	10,090,200
31	630,680	587,397	430,711	1,185,158	3,121,612	23,641	1,829,204	5,958,890	2,769,447	3,018,507	708,105	514,198
32	71,527	424,445	10,180	1,680,767	385,216	65,878,400	6,380,352	7,144,139	1,092,710	9,501,247	4,011,210	4,526,630
33	64,476,987	14,123,304	26,344,115	383,820,350	100,201,049	285,522,900	114,290,410	91,514,270	147,626,600	70,175,941	331,623,000	49,362,250
34	53,313,490	8,542,200	19,433,305	53,439,920	215,839,690	109,231,000	41,014,750	102,414,400	113,471,900	167,076,720	123,693,000	21,029,900
35	38,714,609	7,201,100	9,489,050	30,665,910	75,490,206	1,383,304	18,233,780	63,312,880	63,664,950	39,431,397	30,161,250	9,040,810
36	23,388,609	5,498,891	6,665,825	15,050,362	80,439,876	1,018,238	60,459,626	7,682,584	30,019,510	7,484,719	23,276,170	3,159,063
37	21,274,376	7,340,041	14,990,782	31,145,761	59,465,848	285,500	15,074,139	26,905,022	30,121,229	17,894,739	21,261,770	4,331,227
38	6,539,272	1,194,330	2,042,224	5,641,663	21,000,462	16,244	1,154,167	3,122,538	3,621,918	5,139,420	19,369,952	343,436
39	15,430,188	1,348,258	3,858,092	10,999,230	34,149,878	72,678	4,157,308	15,391,638	16,728,060	8,294,941	30,273,916	2,641,466
40	230,984,800	88,079,600	75,172,530	94,381,650	371,908,790	89,303	40,673,100	83,126,600	128,071,300	170,126,690	162,558,000	20,715,700
41	1,561,496,700	157,660,343	334,205,860	230,774,340	350,774,577	197,946,400	5,019,728	45,748,870	52,647,625	79,255,381	116,876,310	15,266,272
42	220,212,830	50,209,121	277,944,502	51,021,359	149,226,075	576,406	1,756,755	2,463,702	2,496,927	2,347,874	82,875,700	318,239

	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX
43	26,735,396	4,096,977	42,245,220	7,508,416	28,866,539	33,216,305	2,482,787	7,398,379	7,634,263	7,297,457	9,145,504	5,411,518
44	134,270,460	18,770,296	27,587,165	776,639,500	147,972,164	23,366	7,451,494	35,569,860	71,651,760	63,316,945	158,527,100	16,645,470
45	483,343,707	91,877,548	74,229,939	303,795,080	797,521,546	9,742,717	57,593,919	148,938,300	253,644,521	187,884,977	349,509,220	113,842,020
46	0	0	0	0	0	0	0	0	0	0	0	0
47	1,728,070	421,047	932,954	1,114,224	9,528,788	60,834	7,659,318	11,886,448	3,077,262	5,588,739	31,653,900	4,732,031
48	10,705,355	1,957,627	14,040,942	14,761,003	33,443,159	99,236	24,316,673	302,802,000	43,103,902	22,884,213	304,952,000	6,856,550
49	187,406,561	827,657	3,583,163	41,906,527	105,762,384	440,937	3,372,104	9,313,988	483,587,670	10,105,784	28,833,055	3,191,179
50	18,256,395	4,263,589	15,741,077	42,854,403	80,937,215	3,795,711	38,551,255	102,736,715	96,309,596	111,575,329	59,504,201	10,430,878
51	1,839,394	304,273	407,568	2,049,506	2,825,283	79,495	1,157,078	1,649,790	1,409,666	1,042,637	5,054,960	220,950
52	905,612	302,406	355,288	12,136,590	4,627,372	56,397	399,299	887,168	24,637,363	33,014,958	2,237,700	177,529,000
53	3,204,752,864	530,282,006	986,785,872	2,303,936,799	3,611,509,939	918,279,052	662,305,667	1,403,183,289	1,927,438,937	1,411,397,446	2,289,820,722	526,721,869
54												
55	2,001,835,716	241,771,141	374,926,491	334,049,470	2,608,048,722	0	3,244,774,673	4,488,301,571	847,416,552	1,065,520,502	2,716,892,678	547,503,079
56	1,707,529,902	299,334,759	75,345,974	2,576,803,618	1,608,328,302	5,575,345,181	-9,594,259	966,995,717	667,784,679	344,980,348	0	0
57	254,790,887	51,176,508	48,582,253	138,368,947	32,567,141	232,071,527	10,300,707	34,283,688	45,894,953	16,845,706	20,050,750	12,273,314
58	113,659,605	8,208,907	25,093,784	427,715,823	105,408,161	1,028,095,289	49,639,681	160,721,343	88,990,301	41,269,452	187,279,027	11,678,683
59	-139	0	0	0	-392	0	-97	-20,766	-33,283	0	0	0
60	-3,816	0	0	0	-6,981,394	0	-7,022,846	-27,897,455	-98,381,755	0	0	0
61	543,097,655	27,300,855	49,764,585	681,058,716	406,572,594	643,838,740	13,667,982	150,149,390	156,088,586	97,898,062	0	0
62	9,170,838	357,732	91,808	4,294,689	88,434,626	954,630	6,069,476	12,871,986	9,678,353	12,492,873	56,555,824	5,225,462
63	0	0	0	0	0	0	0	0	0	0	0	0
64	135,937,111	20,779,110	34,363,545	106,955,952	631,593,573	209,260,408	47,902,966	494,549,767	246,358,561	376,934,696	591,547,522	57,839,200
65	4,766,017,760	648,929,012	608,168,441	4,269,247,214	5,473,971,333	7,689,565,775	3,355,738,283	6,279,955,241	1,963,796,949	1,955,941,638	3,572,325,801	634,519,737
66	7,970,770,623	1,179,211,018	1,594,954,313	6,573,184,013	9,085,481,271	8,607,844,827	4,018,043,951	7,683,138,529	3,891,235,886	3,367,339,085	5,862,146,524	1,161,241,606

	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH
1										
2		49	50	51	52	53	54	55		
3	***Total intermediate outputs***	Household Consumption	Consumption of Central Government Services	Consumption of Local Government Services	Interregional Exports	International Exports	Net Increases in Stocks	Capital Formation	***Total Final demand***	**Total Gross Output**
4										
5	3,817,103,181	38,707,182	0	0	0	394,675,023	57,477,887	2,333,999	493,194,090	4,310,297,272
6	3,590,879,348	15,427,336	0	0	0	96,703,878	68,904,188	1,507,551	182,542,952	3,773,422,300
7	790,354,264	364,318,009	0	0	0	888,056,918	4,163,383	2,469,752	1,259,008,061	2,049,362,325
8	754,776,908	7,468,636	0	0	0	4,250,795	15,058	45,282,351	57,016,839	811,793,746
9	884,618,291	67,671,435	0	0	0	152,844,843	-430,137	1,192,023	221,278,164	1,105,896,454
10	519,291,024	3,181,048	0	0	0	204,816,917	9,130,291	164,158	217,292,415	736,583,439
11	1,981,316,792	30,124,842	0	0	0	645,277,431	224,172,568	3,927,010	903,501,852	2,884,818,643
12	449,295,168	2,075,254	0	0	0	199,268,104	-108,244	4,869,045	206,104,158	655,399,326
13	619,608,279	22,638,338	0	0	0	141,093,787	3,633,469	7,574,398	174,939,991	794,548,270
14	2,419,784,694	1,236,213,291	0	0	0	3,464,068,501	109,516,449	3,603,489	4,813,401,730	7,233,186,424
15	1,125,427,490	1,037,915,053	0	0	0	3,270,807,653	-323,942,966	6,601,868	3,991,381,607	5,116,809,097
16	1,391,250,329	2,212,206,565	0	0	0	1,518,875,869	39,051,401	13,768,513	3,783,902,348	5,175,152,677
17	510,796,287	1,164,913,108	0	0	0	92,377,685	29,618,883	2,405,072	1,289,314,748	1,800,111,035
18	847,441,107	1,363,000,369	0	0	0	1,830,685,801	67,034,189	8,582,342	3,269,302,701	4,116,743,807
19	2,332,119,179	566,911,966	0	0	0	969,243,589	28,166,964	299,785,825	1,864,108,344	4,196,227,524
20	2,004,978,758	225,668,575	0	0	0	743,237,149	16,633,705	33,134,885	1,018,674,313	3,023,653,072
21	2,230,163,909	545,204,718	0	0	0	91,887,805	22,930,034	2,521,151	662,543,709	2,892,707,618
22	2,012,076,409	822,434,164	0	0	0	550,823,955	41,226,359	26,405,134	1,440,889,612	3,452,966,021
23	2,770,233,685	1,060,393,537	0	0	0	610,360,154	35,361,452	11,400,822	1,717,515,966	4,487,749,651
24	1,572,256,106	121,751,660	0	0	0	85,468,243	9,114,269	22,296,136	238,630,308	1,810,886,413
25	1,113,435,570	13,743,081	0	0	0	669,778,835	-1,050,237	34,272,803	716,744,482	1,830,180,052
26	2,456,928,728	173,799,385	0	0	0	382,420,561	23,771,124	428,433,154	1,008,424,224	3,465,352,952
27	1,736,791,830	419,401,907	0	0	0	1,226,758,642	56,571,851	1,683,348,335	3,386,080,734	5,122,872,563
28	1,023,461,638	727,588,051	0	0	0	303,620,918	55,306,304	1,077,644,912	2,164,160,185	3,187,621,823
29	45,390,180	134,668,213	0	0	0	242,437,955	20,511,312	7,484,264	405,101,745	450,491,925
30	3,798,912,897	1,270,708,679	0	0	0	5,019,695	44,959	10,481,659	1,286,254,991	5,085,167,888
31	331,563,687	97,586,881	0	0	0	787,955	-45,495	3,074,248	101,403,590	432,967,276
32	444,432,142	4,211	0	0	0	59,775	965	70,705	135,656	444,567,798
33	7,970,636,168	1,136,580,175	0	0	0	32,671,107	509,444	7,962,365,488	9,132,126,215	17,102,762,383
34	9,350,664,164	9,000,667,876	0	0	0	3,106,760,207	-5,998,926	2,384,922,276	14,486,351,432	23,837,015,596
35	1,107,433,782	3,447,979,235	0	0	0	1,285,035,599	25,614	30,362,270	4,763,402,718	5,870,836,500
36	2,810,644,351	394,187,830	0	0	0	219,054,055	49,621	7,067,782	620,359,288	3,431,003,639
37	1,614,055,366	84,732,083	0	662,941,874	0	238,330,989	28,294	2,824,629	988,857,869	2,602,913,236
38	1,282,590,494	35,228,799	0	0	0	636,357,452	248,908	8,318,459	680,153,618	1,962,744,112
39	766,945,475	701,969,396	0	0	0	2,080,822,588	251,052	15,241,142	2,798,284,177	3,565,229,652
40	3,994,104,612	1,279,287,283	0	0	0	306,507,300	0	148,830,311	1,734,624,894	5,728,729,506
41	7,887,566,224	40,590,941	0	0	0	35,877,095	8,949	6,727,415	83,204,399	7,970,770,623
42	1,055,642,737	83,471,145	0	0	0	39,363,034	0	734,101	123,568,280	1,179,211,018

	AY	AZ	BA	BB	BC	BD	BE	BF	BG	BH
43	507,089,279	1,074,032,191	0	0	0	10,501,475	0	3,331,368	1,087,865,034	1,594,954,313
44	3,222,826,561	2,535,736,372	0	0	0	40,371,565	2,894	774,246,621	3,350,357,451	6,573,184,013
45	7,816,622,025	266,799,648	0	0	0	331,034,103	25,078	671,000,417	1,268,859,246	9,085,481,271
46	0	8,607,844,827	0	0	0	0	0	0	8,607,844,827	8,607,844,827
47	186,867,814	318,840,138	3,452,387,241	0	0	45,551,418	150,738	14,246,601	3,831,176,137	4,018,043,951
48	1,265,032,376	2,564,321,129	3,784,934,842	0	0	31,163,381	-26,686	37,713,486	6,418,106,153	7,683,138,529
49	1,203,701,544	1,852,562,766	124,066,023	470,244,496	0	230,965,962	342,255	9,352,840	2,687,534,342	3,891,235,886
50	1,609,619,157	1,449,821,856	0	253,043,347	0	44,043,001	248,908	10,562,816	1,757,719,927	3,367,339,085
51	54,770,334	79,931,980	5,625,839,868	0	0	48,074,441	118,211	53,411,689	5,807,376,189	5,862,146,524
52	525,626,220	79,195,200	0	554,542,308	0	1,458,476	11,896	407,506	635,615,387	1,161,241,606
53	97,807,126,563	48,779,506,362	12,987,227,975	1,940,772,025	0	27,549,651,683	592,776,235	15,886,302,818	107,736,237,098	205,543,363,661
54										
55	43,721,000,000	0	0	0	0	0	0	0	0	43,721,000,000
56	31,573,000,000	0	0	0	0	0	0	0	0	31,573,000,000
57	2,082,123,251	6,647,158,436	0	0	0	415,638,927	15,945,110	674,569,827	7,753,312,299	9,835,435,550
58	3,727,474,894	0	0	0	0	0	0	119,089,556	119,089,556	3,846,564,450
59	-2,034,251	0	0	0	0	0	0	0	0	-2,034,251
60	-316,965,749	0	0	0	0	0	0	0	0	-316,965,749
61	9,590,000,000	0	0	0	0	0	0	0	0	9,590,000,000
62	858,905,838	576,199,923	0	0	0	148,412,306	30,328,980	-1,613,847,047	-858,905,838	0
63	0	0	0	0	0	0	0	0	0	0
64	16,502,733,116	7,188,172,930	0	0	0	0	240,949,675	4,464,880,419	11,894,003,024	28,396,736,140
65	107,736,237,098	14,411,531,289	0	0	0	564,051,233	287,223,765	3,644,692,755	18,907,499,042	126,643,736,140
66	205,543,363,661	63,191,037,651	12,987,227,975	1,940,772,025	0	28,113,702,916	880,000,000	19,530,995,573	126,643,736,140	332,187,099,802

5.1.2 46 sector input-output matrices (after removing double counting)

Double counting between physical and monetary measures was identified in several areas. The table below outlines how each ecosystem service is addressed so as to remove any double counting, if appropriate. Specifically, ensuring no double counting requires that direct extraction, distribution/reticulation, output are measured in different units (see Chapter 7).

Table A5-1: Table showing how each ecosystem service is addressed to remove double counting

Ecosystem service	Direct extraction measured in:	Distribution/ reticulation measured in:	Output measured in:	Comments
Water inputs	m^3	$	NA	Double counting is not an issue. Direct water inputs in m^3. Water works sector in input-output table traces water reticulation in dollars.
Land inputs	Ha	NA	NA	No double counting
Energy inputs				
coal	$	J	NA	Double counting is a potential problem. To remove double counting, coal mining activity is included in input-output table, but coal merchants and distribution activities are excluded. This follows the standard approach used in this thesis to account for direct extraction in monetary units.
petroleum fuels (aviation gas, fuel oil, diesel, petrol)	$	J	NA	Petroleum mining is included in the input-output table in $. Delivered energy is measured in physical terms. Potential for double counting still exists in petroleum products distribution. This is difficult to remove because it is not clear from the NZSIC where the petroleum products activity is recorded – it seems that it is split between 'Petroleum, Coal and Basic Chemical Product Manufacturing' and 'wholesale and retail trade').
electricity	$	J	NA	'Electricity generation and distribution' sector is excluded from the input-output table to avoid double counting with physical distribution data (in J).
natural gas	$	J	NA	Gas distribution sector removed from input-output table following the same argument for electricity.
geothermal	NA	J	NA	No double counting.
wood use for energy source	NA	J	NA	By accounting for energy distribution in physical units there is possible double counting with distribution of wood products measured in $. But wood is too dispersed through economic sectors

				to allow meaningful removal from the input-output table of potential double counting.
Mineral inputs	Tonnes	$	NA	Difficult to remove mineral extraction component from the rest of 'other mining' sector of input-output table.
Water discharge	NA	NA	m^3	No double counting.
Water pollutants	NA	NA	m^3	Possible double counting where cost of pollution control is included in input-output table. However, not clear which sector(s) this is in.
Air pollutants	NA	NA	tonnes	Possible double counting where cost of pollution control is included in input-output table. However, not clear which sector(s) this is in.

	A	B	C	D	E	F	G	H	I	J	K	L
1	**1994-95 New Zealand Input-Output Matrix (46 sector transaction matrix)**											
2		in 1994/95 $NZ										
3			1	2	3	4	5	6	7	8	9	10
4			Mixed livestock	Dairy farming	Horticulture	Services to Agriculture	All other farming	Fishing and Hunting	Forestry & Logging	Oil and Gas Exploration	Other mining	Meat Products
5		***Intermediate Inputs***										
6		1 Mixed livestock	479,158,520	268,402,000	16,076,232	1,852,083	62,874,990	81,770	4,941,666	14,652	17,428	1,793,917,920
7		2 Dairy farming	82,059,500	50,511,700	8,144,260	7,208,821	13,402,700	50,876	1,123,038	7,990	9,062	206,194,390
8		3 Horticulture	18,998,860	10,421,530	26,613,290	8,700,463	4,440,721	78,459	927,727	13,625	18,143	11,014,658
9		4 Services to Agriculture	262,867,130	97,248,395	180,709,940	18,995,342	43,879,641	892,474	13,500,424	0	0	1,497,658
10		5 All other farming	72,935,250	30,483,800	6,619,833	1,035,342	103,808,000	37,657	2,127,182	6,606	7,860	235,719,100
11		6 Fishing and Hunting	7,872,548	1,920,352	1,935,713	3,958,926	5,479,012	147,526	13,415	8,736	6,970	348,794
12		7 Forestry & Logging	1,584,963	580,551	1,000,280	1,038,136	732,182	10,257	880,689,075	15,964	31,300	1,012,967
13		8 Oil and Gas Exploration	258,702	210,240	55,142	553	27,871	2,449	14,261	178,766,767	94,340	100
14		9 Other mining	2,322,267	1,493,604	869,177	1,033,498	344,833	25,891	5,362,331	13,768,457	23,537,062	10,145,582
15		10 Meat Products	2,096,530	2,887,441	363,727	546,783	7,276,720	307,975	1,126,120	113,000	100,226	940,233,030
16		11 Dairy Products	938,309	520,516	240,412	259,131	192,340	70,848	350,476	61,414	132,292	1,504,291
17		12 Manufacture of other foo	10,004,545	37,528,151	618,887	1,332,184	17,891,919	4,309,207	7,733,150	314,372	162,986	34,381,528
18		13 Beverage Manufacture	187,666	298,251	42,909	96,383	211,598	36,567	88,569	9,618	20,607	572,247
19		14 Textile Manufacture	15,912,363	2,295,126	2,216,891	3,324,068	498,646	6,403,023	736,685	115,231	407,882	15,498,928
20		15 Wood & Wood Products	4,737,835	1,722,726	18,784,159	406,126	268,241	194,043	2,520,140	141,432	818,275	5,248,165
21		16 Paper Manufacturing	406,607	144,101	46,849,993	8,957,774	345,649	839,718	1,399,561	385,232	1,106,820	69,516,952
22		17 Printing & Publishing	1,022,712	209,296	8,741,370	2,046,547	85,909	643,502	1,544,881	352,106	1,345,385	41,880,400
23		18 Other Chemicals	22,250,223	29,712,799	16,394,096	4,666,634	2,503,998	1,351,069	6,041,112	631,191	4,579,587	97,766,517
24		19 Basic Chemicals	255,168,315	182,571,391	94,706,776	30,765,100	38,426,818	6,408,338	52,171,076	2,044,960	10,383,670	30,634,214
25		20 Non-metallic Minerals	286,514	190,536	2,168,770	5,404,767	100,564	95,826	247,358	397,435	380,511	1,141,609
26		21 Basic Metal Industries	192,944	152,062	37,495	30,042	26,398	114,000	39,319	10,285	271,782	194,715
27		22 Fabricated Metals	42,562,594	40,641,740	3,866,055	4,585,217	4,358,689	2,722,661	8,840,307	3,140,015	8,797,159	15,190,206
28		23 Equipment Manufacture	2,390,941	2,587,708	1,200,868	6,565,538	405,608	2,373,892	16,689,864	2,071,947	16,458,041	33,457,405
29		24 Transport Equipment	1,107,280	1,041,012	446,828	963,397	181,925	14,295,300	313,424	41,234	238,879	843,050
30		25 Other Manufacturing	317,461	181,241	156,359	77,262	23,911	36,048	99,589	20,599	46,561	985,896
31		28 Water works	7,940	11,169	4,563	43,569	2,457	4,365	18,750	272	44,620	40,440,270
32		29 Construction	196,977,142	101,955,190	52,656,184	9,700,536	19,748,776	2,120,741	8,922,626	10,678,041	38,909,235	49,141,055
33		30 Trade	207,438,400	123,584,000	62,875,900	28,863,170	37,676,100	14,106,677	46,652,611	3,796,168	25,055,250	291,260,700
34		31 Accommodation	9,856,279	2,811,070	1,284,109	3,329,955	1,961,361	1,556,938	1,754,321	459,620	3,962,985	15,597,787
35		32 Road Transport	125,474,305	18,271,700	16,418,108	6,979,426	9,380,016	6,105,779	120,259,267	16,818,605	34,424,619	106,431,282
36		33 Services to Transport	15,767,203	10,829,692	3,763,079	3,521,854	3,881,382	2,147,937	27,390,994	5,537,515	4,399,637	49,225,675
37		34 Water Transport	2,937,099	1,452,070	4,409,828	156,977	2,311,328	166,123,703	1,522,882	2,115,305	3,060,994	16,691,228
38		35 Air Transport	1,326,519	1,025,827	1,472,174	1,195,337	949,227	997,884	2,174,446	465,966	1,044,250	9,317,745
39		36 Communications	20,537,380	10,961,100	7,335,820	3,653,824	6,071,730	1,360,634	5,252,869	1,523,751	4,172,744	42,530,000
40		37 Finance	88,848,120	73,196,400	36,500,680	17,785,775	22,152,120	10,887,280	46,592,277	21,416,527	7,724,849	114,962,420
41		38 Finance services	173,277	2,779,799	513,701	1,595,971	1,465,261	66,718	149,622	94,282	66,784	5,220,797

	A	B	C	D	E	F	G	H	I	J	K	L
42		39 Insurance	16,860,762	10,327,982	3,827,800	2,265,314	3,458,082	1,805,178	2,492,748	2,874,828	833,217	11,362,924
43		40 Real Estate	39,457,236	55,113,810	20,971,754	516,550	12,013,020	439,790	3,332,734	638,172	731,251	40,272,145
44		41 Business Services	80,592,040	21,314,060	29,893,614	42,974,841	21,508,340	12,136,054	38,072,178	38,792,865	21,372,792	225,123,047
45		42 Dwelling ownership	0	0	0	0	0	0	0	0	0	0
46		43 Education	1,837,103	1,160,088	276,286	108,964	348,659	9,114	39,841	25,823	54,204	1,940,680
47		44 Community Services	6,083,471	5,465,782	403,596	126,597	1,392,443	43,264	193,799	61,812	286,882	1,115,481
48		45 Recreation Services	10,474,273	21,014,552	11,173,084	767,417	7,556,853	282,147	450,131	254,839	195,964	24,226,363
49		46 Personal Services	70,424,653	82,410,034	26,709,635	3,696,996	11,355,773	974,035	13,060,875	1,126,853	2,259,030	17,345,831
50		47 Central Government	5,854,864	6,076,370	2,375,274	630,333	2,056,180	416,999	1,426,352	1,002,937	1,685,407	8,763,487
51		48 Local Government	2,074,127	824,791	715,678	941,480	1,678,010	101,948	763,041	22,907	24,621	944,248
52		*Total*	2,190,642,772	1,314,541,754	722,440,327	242,705,002	474,756,000	263,216,560	1,329,163,113	310,159,958	219,282,163	4,620,813,487
53												
54		49 Compensation of Emplo'	296,705,300	193,845,000	281,320,700	179,075,400	62,091,500	55,880,300	167,922,950	68,947,110	99,276,019	782,583,300
55		50 Operating Surplus	944,337,000	1,018,220,000	307,867,700	163,636,600	235,069,000	157,731,450	1,033,502,670	356,212,500	98,745,807	77,563,300
56		51 Commodity Indirect Tax	62,137,860	33,260,900	11,556,650	8,791,150	7,312,830	6,005,960	22,216,336	15,631,792	9,560,223	20,292,280
57		52 Non-Commodity Indirect	162,924,000	77,719,400	32,428,100	9,568,120	17,914,300	18,000,426	17,352,077	8,172,000	10,225,924	14,682,170
58		53 Commodity Subsidies	-1,028,200	-976,500	0	0	0	-100	0	0	0	-200
59		54 Non-Commodity Subsidi	-3,741,800	-3,049,500	-4,383,000	-3,354,900	-1,132,000	-5,050,400	-4,575,800	0	0	-4,917,100
60		55 Consumption of Fixed C	267,484,600	189,265,000	106,629,400	50,208,490	60,122,200	45,772,087	35,787,486	176,810,060	56,916,700	98,981,500
61		56 Second Hand Assets	0	0	0	0	0	0	0	0	0	0
62		57 Interregional Imports	0	0	0	0	0	0	0	0	0	0
63		58 International Imports	204,731,969	145,195,180	86,165,390	48,686,626	61,088,560	159,190,223	68,709,955	19,389,388	48,610,231	325,075,784
64		*Total primary inputs*	1,933,550,729	1,653,479,480	821,584,940	456,611,486	442,466,390	437,529,946	1,340,915,674	645,162,850	323,334,904	1,314,261,034
65		***Total***	4,124,193,501	2,968,021,234	1,544,025,267	699,316,488	917,222,390	700,746,505	2,670,078,788	955,322,808	542,617,067	5,935,074,521

	M	N	O	P	Q	R	S	T	U	V	W	X
1												
2												
3	11	12	13	14	15	16	17	18	19	20	21	22
4	Dairy Products	Manufacture of other food	Beverage Manufacture	Textile Manufacture	Wood & Wood Products	Paper Manufacturing	Printing & Publishing	Other Chemicals	Basic Chemicals	Non-metallic Minerals	Basic Metal Industries	Fabricated Metals
5												
6	78,321,318	65,618,678	14,983,325	766,457,199	3,410,007	1,221,709	599,828	5,695,295	332,936	290,349	97,772	948,260
7	2,261,408,500	19,722,209	5,719,999	75,787,225	893,388	294,790	323,109	1,488,140	159,347	162,483	69,357	512,490
8	6,518,959	126,565,733	63,665,809	4,516,059	1,166,905	238,275	276,612	491,979	206,050	181,442	41,751	429,216
9	1,008,284	615,546	243,854	1,034,383	44,155	15,093	0	20,628	96	101	0	0
10	21,007,002	141,038,706	29,179,595	24,859,211	1,259,388	442,794	235,142	11,411,437	138,622	113,098	37,712	369,396
11	9,435	431,808,685	64,098	3,502,275	25,354	28,914	28,912	892,086	28,994	19,169	9,471	34,796
12	2,728,186	594,845	138,443	79,412	485,703,417	186,824,613	70,290	188,658	81,110	37,302	29,346	65,464
13	0	0	0	0	36,862	0	631	0	315,349,713	0	0	0
14	13,996,414	3,259,486	918,889	1,282,766	497,022	416,877	179,215	4,596,869	84,615,411	100,394,337	85,334,425	1,324,689
15	5,637,797	86,344,863	3,148,527	143,176,197	1,892,191	960,879	509,226	2,730,297	15,713,708	365,281	270,626	1,029,611
16	100,738,399	32,010,502	3,159,104	799,573	912,032	650,943	400,357	1,779,967	1,025,134	343,264	318,909	580,372
17	134,018,006	608,457,438	49,029,313	3,605,013	2,062,510	1,554,273	688,962	10,369,660	3,883,000	523,200	217,355	3,726,965
18	879,686	4,203,479	81,071,289	175,891	218,284	132,252	74,593	181,962	244,673	63,167	60,494	131,958
19	1,153,881	19,822,098	9,771,755	953,527,965	39,218,446	3,432,453	2,504,955	10,175,121	6,944,563	1,573,323	1,492,567	10,019,516
20	6,096,488	6,299,125	4,952,041	4,134,105	603,031,061	49,481,451	9,353,031	9,776,415	4,004,200	10,666,719	3,026,663	35,259,493
21	46,959,780	82,790,403	33,403,087	19,849,480	43,251,615	452,387,090	285,239,800	47,452,738	15,639,941	16,791,692	2,644,763	14,705,811
22	54,282,070	41,589,468	16,011,190	6,524,805	8,170,004	72,428,500	309,748,000	20,523,628	4,662,486	5,456,827	519,220	11,427,791
23	56,570,697	90,731,688	33,903,104	39,935,288	43,374,625	25,087,048	52,713,288	145,689,062	46,868,270	8,935,380	3,511,522	39,947,344
24	28,147,639	31,071,944	14,487,863	40,332,802	57,162,958	29,344,857	8,882,100	230,443,507	467,620,999	17,829,286	27,291,534	21,118,501
25	16,329,762	15,775,052	67,672,804	432,339	18,693,122	404,214	145,640	5,705,098	3,671,294	198,311,210	2,350,876	23,015,303
26	98,899	324,915	286,212	812,005	3,476,074	1,339,733	747,232	2,542,449	6,620,066	3,232,436	111,786,110	208,501,720
27	13,797,992	46,928,507	39,589,610	4,619,104	76,029,825	7,382,998	2,932,093	30,487,398	6,391,653	26,364,483	34,113,308	206,257,403
28	23,363,454	27,079,825	5,226,062	10,419,708	29,834,737	45,002,265	8,401,177	9,047,212	18,179,434	9,848,832	11,313,660	39,487,244
29	725,585	1,313,046	1,007,307	343,141	2,731,570	787,444	211,889	766,949	482,172	1,217,213	1,685,145	3,869,072
30	536,337	870,350	478,998	7,857,417	487,659	201,688	4,315,693	710,236	237,857	298,865	56,054	480,380
31	5,577,448	12,847,478	7,853,410	6,903,813	990,141	15,622,569	7,095	1,958,761	2,872,825	6,099,618	926,122	2,923,858
32	13,803,775	37,600,050	4,924,325	33,469,015	68,978,276	8,510,300	12,041,353	23,505,608	55,304,544	60,413,239	44,682,498	22,144,415
33	106,508,630	275,012,200	206,346,200	204,798,534	215,327,970	120,518,400	72,972,100	158,203,290	307,049,300	85,367,360	169,320,200	273,967,100
34	10,923,627	17,781,245	10,890,992	12,030,680	18,006,437	12,051,908	11,395,570	18,587,142	9,538,231	6,260,696	6,809,005	13,698,334
35	95,500,639	131,896,061	39,502,775	33,272,535	109,598,263	94,723,125	48,670,260	46,223,345	26,560,670	27,509,356	11,851,133	38,863,276
36	26,635,987	33,647,185	13,771,893	12,013,915	45,336,939	28,344,020	8,098,049	21,592,087	7,566,196	12,747,821	10,185,736	25,288,000
37	22,016,664	67,177,210	3,537,595	8,287,784	17,305,777	66,116,383	5,237,442	11,301,971	15,588,402	14,177,966	13,818,073	8,986,392
38	3,358,641	8,707,882	2,500,055	7,584,102	7,999,604	9,894,668	4,166,067	6,933,805	2,509,099	2,348,496	1,701,844	5,916,121
39	17,406,340	36,374,025	11,141,880	27,388,207	30,553,426	14,776,600	45,680,800	25,099,600	11,253,591	9,880,495	5,923,110	26,504,490
40	95,018,611	155,888,997	58,367,777	88,435,502	85,480,896	83,414,870	75,225,100	97,416,953	56,940,802	34,566,624	39,199,300	90,726,919
41	852,368	13,313,460	1,114,264	1,591,582	1,065,501	4,969,188	4,726,970	9,757,947	4,675,089	337,431	33,566	5,825,447

	M	N	O	P	Q	R	S	T	U	V	W	X
42	4,969,260	8,182,568	1,588,816	4,648,083	8,478,217	6,271,112	5,188,457	5,544,750	6,111,948	2,625,839	2,115,786	5,040,287
43	5,527,578	19,850,467	3,259,169	30,289,124	35,482,977	11,422,857	26,297,030	28,890,660	11,331,481	11,562,036	4,973,735	36,787,628
44	48,464,818	124,273,901	26,345,109	88,474,943	79,666,871	3,710,026	109,291,979	127,187,021	59,347,345	57,035,491	43,803,841	92,347,713
45	0	0	0	0	0	0	0	0	0	0	0	0
46	84,773	1,466,809	696,209	372,585	314,983	87,188	1,659,595	941,107	480,212	155,679	527,449	304,829
47	345,763	530,523	175,355	508,502	481,502	308,221	716,499	684,383	262,157	157,508	420,867	381,770
48	560,929	10,303,879	3,988,414	1,848,432	2,854,376	1,922,116	2,759,943	10,769,622	1,918,950	1,540,993	501,478	2,021,804
49	18,901,261	12,637,711	9,509,071	8,871,713	11,439,932	9,588,041	13,615,473	9,185,217	8,073,704	6,871,031	5,420,409	8,052,342
50	1,241,909	3,958,709	1,096,605	5,190,703	5,088,826	1,161,649	5,788,390	4,717,525	2,258,471	1,942,748	1,216,885	3,996,376
51	896,488	757,237	230,536	936,564	262,080	678,437	2,586,940	389,747	198,791	137,977	87,855	305,326
52	3,352,930,079	2,857,044,187	884,952,725	2,690,979,681	2,168,296,205	1,374,152,832	1,144,706,886	1,162,057,332	1,592,943,534	744,757,865	649,797,529	1,287,325,219
53												
54	414,534,200	719,264,000	170,378,500	607,212,370	714,550,700	447,404,700	753,224,000	628,293,600	276,594,900	268,318,310	345,873,000	675,138,500
55	80,494,780	440,271,460	153,434,900	190,567,260	259,690,670	322,918,700	277,840,000	333,737,600	427,129,700	189,413,900	108,687,700	353,693,700
56	18,544,560	21,224,489	40,871,250	6,628,753	21,703,762	16,605,680	8,991,520	14,629,153	55,670,870	7,501,800	4,963,200	9,142,007
57	29,142,500	31,428,015	10,478,390	14,616,251	17,591,080	14,598,060	16,719,900	20,987,136	13,343,700	16,434,622	10,444,550	17,522,460
58	0	-100	0	0	0	0	0	0	0	0	0	0
59	0	-4,942,400	-328,600	-7,958,000	0	-2,053,700	-11,700	0	0	0	0	-447,500
60	236,374,660	146,942,560	60,624,230	63,764,154	117,837,020	185,052,500	111,462,000	113,643,130	258,031,000	74,066,420	162,861,900	81,338,980
61	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0
63	150,342,423	453,517,009	139,292,662	628,826,897	345,618,234	281,554,160	224,793,020	768,642,019	1,335,278,421	172,435,349	257,244,001	506,449,264
64	929,433,123	1,807,705,033	574,751,332	1,503,657,685	1,476,991,466	1,266,080,100	1,393,018,740	1,879,932,638	2,366,048,591	728,170,401	890,074,351	1,642,837,411
65	4,282,363,201	4,664,749,220	1,459,704,057	4,194,637,366	3,645,287,671	2,640,232,932	2,537,725,626	3,041,989,970	3,958,992,125	1,472,928,266	1,539,871,880	2,930,162,630

	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1												
2												
3	23	24	25	28	29	30	31	32	33	34	35	36
4	Equipment Manufacture	Transport Equipment	Other Manufacturing	Water works	Construction	Trade	Accommodation	Road Transport	Services to Transport	Water Transport	Air Transport	Communications
5												
6	1,304,484	407,012	170,752	38,265	610,773	18,612,460	10,182,034	658,037	935,630	558,578	558,176	7,446,360
7	686,637	229,850	99,246	21,131	335,651	11,497,000	5,891,430	349,088	490,451	297,372	344,837	3,998,390
8	615,092	262,786	333,430	53,731	812,082	26,980,950	65,246,550	311,335	399,347	1,627,960	4,729,951	2,961,285
9	238	0	1,003	87	34,669	560,742	229,158	0	0	6,098	22,770	0
10	527,562	141,897	72,423	19,586	288,759	7,604,010	13,613,600	255,645	370,004	430,055	744,817	2,871,840
11	59,597	25,929	1,501,200	18,005	267,645	415,852	13,587,857	40,009	37,378	570,789	2,001,097	44,268
12	147,082	59,758	14,152	42,772	363,184	19,213,534	222,866	72,818	99,408	53,339	137,809	195,693
13	3,299	95	0	1,183	1,302,880	37,624,955	405	983	115	227,812	1,216	0
14	621,496	273,762	17,674,901	24,793	11,637,467	2,409,786	410,247	753,334	277,188	432,589	83,945	2,789,250
15	1,374,819	769,463	1,633,034	155,384	3,300,078	12,359,140	411,730,600	1,486,160	792,245	4,809,500	19,945,298	416,213
16	936,870	1,028,806	112,491	77,423	3,320,935	144,094,000	68,327,130	929,447	159,021	2,481,200	8,176,176	470,606
17	5,185,392	1,106,271	193,283	217,488	5,156,549	12,409,426	404,810,960	875,575	475,433	12,072,037	32,912,796	118,834
18	369,641	235,770	21,212	30,001	947,724	23,809,630	342,430,300	113,794	27,002	1,150,825	6,396,216	23,889
19	10,090,898	2,673,005	2,613,432	233,615	28,164,706	65,458,518	7,077,136	4,287,678	835,614	1,086,491	1,942,189	2,068,080
20	84,409,217	49,533,465	2,883,677	254,075	846,325,553	50,783,370	9,897,959	802,129	1,979,309	839,719	203,618	1,572,359
21	39,984,141	5,252,571	7,603,447	1,169,620	60,250,132	306,326,500	8,149,040	3,858,947	5,713,034	1,464,816	2,210,073	1,701,760
22	39,819,550	6,659,172	789,123	1,711,230	58,344,400	222,932,000	30,316,600	7,272,432	16,695,560	837,044	19,022,297	15,523,200
23	65,494,582	34,726,868	13,498,582	533,815	218,424,722	260,188,450	14,817,789	52,554,742	5,544,412	3,860,350	11,091,441	15,912,751
24	58,014,837	9,086,526	6,506,654	1,695,854	271,472,174	179,317,341	11,526,543	156,620,888	8,387,269	23,100,862	53,564,013	31,497,844
25	9,507,065	18,227,469	1,059,247	8,490,413	835,077,600	12,367,114	10,112,869	365,396	168,566	151,257	490,395	509,023
26	98,600,238	40,212,077	10,071,817	482,295	37,605,887	556,921,000	148,361	94,364	14,388	45,940	1,051,415	84,403
27	149,638,975	36,821,673	4,253,756	5,045,614	895,313,620	54,255,130	14,403,072	1,275,127	1,288,332	2,133,195	946,674	1,366,329
28	294,647,981	26,998,002	1,588,121	866,133	218,437,329	108,768,914	9,472,387	19,532,879	4,707,042	7,461,283	7,595,464	17,487,893
29	8,006,848	597,048,176	153,614	73,780	7,737,187	151,635,414	893,085	97,222,024	371,002	16,099,795	65,125,601	1,337,339
30	803,729	274,161	4,445,267	45,893	2,913,581	6,956,099	242,298	486,265	273,362	42,199	167,942	279,966
31	1,522,308	849,493	10,818	100,108,000	2,102,259	7,407,120	5,031,140	4,461,404	1,474,221	80,748	32,657	4,495,740
32	38,715,618	6,932,974	5,525,960	7,322,218	2,585,329,300	179,071,970	93,469,351	24,899,296	505,631,730	74,327,845	19,600,013	25,153,960
33	332,066,130	264,460,590	35,408,434	6,856,300	853,223,000	1,401,160,000	205,525,000	250,067,900	35,691,700	45,736,925	129,589,860	109,195,000
34	37,566,798	7,925,634	2,729,286	1,602,269	53,121,020	146,266,700	51,900,620	16,550,690	11,978,849	9,044,223	73,438,963	22,284,920
35	49,719,977	9,999,206	5,185,311	1,326,390	54,174,041	493,579,700	6,143,060	299,939,763	15,673,798	43,043,359	25,738,906	33,251,927
36	27,739,643	10,128,620	2,590,061	1,558,093	22,870,491	252,176,859	5,970,316	75,377,702	54,694,234	25,321,254	204,721,173	8,715,396
37	12,727,629	5,940,942	1,365,131	344,340	7,529,266	194,152,508	4,138,695	27,123,290	2,291,030	168,136,370	12,588,320	23,313,421
38	14,025,501	7,670,345	1,359,294	294,067	12,045,179	95,594,161	2,965,447	18,166,398	50,785,721	7,105,000	209,050,465	20,220,733
39	67,169,705	15,227,974	3,704,481	975,971	114,677,800	532,432,000	74,592,100	49,204,950	101,127,960	9,135,246	27,423,540	175,483,000
40	122,511,736	67,332,527	9,850,395	462,413	429,247,500	992,870,000	121,609,420	86,787,220	23,851,090	29,914,935	68,118,207	110,950,700
41	8,088,609	5,295,520	28,183	396,137	43,334,265	92,598,270	2,686,812	2,454,516	6,126,235	120,823	1,610,542	971,622

	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
42	8,089,897	3,305,994	963,275	501,092	18,466,126	66,887,200	11,241,829	13,982,959	5,370,808	1,981,230	9,674,826	25,893,358
43	49,110,787	16,144,958	6,312,337	1,631,511	35,583,862	576,667,300	122,579,380	25,704,869	35,651,342	15,786,726	13,508,320	285,518,500
44	188,312,191	67,701,822	18,262,716	9,657,960	479,306,059	836,271,937	161,394,187	101,190,734	171,059,447	79,377,382	254,997,003	126,598,520
45	0	0	0	0	0	0	0	0	0	0	0	0
46	1,683,381	169,687	189,759	625,038	1,578,529	4,354,750	656,603	137,449	1,712,697	518,048	9,557,153	2,316,731
47	1,058,813	171,488	70,506	596,181	2,086,945	5,731,270	1,045,591	315,652	972,094	334,593	33,466,732	2,307,382
48	15,337,801	2,203,533	359,505	1,046,960	12,207,787	46,434,342	10,778,108	2,415,602	7,591,262	1,345,700	14,421,299	9,621,513
49	21,443,006	11,671,482	1,892,297	5,832,080	95,136,245	143,861,043	59,719,812	60,399,288	9,944,807	4,567,326	15,004,354	65,183,587
50	7,475,594	2,454,660	786,120	619,605	36,082,840	49,213,200	9,601,550	4,031,474	33,487,463	6,489,421	53,320,060	21,487,100
51	595,310	160,392	33,214	44,502,100	156,880,630	4,110,420	1,196,636	5,633,759	1,608,242	159,622	3,762,153	1,152,120
52	1,875,810,702	1,337,802,404	173,920,948	207,560,912	8,523,428,433	8,414,342,085	2,405,985,930	1,419,064,009	1,126,765,841	604,367,882	1,419,090,772	1,184,792,803
53												
54	789,958,010	404,856,270	83,405,935	42,200,000	1,766,642,000	5,880,950,000	1,007,675,000	668,281,000	359,417,300	506,711,040	571,326,000	957,095,000
55	614,052,260	87,947,200	63,186,189	45,700,100	675,419,400	3,520,180,000	635,949,000	325,718,100	283,650,000	224,187,000	382,802,600	1,012,080,000
56	14,255,020	3,163,481	1,276,174	705,450	63,025,650	144,533,000	139,883,200	115,455,790	7,952,211	21,207,264	30,070,860	26,909,200
57	18,539,774	8,803,186	2,294,081	357,850	65,829,200	375,862,000	74,116,800	21,558,150	25,964,240	27,043,146	17,420,300	16,784,100
58	-100	0	0	0	-600	-1,800	-11,300	0	0	0	0	0
59	-12,470,600	-40,700	0	0	-8,288,500	-33,733,500	-2,765,000	-74,254,700	-6,701,200	-357,700	-130,400	0
60	121,927,420	55,502,818	11,261,529	12,594,700	307,395,500	854,168,000	173,211,300	252,515,800	225,071,240	103,277,510	163,854,190	572,310,000
61	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0
63	855,973,016	981,365,791	67,305,890	13,037,883	1,256,998,140	1,361,084,000	336,672,290	187,852,450	98,109,777	162,920,128	565,713,674	119,110,680
64	2,402,234,800	1,541,598,046	228,729,797	114,595,983	4,127,020,790	12,103,041,700	2,364,731,290	1,497,126,590	993,463,568	1,044,988,388	1,731,057,224	2,704,288,980
65	4,278,045,502	2,879,400,450	402,650,745	322,156,895	12,650,449,223	20,517,383,785	4,770,717,220	2,916,190,599	2,120,229,409	1,649,356,270	3,150,147,996	3,889,081,783

	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
1												
2												
3	37	38	39	40	41	42	43	44	45	46	47	48
4	Finance	Finance services	Insurance	Real Estate	Business Services	Dwelling ownership	Education	Community Services	Recreation Services	Personal Services	Central Government	Local Government
5												
6	2,980,818	451,044	554,404	1,436,904	3,552,944	0	1,300,344	3,828,094	2,850,742	1,368,194	3,083,883	96,840
7	1,615,146	250,461	299,856	763,604	1,825,109	0	420,411	1,348,806	1,546,180	731,166	1,675,340	50,029
8	1,538,066	181,411	287,135	595,527	2,288,000	0	460,699	5,250,208	6,222,555	649,959	1,320,353	422,113
9	1,468	0	111	546,415	15,800	0	3,323,360	3,320,772	23,723,477	59,327	1,007,939	105,168
10	1,176,695	169,762	222,288	542,280	1,551,191	0	1,906,896	1,161,047	4,822,002	559,845	1,834,860	72,809
11	156,928	10,952	32,426	48,929	164,284	3,873	120,249	1,291,922	227,573	53,904	2,940,810	287,946
12	236,263	37,407	36,407	135,475	404,417	22,596	228,279	5,259,133	1,778,093	123,304	2,847,528	112,801
13	3,752	0	1,736	1,394	5,287	0	178,939	225,242	477,084	267,883	247,821	653,305
14	144,274	22,044	27,616	568,988	371,867	139,841	38,382	5,729,204	308,677	334,009	2,438,450	846,760
15	1,109,784	98,185	328,623	359,486	1,754,598	1,005,450	981,403	12,868,730	3,889,733	910,957	946,619	1,075,878
16	675,361	48,184	173,482	258,570	1,157,387	520,631	341,675	6,421,656	1,807,632	560,882	1,824,601	636,903
17	1,936,418	48,236	366,360	211,751	8,284,475	424,745	3,866,135	30,731,789	21,087,104	1,254,950	7,076,686	1,814,392
18	153,609	1,932	43,014	27,607	240,529	110,191	138,325	2,292,474	6,240,760	176,872	264,887	235,930
19	2,231,098	200,541	567,500	3,888,175	10,693,083	53,245,342	1,569,926	34,630,229	24,174,608	3,993,038	12,606,420	369,456
20	2,664,586	277,724	570,135	2,713,976	13,191,297	70,349,335	18,114,508	3,090,729	5,881,213	18,065,902	7,083,937	149,029
21	25,990,127	7,314,623	7,760,289	10,325,273	62,564,573	24,958,840	24,609,616	28,573,008	16,977,716	14,158,949	16,569,357	2,874,892
22	34,266,120	33,308,690	9,929,936	63,282,100	538,250,410	792,947	83,596,920	58,818,000	65,042,190	28,377,720	70,410,400	6,289,810
23	3,399,197	927,780	840,550	4,811,175	55,518,818	22,267,794	19,133,609	86,760,154	28,713,442	103,726,672	44,165,974	1,955,839
24	2,285,962	1,697,497	3,092,963	8,399,689	32,090,221	7,736,820	24,603,097	38,625,795	40,178,595	44,027,872	32,563,636	14,250,304
25	260,151	20,198	51,665	8,079,634	5,617,486	34,762,001	2,934,863	1,930,227	1,209,357	3,341,434	2,938,036	46,144
26	52,395	8,622	7,648	347,205	186,635	356,331	418,200	297,900	114,467	453,204	1,372,768	14,047
27	1,282,920	87,557	344,691	22,433,999	18,016,554	98,957,220	9,190,973	2,883,973	20,257,206	20,591,404	26,816,150	2,185,409
28	6,508,142	622,549	686,786	7,111,358	47,875,074	7,705,650	6,281,805	44,983,819	6,979,302	37,610,614	23,718,690	5,036,318
29	461,800	63,743	59,333	384,323	4,775,242	954,750	277,014	1,057,814	2,248,732	53,071,686	96,734,033	104,591
30	739,358	275,018	245,736	250,516	10,422,335	196,004	3,657,174	3,505,658	7,381,519	2,281,324	504,686	82,049
31	51,772	241,692	6,817	897,504	273,352	78,239,600	5,680,011	8,269,218	820,167	6,442,517	3,106,920	3,103,350
32	52,850,473	11,123,140	20,534,205	284,538,280	80,194,901	383,507,500	116,967,239	125,434,610	121,575,428	51,112,473	264,380,000	37,521,984
33	46,872,280	7,158,616	15,734,157	37,388,900	195,492,000	157,305,000	43,770,170	146,628,300	99,825,460	138,001,810	116,175,000	17,482,700
34	34,530,596	6,279,802	7,572,755	22,213,290	68,185,282	1,980,877	20,294,360	93,076,400	58,839,120	25,289,764	27,746,060	7,608,650
35	17,784,105	3,967,759	4,640,326	9,388,126	70,119,989	1,473,852	58,922,053	10,509,766	23,812,429	5,294,630	20,141,430	2,287,065
36	14,373,647	1,621,768	5,819,438	3,489,203	38,434,283	349,674	12,386,245	28,044,377	20,432,737	9,815,171	10,530,006	1,797,610
37	4,301,527	852,371	1,157,432	3,345,930	16,720,821	18,454	913,167	3,659,599	2,526,286	3,161,664	15,410,655	224,479
38	12,432,010	1,185,280	2,665,884	7,440,716	28,121,007	96,691	3,747,785	20,900,811	13,890,978	5,279,294	26,213,303	1,946,645
39	144,846,000	52,101,800	40,283,422	46,507,420	231,775,910	91,170	29,318,300	87,121,700	80,249,900	87,382,040	108,229,000	12,207,700
40	1,100,085,700	120,545,368	239,200,345	142,324,280	265,491,375	246,652,300	4,840,599	57,729,840	40,732,790	56,941,761	93,084,790	10,224,717
41	205,647,654	50,761,630	284,159,024	41,631,760	139,027,647	1,077,608	2,478,725	4,425,066	2,747,346	1,928,002	86,081,800	327,062

	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
42	25,020,524	4,012,276	32,665,654	7,706,489	25,193,653	47,268,540	2,661,703	11,159,406	7,217,087	6,161,137	9,762,413	4,469,857
43	116,659,920	17,902,654	22,012,078	514,880,600	127,092,348	36,275	7,610,946	53,319,040	63,514,770	52,588,996	148,607,600	11,219,540
44	395,827,144	76,216,033	60,270,467	255,593,105	660,840,648	13,422,984	53,553,691	200,393,844	213,092,513	127,939,698	312,083,950	90,248,480
45	0	0	0	0	0	0	0	0	0	0	0	0
46	486,137	126,489	207,837	640,400	2,735,921	34,483	14,445,051	6,992,653	1,113,325	519,866	21,256,620	1,095,807
47	1,031,161	180,956	2,962,874	780,738	1,858,789	7,616	3,930,706	111,701,440	7,260,776	411,117	73,638,230	230,246
48	154,839,735	802,106	2,496,068	30,113,957	85,533,041	439,926	3,269,002	12,323,265	362,294,504	6,341,356	23,976,379	2,365,889
49	15,266,948	3,463,280	12,222,255	29,978,963	66,387,576	4,852,849	35,636,791	138,931,252	80,090,306	81,272,174	47,633,034	8,943,938
50	14,709,580	2,533,018	3,041,320	15,189,950	21,949,675	1,039,880	10,997,340	22,400,200	11,158,530	7,508,133	43,125,300	1,668,440
51	933,385	317,280	346,487	11,810,570	4,640,806	94,872	489,738	1,524,847	26,414,217	31,426,809	2,455,090	172,400,000
52	2,450,420,737	407,517,478	784,529,535	1,603,384,536	2,950,886,637	1,262,500,510	639,606,422	1,529,432,016	1,531,748,628	1,041,569,482	1,816,631,444	427,142,922
53												
54	1,526,506,000	294,831,100	399,880,550	293,031,700	2,106,943,000	0	2,872,404,000	3,425,837,000	713,944,500	884,517,000	2,712,970,000	531,497,000
55	1,304,684,600	259,061,500	95,144,710	2,435,750,000	1,409,158,800	5,052,060,000	-9,869,800	830,285,000	581,670,700	344,990,700	0	0
56	187,238,800	55,280,800	56,586,050	119,406,300	25,621,410	191,382,000	9,071,260	24,811,360	36,905,290	14,711,470	19,670,200	11,705,300
57	85,572,200	10,490,783	24,830,214	365,629,000	83,420,350	838,826,000	43,326,070	109,644,300	70,482,690	33,136,920	181,772,000	11,019,800
58	-100	0	0	0	-400	0	-100	-19,700	-33,700	0	0	0
59	-2,900	0	0	0	-6,862,800	0	-8,832,900	-24,897,200	-97,703,400	0	0	0
60	391,058,400	34,699,730	55,376,270	597,642,300	317,861,600	544,595,000	12,531,820	103,567,000	126,929,400	86,281,080	0	0
61	0	0	0	0	0	0	0	0	0	0	0	0
62	0	0	0	0	0	0	0	0	0	0	0	0
63	105,615,123	24,154,604	39,877,662	95,536,760	536,021,891	175,372,530	42,608,719	396,763,891	211,120,400	346,671,241	606,427,600	59,057,400
64	3,600,672,123	678,518,517	671,695,456	3,906,996,060	4,472,163,851	6,802,235,530	2,961,239,069	4,865,991,651	1,643,315,880	1,710,308,411	3,520,839,800	613,279,500
65	6,051,092,859	1,086,035,995	1,456,224,991	5,510,380,595	7,423,050,487	8,064,736,040	3,600,845,491	6,395,423,667	3,175,064,508	2,751,877,892	5,337,471,244	1,040,422,422

	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF
1										
2										
3		49	50	51	52	53	54	55		
4	***Total intermediate outputs***	Household Consumption	Consumption of Central Government Services	Consumption of Local Government Services	Interregional Exports	International Exports	Net Increases in Stocks	Capital Formation	***Total Final demand***	**Total Gross Output**
5										
6	3,628,300,708	27,969,429	0	0	0	383,819,530	107,479,158	1,919,634	521,187,750	4,149,488,458
7	2,770,020,567	17,061,100	0	0	0	95,148,400	128,646,785	1,239,590	242,095,875	3,012,116,442
8	409,076,790	272,921,000	0	0	0	860,886,000	7,865,812	2,033,396	1,143,706,208	1,552,782,999
9	655,531,746	5,125,799	0	0	0	4,431,625	33,016	37,120,988	46,711,427	702,243,173
10	723,832,607	49,983,300	0	0	0	148,371,000	-725,997	980,510	198,608,813	922,441,420
11	482,053,598	3,462,055	0	0	0	198,522,076	17,058,312	135,042	219,177,485	701,231,082
12	1,595,080,878	31,254,420	0	0	0	625,571,370	418,519,291	3,230,271	1,078,575,352	2,673,656,230
13	536,043,018	1,133,079	0	0	0	193,065,800	-189,864	4,001,786	198,010,801	734,053,819
14	404,077,968	8,382,950	0	0	0	104,414,817	5,185,651	4,752,012	122,735,430	526,813,398
15	1,700,932,134	743,933,000	0	0	0	3,358,223,000	204,769,668	2,966,536	4,309,892,204	6,010,824,338
16	391,529,658	1,390,404,000	0	0	0	3,171,457,900	-604,478,509	5,437,192	3,962,820,583	4,354,350,241
17	1,485,049,709	1,670,330,700	0	0	0	1,473,258,980	73,120,996	11,338,218	3,228,048,894	4,713,098,602
18	474,484,280	847,713,000	0	0	0	89,982,680	55,449,605	1,980,983	995,126,268	1,469,610,547
19	1,381,746,262	929,412,840	0	0	0	1,774,444,330	125,727,825	7,063,154	2,836,648,149	4,218,394,411
20	1,972,558,751	480,540,910	0	0	0	939,035,920	52,627,264	246,246,290	1,718,450,384	3,691,009,136
21	1,877,429,950	140,258,100	0	0	0	720,513,900	32,604,390	27,254,520	920,630,910	2,798,060,861
22	2,021,503,947	384,712,000	0	0	0	89,986,700	46,744,093	2,073,580	523,516,373	2,545,020,320
23	1,842,034,050	588,064,400	0	0	0	534,319,300	77,144,462	21,724,209	1,221,252,371	3,063,286,421
24	2,737,357,903	636,566,610	0	0	0	592,232,000	66,671,473	9,377,189	1,304,847,271	4,042,205,174
25	1,320,638,214	82,924,460	0	0	0	83,410,630	17,010,499	18,325,817	201,671,406	1,522,309,620
26	1,089,798,501	10,174,490	0	0	0	648,928,000	-1,959,798	28,181,800	685,324,492	1,775,122,993
27	2,019,388,569	152,198,700	0	0	0	370,685,700	44,379,932	351,471,900	918,736,232	2,938,124,801
28	1,234,088,952	381,372,940	0	0	0	1,185,379,660	104,806,669	1,378,792,350	3,050,351,619	4,284,440,571
29	1,140,509,788	474,734,475	0	0	0	294,359,640	102,817,087	882,167,962	1,754,079,164	2,894,588,952
30	64,948,601	65,621,736	0	0	0	234,869,560	38,368,438	6,160,509	345,020,243	409,968,844
31	339,869,940	1,595	0	0	0	273,740	2,401	58,124	335,859	340,205,799
32	5,991,907,394	113,220,100	0	0	0	36,544,210	2,575,092	6,491,810,700	6,644,150,102	12,636,057,496
33	7,727,515,492	7,990,870,000	0	0	0	3,012,190,000	-8,805,443	1,961,270,000	12,955,524,557	20,683,040,049
34	998,575,217	2,601,430,000	0	0	0	1,246,804,000	5,289,303	25,009,200	3,878,532,503	4,877,107,720
35	2,430,851,515	252,466,900	0	0	0	213,443,860	494,557	5,811,414	472,216,731	2,903,068,246
36	1,210,650,794	89,882,658	0	605,882,000	0	231,551,847	1,197,538	2,323,156	930,837,199	2,141,487,993
37	966,276,400	48,206,370	0	0	0	616,585,500	630,914	6,843,178	672,265,962	1,638,542,362
38	646,792,475	480,553,410	0	0	0	2,016,753,900	1,184,966	12,548,411	2,511,040,687	3,157,833,162
39	2,456,651,504	1,062,530,000	0	0	0	298,238,000	8,274,419	122,419,000	1,491,461,419	3,948,112,923
40	5,842,108,806	149,777,900	0	0	0	37,887,965	311,363	5,530,287	193,507,516	6,035,616,321
41	1,044,393,882	9,692,539	0	0	0	38,534,320	302,018	603,458	49,132,334	1,093,526,216

	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF
42	466,531,289	975,605,600	0	0	0	10,610,381	231,911	2,743,691	989,191,582	1,455,722,871
43	2,718,805,863	2,117,575,000	0	0	0	40,654,700	1,702,665	636,196,576	2,796,128,941	5,514,934,804
44	6,345,341,404	185,584,030	0	0	0	323,214,065	13,857,845	548,270,422	1,070,926,362	7,416,267,765
45	0	8,064,880,298	0	0	0	0	0	0	8,064,880,298	8,064,880,298
46	86,046,595	633,982,800	2,860,919,000	0	0	44,396,100	764,667	11,731,230	3,551,793,797	3,637,840,391
47	272,298,069	3,035,000,000	3,137,084,000	0	0	31,002,800	231,275	31,081,400	6,234,399,475	6,506,697,544
48	925,945,198	1,528,453,000	102,680,000	429,942,400	0	224,670,930	1,384,168	7,699,956	2,294,830,454	3,220,775,653
49	1,370,864,314	1,200,145,880	0	231,204,000	0	36,869,864	-70,591,233	8,694,870	1,406,323,381	2,777,187,695
50	448,317,452	158,968,000	4,660,340,000	0	0	47,268,900	575,253	43,982,300	4,911,134,453	5,359,451,906
51	488,207,527	32,658,500	0	506,627,000	0	1,713,250	297,802	335,001	541,631,553	1,029,839,080
52	76,735,968,279	40,127,740,073	10,761,023,000	1,773,655,400	0	26,684,526,848	1,079,587,739	12,980,937,810	93,407,470,871	170,143,439,150
53										
54	37,009,313,764	0	0	0	0	0	0	0	0	37,009,313,764
55	27,704,574,456	0	0	0	0	0	0	0	0	27,704,574,456
56	1,744,070,565	5,431,130,000	0	0	0	397,602,000	28,856,700	610,795,000	6,468,383,700	8,212,454,265
57	3,095,016,334	0	0	0	0	0	0	106,685,000	106,685,000	3,201,701,334
58	-2,072,900	0	0	0	0	0	0	0	0	-2,072,900
59	-322,987,900	0	0	0	0	0	0	0	0	-322,987,900
60	7,823,608,684	0	0	0	0	0	0	0	0	7,823,608,684
61	0	201,820,000	0	0	0	43,162,000	0	-244,982,000	0	0
62	0	0	0	0	0	0	0	0	0	0
63	15,076,208,303	6,083,096,000	0	0	0	0	467,418,800	4,143,615,000	10,694,129,800	25,770,338,103
64	92,127,731,307	11,716,046,000	0	0	0	440,764,000	496,275,500	4,616,113,000	17,269,198,500	109,396,929,807
65	168,863,699,586	51,843,786,073	10,761,023,000	1,773,655,400	0	27,125,290,848	1,575,863,239	17,597,050,810	110,676,669,371	279,540,368,956

	A	B	C	D	E	F	G	H	I	J	K	L
1	**1997-98 New Zealand Input-Output Matrix (46 sector transaction matrix)**											
2		in 1994/95 $NZ	1	2	3	4	5	6	7	8	9	10
3			Mixed livestock	Dairy farming	Horticulture	Services to Agriculture	All other farming	Fishing and Hunting	Forestry & Logging	Oil and Gas Exploration	Other mining	Meat Products
4		***Intermediate Inputs***										
5		1 Mixed livestock	592,502,150	353,448,583	18,760,650	2,693,246	75,158,505	86,372	5,501,216	31,026	20,933	2,065,535,559
6		2 Dairy farming	137,922,980	103,113,235	12,872,432	14,928,914	21,533,539	74,509	1,540,250	24,518	15,919	325,707,109
7		3 Horticulture	39,841,500	22,475,789	46,271,573	14,754,808	10,833,026	157,734	1,584,601	63,941	48,247	23,374,525
8		4 Services to Agriculture	255,903,775	114,138,124	196,669,288	26,239,895	50,449,147	933,629	11,057,210	0	0	1,480,224
9		5 All other farming	93,308,337	50,931,046	8,343,652	1,853,665	136,503,964	45,817	2,398,859	16,580	11,139	306,800,961
10		6 Fishing and Hunting	9,584,932	2,610,651	2,059,138	5,880,386	5,863,707	136,225	12,040	17,660	8,029	390,083
11		7 Forestry & Logging	2,205,282	1,017,630	1,340,885	1,778,370	1,014,781	14,788	1,034,171,430	41,051	46,593	1,435,272
12		8 Oil and Gas Exploration	90,747	91,489	18,884	253	9,544	754	3,802	100,415,394	21,167	34
13		9 Other mining	2,171,946	1,720,595	792,129	1,182,976	313,214	22,592	4,085,686	23,777,061	22,072,843	10,135,938
14		10 Meat Products	2,602,946	3,728,839	495,014	1,072,719	10,060,933	373,505	1,519,088	353,563	156,060	1,508,611,022
15		11 Dairy Products	2,459,072	1,722,983	619,705	1,065,088	514,509	186,398	814,397	338,919	374,943	4,444,516
16		12 Manufacture of other food	6,488,982	25,824,632	625,280	1,694,944	24,937,300	3,923,362	6,788,587	583,366	158,845	29,303,222
17		13 Beverage Manufacture	172,570	329,257	37,943	129,267	188,361	33,078	72,603	18,233	21,017	556,721
18		14 Textile Manufacture	12,473,475	2,088,048	1,688,512	2,540,487	382,687	4,634,410	308,429	105,999	186,946	7,464,388
19		15 Wood & Wood Products	4,988,228	2,252,380	21,862,982	642,946	307,361	199,300	2,177,330	291,653	922,314	5,934,432
20		16 Paper Manufacturing	436,505	196,429	50,428,795	13,601,946	369,642	849,611	1,287,042	792,217	1,189,217	76,742,388
21		17 Printing & Publishing	1,023,789	258,215	8,107,206	2,645,369	83,420	591,088	1,290,462	653,608	1,329,875	40,736,292
22		18 Other Chemicals	16,960,787	30,620,119	16,899,056	5,522,556	2,188,916	1,276,326	5,309,016	1,049,186	4,796,863	103,145,650
23		19 Basic Chemicals	333,416,586	297,499,498	122,055,294	47,203,807	48,320,954	5,414,783	52,061,063	3,509,652	9,516,828	32,080,914
24		20 Non-metallic Minerals	282,372	234,309	2,067,872	6,515,779	97,163	80,652	203,625	737,206	382,674	1,089,657
25		21 Basic Metal Industries	183,418	182,644	34,356	37,463	24,443	92,630	30,535	18,835	275,468	191,192
26		22 Fabricated Metals	44,029,333	52,707,095	3,990,272	6,827,582	4,106,927	2,807,364	8,356,487	5,887,916	9,047,209	16,776,429
27		23 Equipment Manufacture	4,424,596	5,039,260	2,477,974	3,930,002	1,140,198	2,185,763	11,478,274	5,250,641	16,251,225	31,782,384
28		24 Transport Equipment	1,257,717	1,367,483	380,902	1,041,032	159,792	11,570,584	250,144	75,354	223,928	847,873
29		25 Other Manufacturing	196,313	145,690	102,926	65,504	19,049	22,741	53,428	23,609	27,443	646,216
30		28 Water works	10,599	18,394	5,836	71,106	3,188	5,652	20,500	660	57,583	51,681,110
31		29 Construction	234,783,988	152,467,214	59,586,078	14,980,706	23,032,035	2,328,887	8,877,264	23,891,357	44,923,050	54,842,677
32		30 Trade	238,531,552	176,602,285	69,233,456	43,528,339	42,374,174	14,224,033	44,626,921	8,148,488	28,154,217	325,916,984
33		31 Accommodation	10,826,411	3,636,381	1,288,460	4,634,412	2,214,244	1,479,636	1,496,722	874,620	4,126,097	15,370,647
34		32 Road Transport	145,831,549	26,043,477	18,889,550	10,886,465	10,707,180	6,234,908	115,281,672	36,113,441	37,304,154	119,743,401
35		33 Services to Transport	19,724,256	17,035,616	4,560,952	6,603,931	5,150,853	2,664,296	29,323,394	14,188,918	5,530,562	63,141,672
36		34 Water Transport	3,814,860	2,667,184	5,630,390	305,521	2,959,357	227,663,213	1,854,910	5,166,141	4,299,809	22,532,239
37		35 Air Transport	1,466,078	1,558,931	1,694,868	1,886,429	1,081,648	1,025,528	2,189,400	1,008,932	1,276,213	10,563,102

	A	B	C	D	E	F	G	H	I	J	K	L
38	36	Communications	33,423,178	22,609,548	11,809,927	8,096,695	9,857,120	2,099,590	7,274,763	4,723,455	6,857,511	70,129,839
39	37	Finance	108,920,566	111,695,268	42,520,174	28,727,822	26,602,798	11,609,934	47,838,527	49,277,550	9,694,202	139,722,487
40	38	Finance services	123,359	2,527,423	359,133	1,512,355	1,048,406	43,464	93,234	131,577	50,761	3,856,692
41	39	Insurance	17,119,172	12,980,338	3,682,304	3,075,390	3,334,350	1,648,965	2,149,447	5,542,464	841,476	11,025,994
42	40	Real Estate	37,849,845	67,536,344	19,967,531	672,668	11,576,310	388,798	2,751,670	1,157,670	722,929	38,371,757
43	41	Business Services	84,866,693	28,563,408	30,328,887	60,501,181	22,582,966	11,677,937	34,906,503	77,427,573	22,457,951	237,206,221
44	42	Dwelling ownership	0	0	0	0	0	0	0	0	0	0
45	43	Education	3,252,827	3,283,353	305,076	308,916	337,244	11,206	21,717	118,269	78,201	4,065,657
46	44	Community Services	22,281,490	24,704,235	6,280,119	2,180,994	5,731,219	382,136	2,403,207	1,917,981	2,712,930	15,352,924
47	45	Recreation Services	12,283,337	29,150,234	11,841,050	1,146,908	8,447,130	288,194	459,548	537,352	246,279	29,472,312
48	46	Personal Services	68,689,229	100,141,709	25,216,543	5,604,053	10,695,042	997,425	12,028,356	2,539,131	2,587,406	19,185,326
49	47	Central Government	692,866	908,401	276,793	100,512	241,933	44,173	144,058	225,262	197,849	1,018,099
50	48	Local Government	1,888,732	958,799	639,911	1,179,596	1,535,245	96,592	589,318	39,973	24,970	855,106
51		*Total Intermediate Inputs*	2,611,308,923	1,858,832,565	833,119,758	359,853,003	584,093,523	320,628,584	1,466,686,736	377,108,002	239,249,878	5,829,267,243
52												
53	49	Compensation of Emplo:	269,829,390	224,033,570	402,476,103	166,530,360	73,499,163	54,666,799	177,307,301	24,309,962	103,601,071	938,228,398
54	50	Operating Surplus	778,627,695	1,065,577,506	406,218,683	143,286,652	251,959,129	133,926,408	988,765,297	124,071,900	95,160,055	86,415,452
55	51	Commodity Indirect Tax	57,862,050	38,246,881	15,677,145	8,504,832	8,612,699	5,714,412	23,120,139	6,259,512	9,411,673	23,067,003
56	52	Non-Commodity Indirec	155,807,537	90,329,968	45,099,968	9,198,235	21,325,243	16,898,838	18,451,887	3,156,367	10,705,864	17,949,616
57	53	Commodity Subsidies	-878,747	-931,391	0	0	0	-77	0	0	0	-203
58	54	Non-Commodity Subsid	-2,803,323	-2,758,618	-5,284,681	-2,730,909	-1,048,686	-3,708,724	-3,787,142	0	0	-4,657,267
59	55	Consumption of Fixed C	239,426,135	212,184,870	145,270,875	47,855,708	69,035,204	42,206,516	36,484,908	69,210,454	54,936,389	114,308,723
60	56	Second Hand Assets	1,468,464	1,501,033	740,899	4,697,692	308,678	4,947,216	2,879,726	1,363,439	10,442,523	7,292,719
61	57	Interregional Imports	0	0	0	0	0	0	0	0	0	0
62	58	International Imports	137,594,604	158,679,221	118,578,645	41,487,987	69,459,449	141,447,557	67,642,484	5,407,104	45,576,856	375,008,672
63		*Total Primary inputs*	1,636,933,804	1,786,863,040	1,128,777,638	418,830,557	493,150,879	396,098,946	1,310,864,600	233,778,737	329,834,431	1,557,613,114
64		**Total**	4,248,242,727	3,645,695,605	1,961,897,396	778,683,560	1,077,244,402	716,727,529	2,777,551,336	610,886,739	569,084,310	7,386,880,356

	M	N	O	P	Q	R	S	T	U	V	W	X
1												
2	11	12	13	14	15	16	17	18	19	20	21	22
3	Dairy Products	Manufacture of other food	Beverage Manufacture	Textile Manufacture	Wood & Wood Products	Paper Manufacturing	Printing & Publishing	Other Chemicals	Basic Chemicals	Non-metallic Minerals	Basic Metal Industries	Fabricated Metals
4												
5	61,344,146	69,880,633	17,607,716	890,932,505	4,515,888	1,499,865	774,550	7,471,533	475,161	391,737	125,649	1,233,537
6	2,910,190,422	30,068,560	10,588,939	110,030,117	1,459,333	446,224	593,083	2,742,996	298,053	307,934	124,426	937,540
7	14,560,673	239,633,138	150,779,695	8,071,846	1,903,356	538,279	753,149	1,463,126	678,775	484,608	120,457	1,140,888
8	792,200	614,406	266,714	1,443,410	46,422	15,812	0	23,614	176	111	0	0
9	21,342,726	169,783,465	38,726,851	30,293,453	1,798,190	601,539	353,253	17,340,921	233,531	178,538	57,227	558,596
10	7,834	420,145,704	76,313	3,485,794	28,569	29,152	34,398	1,127,635	47,594	25,694	11,461	40,804
11	2,851,577	816,210	198,520	154,492	649,237,522	231,378,854	115,956	298,644	140,273	60,347	45,950	100,258
12	0	0	0	0	13,219	0	247	0	203,202,063	0	0	0
13	11,440,124	3,146,492	1,027,321	1,404,721	482,715	415,648	187,907	4,958,773	74,005,608	111,911,074	84,048,026	1,394,199
14	6,182,799	136,612,076	5,019,746	208,433,789	2,877,693	1,367,829	862,141	4,908,922	25,974,365	674,122	456,718	1,788,394
15	192,571,914	91,420,429	7,655,190	3,102,421	2,527,164	1,789,377	1,248,654	5,358,791	4,408,397	1,089,693	922,273	1,820,066
16	87,093,970	578,065,874	56,276,943	3,325,201	2,167,832	1,565,622	749,032	11,988,458	4,673,122	544,786	256,122	4,338,401
17	760,729	4,893,221	75,562,349	236,338	243,877	132,681	79,463	195,766	365,023	70,873	66,114	140,852
18	442,726	9,414,572	5,167,677	639,925,303	29,239,843	2,357,995	1,403,080	7,472,871	5,657,951	1,050,647	847,059	6,623,358
19	5,732,908	6,996,085	6,715,601	6,426,100	650,495,541	49,250,203	10,875,424	11,215,524	5,496,657	14,725,802	4,070,449	42,322,928
20	41,784,506	90,708,473	41,674,210	32,278,387	50,845,814	562,145,467	349,542,817	61,345,277	19,959,224	21,901,154	3,444,348	18,121,324
21	41,567,943	43,129,408	17,799,700	9,082,634	8,532,189	80,540,559	343,620,583	22,857,861	6,372,308	6,481,471	573,529	12,299,887
22	47,283,695	98,729,622	41,098,323	63,425,858	47,877,037	30,428,942	65,456,768	167,061,432	64,414,974	10,501,338	3,969,478	44,661,451
23	20,694,664	30,610,798	15,732,587	64,936,826	62,078,207	30,214,777	10,375,717	284,417,908	778,133,538	21,245,188	32,690,732	24,313,987
24	12,471,689	14,438,493	67,984,411	567,285	19,355,185	446,028	159,353	6,408,925	4,022,945	222,392,480	2,538,617	24,286,686
25	70,854	312,473	298,336	927,749	3,531,525	1,481,960	753,648	2,535,274	6,533,159	4,363,271	118,595,204	229,824,646
26	12,759,700	49,331,578	53,356,161	6,621,219	85,018,573	7,971,424	3,440,774	38,985,823	9,995,645	34,550,056	40,769,731	229,343,000
27	18,821,589	28,553,333	7,570,062	16,640,229	36,776,147	43,786,363	10,996,140	12,273,975	30,787,168	12,013,152	12,930,075	51,238,411
28	597,307	1,353,944	1,380,884	439,767	3,018,642	711,288	217,915	999,545	717,618	1,285,609	2,162,826	5,349,339
29	281,621	613,434	349,193	6,627,706	320,509	145,489	2,952,157	483,863	217,337	204,363	41,644	348,466
30	5,896,464	16,816,298	11,798,654	10,036,573	1,307,825	19,081,174	10,512	2,988,655	5,838,491	8,749,275	1,416,705	4,367,789
31	12,596,585	41,378,136	6,312,128	51,235,673	81,636,437	9,786,843	15,628,192	30,096,018	86,284,206	81,963,627	56,800,632	28,546,640
32	93,882,376	305,748,731	259,943,175	320,679,519	255,833,752	141,381,128	93,763,578	205,559,289	538,416,927	116,045,714	216,339,891	351,829,144
33	9,514,872	17,423,053	12,077,920	17,484,722	20,230,830	13,126,208	13,053,296	22,576,435	14,356,034	7,959,936	8,195,547	16,435,239
34	81,348,056	148,249,738	48,589,333	50,841,103	129,549,727	107,946,714	62,976,096	60,763,764	34,101,295	37,555,527	15,618,746	50,317,385
35	26,367,380	42,492,207	19,009,629	22,784,449	57,929,541	34,337,419	12,356,588	33,656,870	13,180,040	19,613,596	13,910,481	35,442,200
36	23,106,025	84,223,611	5,256,161	13,353,950	23,183,062	83,445,111	7,724,383	17,153,109	21,559,120	21,185,318	19,119,216	13,096,169
37	2,996,243	9,650,452	3,067,741	12,274,558	9,667,603	11,063,144	5,415,394	9,096,323	3,743,234	3,202,348	2,215,270	7,580,345

	M	N	O	P	Q	R	S	T	U	V	W	X
38	22,260,219	60,158,864	19,834,559	62,159,202	52,388,382	26,334,291	84,725,433	47,208,517	22,958,570	19,193,006	10,750,203	49,012,383
39	91,144,030	192,113,421	79,183,457	138,398,893	107,328,163	101,032,413	103,857,478	132,699,703	89,171,148	50,166,894	53,426,602	124,189,708
40	508,415	9,746,069	984,435	1,574,210	845,055	3,794,900	4,005,233	8,539,001	4,520,087	291,470	27,293	4,950,040
41	3,944,274	7,967,621	1,738,861	6,178,446	8,740,552	6,206,443	5,756,405	6,131,061	8,597,452	3,056,412	2,349,629	5,454,744
42	4,102,740	19,791,098	3,400,406	41,804,505	37,234,355	12,724,439	28,981,276	31,896,351	12,722,687	13,153,921	5,348,227	40,429,515
43	40,606,171	132,843,192	29,977,101	130,010,377	89,277,187	4,303,856	132,455,368	156,746,082	83,451,873	72,447,173	52,874,940	112,273,161
44	0	0	0	0	0	0	0	0	0	0	0	0
45	82,886	4,337,859	2,778,116	1,379,077	1,162,772	98,660	2,823,366	2,615,429	975,031	558,338	1,238,690	1,275,230
46	4,098,849	5,279,504	4,218,477	9,767,599	4,066,869	2,421,289	17,325,224	10,383,614	5,418,472	2,459,117	5,044,626	4,612,226
47	628,352	13,631,112	5,194,001	3,565,804	4,074,624	2,567,796	3,843,399	14,611,266	3,566,178	2,421,831	833,464	3,047,977
48	16,479,761	14,022,861	10,843,603	13,400,486	13,075,432	11,769,076	16,411,115	11,715,910	13,053,311	9,089,837	7,082,547	10,294,552
49	113,726	464,952	140,193	846,254	641,025	149,952	778,098	640,416	343,334	273,113	161,466	535,412
50	682,945	710,554	232,673	1,224,160	257,026	683,473	2,704,032	411,912	237,274	152,210	92,238	318,189
51	3,952,008,685	3,246,321,753	1,147,494,066	3,017,812,710	2,562,821,210	1,641,515,707	1,420,140,672	1,479,427,181	2,209,305,427	935,992,711	781,714,529	1,566,235,067
52												
53	513,239,538	704,553,365	186,030,653	479,592,397	748,671,458	433,008,614	750,219,451	637,240,005	253,019,925	280,816,876	310,001,896	738.401,871
54	90,355,387	398,363,809	147,801,232	136,220,311	246,062,343	262,328,288	250,577,833	305,325,741	359,034,334	183,221,532	78,847,551	329,130,604
55	22,638,425	20,632,355	45,031,170	5,196,241	22,662,083	16,213,166	8,910,460	14,802,396	51,604,065	7,938,146	4,318,519	9,687,654
56	36,979,426	30,963,629	11,579,533	11,637,911	18,576,162	13,902,985	16,747,146	21,266,388	12,489,181	17,503,922	9,509,450	19,285,135
57	0	-69	0	0	0	0	0	0	0	0	0	0
58	0	-3,848,317	-348,130	-4,918,646	0	-1,632,081	-9,120	0	0	0	0	-344,320
59	283,952,340	138,526,200	65,365,724	49,019,435	120,463,699	178,371,729	107,689,824	112,607,189	233,747,871	74,107,073	139,125,362	86,548,775
60	23,599,397	22,228,082	3,956,279	3,298,830	8,416,065	44,509,731	6,252,253	7,947,988	15,530,177	4,053,233	1,600,667	11,274,589
61	0	0	0	0	0	0	0	0	0	0	0	0
62	176,654,518	439,824,169	146,562,300	470,547,903	344,366,854	267,763,759	217,967,721	749,655,853	1,220,862,176	177,429,616	221,439,539	558,941,064
63	1,147,419,032	1,751,243,223	605,978,761	1,150,594,383	1,509,218,665	1,214,466,192	1,358,355,568	1,848,845,561	2,146,287,729	745,070,397	764,842,984	1,752,925,372
64	5,099,427,717	4,997,564,976	1,753,472,827	4,168,407,092	4,072,039,875	2,855,981,898	2,778,496,240	3,328,272,742	4,355,593,156	1,681,063,109	1,546,557,513	3,319,160,439

	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1												
2	23	24	25	28	29	30	31	32	33	34	35	36
3	Equipment Manufacture	Transport Equipment	Other Manufacturing	Water works	Construction	Trade	Accommodation	Road Transport	Services to Transport	Water Transport	Air Transport	Communications
4												
5	1,500,678	524,400	231,935	46,118	771,809	21,507,216	10,990,478	825,494	1,028,530	551,595	536,668	7,979,511
6	1,133,326	452,530	190,672	37,660	629,755	18,711,857	10,364,831	622,218	766,913	442,962	517,986	6,013,693
7	1,494,151	563,369	473,917	120,733	1,801,141	71,993,861	111,873,908	793,888	945,654	3,144,914	8,019,789	6,610,211
8	317	0	1,153	103	39,060	606,789	240,842	0	0	5,325	20,783	0
9	696,377	217,748	117,199	28,558	428,631	10,128,938	19,499,566	372,719	474,011	510,517	921,555	3,535,143
10	66,752	25,578	1,673,560	20,880	323,994	438,381	15,253,682	46,355	38,196	557,030	1,984,329	43,598
11	327,394	112,684	23,036	67,745	557,092	25,605,379	326,944	109,941	130,849	64,953	185,994	246,120
12	1,117	65	0	449	508,588	13,060,773	151	368	38	75,631	398	0
13	614,279	288,305	17,148,908	24,923	13,261,945	2,245,012	432,562	758,574	248,204	362,527	79,624	2,633,915
14	2,131,916	1,216,509	3,050,639	268,660	5,589,655	19,510,094	573,609,220	2,426,211	1,327,424	6,593,394	26,732,243	550,638
15	2,680,935	3,573,797	354,926	315,074	11,694,249	428,660,447	221,697,885	2,816,039	484,436	7,594,070	25,002,774	1,254,812
16	5,738,501	1,194,003	284,929	206,048	5,797,351	12,043,756	417,752,427	893,833	410,898	10,181,736	24,477,023	99,804
17	339,737	278,817	23,345	34,308	1,166,128	20,915,433	340,742,628	103,065	23,116	1,119,054	7,050,860	18,447
18	7,031,677	2,056,399	2,229,353	130,296	30,925,131	37,306,988	5,412,423	3,114,540	444,545	692,956	907,921	1,234,818
19	79,095,897	63,369,435	3,863,023	289,362	1,203,777,720	57,181,342	12,438,911	937,812	1,883,767	923,412	221,497	1,530,074
20	41,537,178	6,194,871	9,875,755	1,385,086	90,151,371	344,272,191	9,854,839	4,586,879	5,997,680	1,467,140	2,134,850	1,682,858
21	34,529,571	6,983,358	914,574	1,842,805	70,724,250	219,284,512	31,892,657	7,828,744	15,830,599	790,975	17,316,868	14,110,508
22	69,552,511	49,360,341	20,258,867	535,392	284,479,311	274,732,342	13,749,500	62,953,097	5,567,774	3,418,091	9,352,685	16,142,433
23	61,765,419	10,825,723	9,813,649	1,935,319	317,274,009	182,961,409	11,345,382	150,330,514	7,208,536	20,824,182	45,346,467	25,815,129
24	9,555,412	22,970,531	1,123,608	8,674,175	1,041,482,436	11,825,962	10,060,680	392,079	153,691	158,770	444,135	462,328
25	104,225,654	37,860,439	10,629,233	579,052	51,478,658	590,302,307	148,888	111,380	12,922	52,272	904,687	84,561
26	166,816,480	50,237,085	4,997,452	5,778,659	1,179,874,210	62,636,357	12,515,597	1,470,380	1,329,163	2,209,364	972,955	1,431,266
27	489,900,134	39,961,425	4,003,277	1,181,047	279,713,758	133,399,463	11,470,297	20,467,887	3,908,656	6,822,844	21,097,183	28,466,332
28	7,926,010	520,102,607	194,465	89,950	9,740,825	119,309,216	964,234	122,695,388	283,661	13,411,013	67,940,643	976,623
29	673,700	208,798	5,013,319	30,543	2,297,529	4,456,478	173,468	373,199	162,365	27,223	107,315	163,907
30	2,445,611	1,734,249	15,180	143,881,170	3,016,231	9,724,115	7,050,052	6,406,748	1,902,064	110,139	43,479	5,454,154
31	51,020,731	8,428,840	7,478,360	9,197,862	3,658,106,659	204,429,714	112,415,551	27,885,535	606,007,390	82,357,252	21,071,319	26,389,371
32	372,105,946	489,189,320	47,403,848	8,551,981	1,213,282,938	1,596,365,368	252,355,552	310,097,062	38,857,772	48,517,816	136,606,395	114,966,991
33	37,530,509	9,815,247	3,207,193	1,765,475	66,637,740	151,598,508	54,475,631	17,579,998	11,464,956	9,021,877	67,760,209	21,418,017
34	56,756,751	13,100,589	7,531,672	1,792,373	74,729,629	572,342,381	7,804,248	375,279,251	18,123,078	44,134,811	29,653,621	36,684,691
35	38,139,638	15,597,460	4,411,176	2,686,347	38,763,892	321,252,477	9,078,014	105,302,889	67,356,011	29,211,933	250,812,243	10,919,838
36	15,311,342	11,740,269	2,306,650	542,846	11,461,819	254,345,549	6,643,610	38,920,967	3,144,600	243,251,368	17,517,032	28,395,818
37	15,159,617	8,456,846	1,847,714	392,824	16,304,891	110,179,497	3,680,356	22,927,242	58,651,149	7,455,194	228,295,059	21,531,879

	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
38	103,091,457	29,542,259	7,023,960	1,757,187	227,464,460	875,606,667	130,041,377	88,509,998	160,187,194	13,396,541	41,668,900	266,689,135
39	151,588,477	136,579,915	13,182,540	653,378	655,900,063	1,212,356,186	157,634,109	115,849,508	25,762,237	33,275,003	77,595,562	129,592,108
40	6,452,947	7,113,557	23,598	333,711	40,518,327	70,149,390	2,178,585	1,959,558	4,280,795	80,123	1,084,700	652,600
41	8,193,766	4,153,330	1,098,345	550,367	22,240,068	63,409,445	11,165,510	15,383,733	4,692,827	1,810,613	9,166,669	22,599,614
42	48,656,200	19,326,191	7,381,542	1,746,540	44,465,280	563,824,696	128,072,146	27,527,020	33,458,215	13,962,885	12,235,425	257,829,014
43	196,310,754	104,190,705	23,508,967	11,318,397	627,534,608	896,559,749	181,377,371	119,623,367	174,414,493	76,826,090	250,098,053	122,513,696
44	0	0	0	0	0	0	0	0	0	0	0	0
45	3,938,692	614,698	830,958	276,103	3,036,729	12,133,344	2,325,638	377,840	6,232,762	2,106,175	34,651,138	8,220,062
46	11,960,970	2,184,154	1,232,357	12,394,330	38,068,814	51,310,371	10,682,851	6,415,802	18,582,968	3,738,809	125,348,901	20,588,454
47	15,815,052	3,876,613	575,843	1,270,811	17,285,031	55,708,530	13,938,285	3,142,731	8,246,867	1,616,371	14,879,786	12,846,764
48	26,948,938	16,821,669	2,363,482	7,885,301	125,881,533	158,229,680	76,928,197	71,286,229	8,849,280	5,302,039	16,005,048	66,015,806
49	880,143	369,472	111,583	80,852	5,035,187	5,865,731	1,223,284	514,714	3,823,776	710,774	5,882,064	2,366,697
50	533,753	217,634	36,691	45,154,976	157,685,669	3,809,573	1,184,230	5,719,592	1,452,660	132,439	3,656,778	986,760
51	2,252,176,415	1,701,631,836	228,062,455	275,855,775	11,651,908,180	9,872,297,476	3,013,066,592	1,745,740,390	1,304,152,722	699,020,204	1,606,309,613	1,297,748,196
52												
53	848,341,200	389,090,409	72,447,715	49,473,360	2,131,989,659	6,410,282,045	1,116,948,611	751,426,844	416,619,731	583,346,047	604,280,079	1,487,110,942
54	602,410,270	94,437,872	49,906,559	48,513,261	688,645,284	3,474,396,347	629,220,892	301,987,346	322,688,383	248,514,747	368,325,881	1,423,931,999
55	15,918,220	2,785,958	1,075,275	822,865	73,866,673	156,746,817	154,405,758	124,065,922	9,407,245	22,945,045	31,758,499	41,599,938
56	21,084,794	7,864,000	1,992,473	421,894	78,348,020	412,004,123	82,990,628	23,141,209	31,089,449	29,731,598	18,683,067	26,225,872
57	-79	0	0	0	-596	-1,619	-10,281	0	0	0	0	0
58	-10,285,253	-25,183	0	0	-7,682,473	-28,777,759	-2,438,749	-69,078,342	-6,136,353	-296,917	-108,543	0
59	128,522,622	46,053,544	9,371,732	14,322,909	356,232,182	903,146,511	186,647,924	266,519,960	266,798,285	112,167,657	168,263,042	862,590,721
60	98,710,049	17,544,193	766,616	453,621	169,343,642	64,528,757	6,742,620	6,447,967	2,442,602	15,460,579	16,845,880	5,229,346
61	0	0	0	0	0	0	0	0	0	0	0	0
62	949,138,658	815,886,898	64,595,917	14,684,378	1,425,170,424	1,411,536,273	352,780,244	181,004,527	105,254,160	163,611,194	580,477,323	175,580,702
63	2,653,840,482	1,373,637,691	200,156,288	128,692,287	4,915,912,816	12,803,861,494	2,527,287,647	1,585,515,433	1,148,163,501	1,175,479,950	1,788,525,228	4,022,269,520
64	4,906,016,897	3,075,269,528	428,218,743	404,548,063	16,567,820,996	22,676,158,969	5,540,354,239	3,331,255,822	2,452,316,223	1,874,500,154	3,394,834,841	5,320,017,716

	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
1												
2	37	38	39	40	41	42	43	44	45	46	47	48
3	Finance	Finance services	Insurance	Real Estate	Business Services	Dwelling ownership	Education	Community Services	Recreation Services	Personal Services	Central Government	Local Government
4												
5	3,521,343	503,516	741,734	1,807,609	4,289,346	0	1,482,318	2,562,052	2,394,340	1,965,739	3,350,420	115,650
6	2,710,306	394,540	567,084	1,482,144	3,204,450	0	719,074	1,373,372	2,367,125	1,326,576	2,632,990	88,833
7	3,796,364	386,921	750,717	1,475,116	4,030,529	0	682,193	6,317,466	8,703,449	2,021,233	2,156,811	981,482
8	1,476	0	107	378,306	17,170	0	3,043,256	2,004,521	26,173,344	72,656	966,611	116,035
9	1,605,013	222,643	342,778	720,315	2,196,807	0	2,685,473	943,096	6,290,801	988,506	2,360,155	105,805
10	168,726	10,084	35,555	53,711	186,209	2,595	133,896	875,301	249,751	72,681	3,073,343	332,189
11	336,491	52,755	54,501	163,268	581,173	19,709	386,972	4,686,483	2,472,969	208,033	3,880,845	173,276
12	1,324	0	514	367	1,975	0	55,170	48,140	170,267	108,197	79,706	247,730
13	140,356	20,924	29,420	711,725	358,707	80,928	32,552	3,862,629	284,199	348,843	2,354,860	848,332
14	1,714,982	128,774	541,196	641,857	2,755,211	830,712	1,262,784	11,767,637	4,892,065	1,686,038	1,356,942	1,784,353
15	2,201,524	136,316	589,174	901,336	3,665,676	826,000	960,257	12,610,397	6,673,193	1,969,060	4,867,754	2,552,938
16	1,800,624	39,492	344,292	210,424	7,873,129	285,614	3,076,447	17,171,374	12,978,238	1,402,058	6,721,541	1,708,596
17	141,716	1,633	44,426	26,040	237,101	71,837	120,582	1,561,128	6,367,041	265,799	231,769	270,221
18	1,300,160	109,455	333,966	6,294,922	5,820,116	40,098,365	825,712	14,687,576	13,936,874	2,645,025	6,768,598	204,785
19	2,893,269	323,691	695,933	3,490,497	16,333,749	46,174,473	16,838,714	1,973,116	6,504,757	22,859,308	7,701,970	184,426
20	28,363,743	9,537,558	10,310,798	13,052,790	66,715,120	15,719,232	21,498,230	19,209,538	20,025,266	19,356,302	17,075,055	3,337,352
21	34,426,919	39,517,283	11,867,987	77,556,562	553,018,326	491,207	68,926,893	35,987,428	64,225,114	36,651,520	66,878,855	6,749,751
22	3,646,225	1,252,699	1,033,139	7,147,094	59,113,645	13,035,219	14,005,220	40,381,000	30,922,872	99,579,128	44,884,061	1,834,337
23	2,165,883	1,817,078	3,321,423	9,403,344	31,939,633	4,955,835	19,925,430	22,065,896	39,615,578	47,338,922	29,379,515	13,761,729
24	266,585	20,031	54,889	10,574,160	5,636,843	20,604,249	2,485,560	1,182,793	1,122,325	3,433,385	2,763,754	49,088
25	50,974	7,961	8,502	394,652	176,673	209,756	362,171	175,033	109,945	545,604	1,210,203	14,007
26	1,237,665	78,841	333,593	33,004,895	19,450,560	65,862,057	6,349,980	1,820,761	22,354,607	23,762,605	28,681,264	2,740,219
27	9,821,847	666,654	2,007,093	9,776,960	84,023,620	5,739,140	17,151,065	73,521,517	28,787,180	57,091,918	56,727,998	10,613,513
28	418,230	56,634	55,291	431,213	5,186,627	672,647	266,803	591,746	2,650,121	45,563,976	84,168,265	117,099
29	463,620	205,925	180,462	124,152	6,345,398	79,086	2,075,938	1,332,155	5,500,076	1,570,352	307,260	54,125
30	70,233	416,767	9,996	1,650,361	378,247	64,686,630	6,264,929	7,014,898	1,072,943	9,329,365	3,938,645	4,444,741
31	61,771,659	13,530,718	25,238,767	367,716,000	95,996,809	273,542,918	109,495,008	87,674,510	141,432,477	67,231,496	317,708,748	47,291,107
32	55,088,813	8,826,653	20,080,428	55,219,453	223,027,086	112,868,359	42,380,529	105,824,769	117,250,480	172,640,324	127,811,939	21,730,189
33	36,471,405	6,783,853	8,939,235	28,889,064	71,116,148	1,303,153	17,177,277	59,644,401	59,976,072	37,146,661	28,413,645	8,516,967
34	24,251,399	5,701,741	6,911,723	15,605,560	83,407,250	1,055,800	62,689,941	7,965,989	31,126,910	7,760,826	24,134,812	3,275,598
35	21,871,851	7,546,181	15,411,786	32,020,467	61,135,902	293,518	15,497,485	27,660,629	30,967,161	18,397,299	21,858,891	4,452,866
36	6,928,739	1,265,462	2,163,855	5,977,670	22,251,210	17,211	1,222,907	3,308,511	3,837,632	5,445,514	20,523,590	363,890
37	14,893,352	1,301,350	3,723,865	10,616,553	32,961,761	70,149	4,012,670	14,856,144	16,146,069	8,006,350	29,220,649	2,549,566

	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
38	244,218,304	93,125,827	79,479,290	99,788,932	393,216,064	94,419	43,003,330	87,889,061	135,408,718	179,873,532	171,871,219	21,902,537
39	1,508,564,608	152,315,925	322,876,848	222,951,481	338,883,913	191,236,353	4,849,568	44,198,061	50,862,960	76,568,758	112,914,401	14,748,771
40	189,830,999	43,281,981	239,597,678	43,982,158	128,637,986	496,881	1,514,383	2,123,795	2,152,437	2,023,948	71,441,691	274,333
41	24,507,447	3,755,563	38,724,785	6,882,715	26,460,994	30,448,280	2,275,888	6,781,847	6,998,074	6,689,336	8,383,379	4,960,558
42	121,686,788	17,011,166	25,001,728	703,853,744	134,104,384	21,176	6,753,149	32,236,294	64,936,640	57,382,954	143,670,124	15,085,476
43	439,141,300	83,475,228	67,441,515	276,012,628	724,587,170	8,851,733	52,326,881	135,317,700	230,448,402	170,702,653	317,546,150	103,431,020
44	0	0	0	0	0	0	0	0	0	0	0	0
45	1,696,808	413,430	916,076	1,094,067	9,356,408	59,733	7,520,757	11,671,417	3,021,593	5,487,636	31,081,267	4,646,427
46	10,511,690	1,922,212	13,786,935	14,493,970	32,838,157	97,441	23,876,773	297,324,175	42,324,133	22,470,228	299,435,280	6,732,512
47	174,113,988	768,952	3,329,012	38,934,136	98,260,756	409,662	3,132,924	8,653,356	449,287,246	9,388,990	26,787,953	2,964,831
48	17,586,269	4,107,088	15,163,280	41,281,375	77,966,306	3,656,384	37,136,179	98,965,626	92,774,423	107,479,806	57,320,019	10,047,998
49	1,806,119	298,769	400,195	2,012,430	2,774,172	78,057	1,136,146	1,619,945	1,384,165	1,023,775	4,963,513	216,953
50	889,229	296,936	348,861	11,917,034	4,543,661	55,377	392,076	871,119	24,191,662	32,417,702	2,197,219	174,317,420
51	3,059,096,365	501,637,212	923,790,428	2,160,723,253	3,445,062,176	905,101,896	628,011,489	1,320,314,401	1,821,371,690	1,370,300,616	2,201,803,681	500,939,632
52												
53	1,886,027,037	227,784,380	353,236,529	314,724,294	2,457,169,869	0	3,057,060,435	4,228,647,759	798,392,454	1,003,878,820	2,559,717,067	515,829,347
54	1,572,525,374	275,668,088	69,388,803	2,373,070,637	1,481,167,072	5,134,534,836	-8,835,696	890,540,950	614,986,801	317,704,744	0	0
55	234,646,043	47,130,277	44,741,135	127,428,913	29,992,245	213,722,971	9,486,289	31,573,074	42,266,304	15,513,813	18,465,453	11,302,934
56	104,673,196	7,559,876	23,109,763	393,898,803	97,074,146	946,809,732	45,714,958	148,014,035	81,954,352	38,006,515	172,471,956	10,755,317
57	-128	0	0	0	-361	0	-89	-19,124	-30,651	0	0	0
58	-3,514	0	0	0	-6,429,415	0	-6,467,591	-25,691,764	-90,603,278	0	0	0
59	500,158,060	25,142,334	45,829,987	627,211,337	374,427,247	592,934,129	12,587,334	138,277,945	143,747,563	90,157,828	0	0
60	8,445,753	329,448	84,549	3,955,132	81,442,611	879,153	5,589,598	11,854,272	8,913,142	11,505,133	52,084,282	4,812,315
61	0	0	0	0	0	0	0	0	0	0	0	0
62	125,189,349	19,136,226	31,646,618	98,499,562	581,657,116	192,715,396	44,115,555	455,448,573	226,880,413	347,132,646	544,777,275	53,266,188
63	4,431,661,170	602,750,630	568,037,384	3,938,788,678	5,096,500,530	7,081,596,217	3,159,250,793	5,878,645,720	1,826,507,100	1,823,899,499	3,347,516,034	595,966,100
64	7,490,757,536	1,104,387,842	1,491,827,813	6,099,511,932	8,541,562,706	7,986,698,114	3,787,262,282	7,198,960,121	3,647,878,789	3,194,200,115	5,549,319,715	1,096,905,733

	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF
1										
2		49	50	51	52	53	54	55		
3	***Total intermediate outputs***	Household Consumption	Consumption of Central Government Services	Consumption of Local Government Services	Interregional Exports	International Exports	Net Increases in Stocks	Capital Formation	***Total Final demand***	**Total Gross Output**
4										
5	4,239,219,659	42,990,023	0	0	0	438,344,702	63,837,653	2,592,249	547,764,627	4,786,984,286
6	3,742,271,930	16,078,540	0	0	0	100,785,850	71,812,706	1,571,186	190,248,283	3,932,520,213
7	818,671,550	377,500,568	0	0	0	920,190,556	4,314,032	2,559,118	1,304,564,274	2,123,235,824
8	693,762,008	6,864,884	0	0	0	3,907,168	13,840	41,621,801	52,407,693	746,169,701
9	936,874,667	71,677,355	0	0	0	161,892,740	-455,599	1,262,586	234,377,082	1,171,251,749
10	477,290,181	2,923,897	0	0	0	188,259,861	8,392,214	150,888	199,726,860	677,017,041
11	1,969,239,290	29,942,452	0	0	0	641,370,605	222,815,317	3,903,234	898,031,608	2,867,270,899
12	318,228,563	1,971,694	0	0	0	189,324,196	-102,843	4,626,069	195,819,117	514,047,681
13	407,869,843	16,446,306	0	0	0	102,501,856	2,639,643	5,502,651	127,090,456	534,960,298
14	2,596,501,437	1,326,667,922	0	0	0	3,717,536,928	117,529,847	3,867,159	5,165,601,857	7,762,103,294
15	1,070,537,967	988,144,900	0	0	0	3,113,965,728	-308,409,237	6,285,294	3,799,986,685	4,870,524,652
16	1,384,066,023	2,201,244,193	0	0	0	1,511,349,229	38,857,886	13,700,285	3,765,151,593	5,149,217,616
17	465,460,567	1,061,648,898	0	0	0	84,188,826	26,993,305	2,191,874	1,175,022,903	1,640,483,470
18	925,989,063	1,490,231,784	0	0	0	2,001,574,049	73,291,601	9,383,474	3,574,480,907	4,500,469,970
19	2,405,388,303	586,734,062	0	0	0	1,003,133,225	29,151,823	310,267,847	1,929,286,958	4,334,675,261
20	2,202,986,475	248,935,705	0	0	0	819,867,205	18,348,691	36,551,194	1,123,702,796	3,326,689,271
21	2,067,924,662	507,130,286	0	0	0	85,470,810	21,328,713	2,345,086	616,274,895	2,684,199,557
22	1,999,614,376	819,141,134	0	0	0	548,618,454	41,061,289	26,299,407	1,435,120,284	3,434,734,661
23	3,397,660,314	1,305,812,128	0	0	0	751,622,548	43,545,544	14,039,441	2,115,019,661	5,512,679,975
24	1,542,260,877	120,292,100	0	0	0	84,443,648	9,005,007	22,028,849	235,769,605	1,778,030,481
25	1,169,954,618	14,448,919	0	0	0	704,178,352	-1,104,176	36,033,038	753,556,132	1,923,510,750
26	2,422,626,313	173,276,942	0	0	0	381,271,000	23,699,668	427,145,279	1,005,392,888	3,428,019,202
27	1,762,667,768	436,683,795	0	0	0	1,277,308,495	58,902,952	1,752,712,437	3,525,607,679	5,288,275,446
28	1,039,222,779	739,206,223	0	0	0	308,469,156	56,189,439	1,094,852,814	2,198,717,633	3,237,940,412
29	45,815,097	136,295,624	0	0	0	245,367,719	20,759,183	7,574,709	409,997,234	455,812,331
30	421,243,989	4,135	0	0	0	58,694	947	69,426	133,202	421,377,190
31	7,545,397,175	1,088,891,497	0	0	0	31,300,291	488,069	7,628,280,223	8,748,960,080	16,294,357,255
32	9,581,813,685	9,300,387,391	0	0	0	3,210,214,381	-6,198,688	2,464,339,465	14,968,742,549	24,550,556,235
33	1,035,034,960	3,248,196,222	0	0	0	1,210,577,992	24,130	28,603,018	4,487,401,362	5,522,436,322
34	2,866,713,924	408,729,156	0	0	0	227,134,813	51,451	7,328,508	643,243,928	3,509,957,852
35	1,649,650,801	87,111,721	0	681,560,101	0	245,024,337	29,088	2,903,956	1,016,629,204	2,666,280,005
36	1,316,186,919	37,326,960	0	0	0	674,257,704	263,733	8,813,891	720,662,287	2,036,849,206
37	736,964,530	677,547,001	0	0	0	2,008,428,164	242,317	14,710,884	2,700,928,366	3,437,892,896

	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF
38	4,148,715,624	1,352,579,784	0	0	0	324,067,614	0	157,357.047	1,834,004,445	5,982,720,070
39	7,590,261,972	39,214,977	0	0	0	34,660,922	8,646	6,499,367	80,383,911	7,670,645,883
40	909,718,775	71,954,985	0	0	0	33,932,283	0	632,820	106,520,089	1,016,238,864
41	458,854,952	984,529,509	0	0	0	9,626,352	0	3,053,754	997,209,614	1,456,064,566
42	2,912,813,814	2,298,090,091	0	0	0	36,587,989	2,622	701,685,123	3,036,365,826	5,949,179,640
43	7,041,344,431	242,400,476	0	0	0	300,760,606	22,785	609.636,562	1,152,820,428	8,194,164,859
44	0	7,440,246,074	0	0	0	0	0	0	7,440,246,074	7,440,246,074
45	182,817,676	313,072,176	3,389,931,995	0	0	44,727,372	148,011	13,988,874	3,761,868,428	3,944,686,104
46	1,227,365,388	2,517,931,400	3,716,463,659	0	0	30,599,621	-26,203	37,031,232	6,301,999,710	7,529,365,098
47	1,117,092,637	1,721,162,210	115,266,135	436,890,490	0	214,583,761	317,979	8,689,452	2,496,910,028	3,614,002,665
48	1,540,924,664	1,396,604,188	0	243,755,050	0	42,426,343	239,772	10,175,093	1,693,200,446	3,234,125,110
49	53,516,401	78,485,974	5,524,065,881	0	0	47,204,752	116,073	52,445,448	5,702,318,128	5,755,834,528
50	488,523,981	77,762,523	0	544,510,387	0	1,432,092	11,681	400,134	624,116,817	1,112,640,798
51	92,927,060,629	46,104,518,784	12,745,727,670	1,906,716,029	0	28,112,548,992	638,160,910	15,585,712,245	105,093,384,630	198,020,445,259
52										
53	40,733,102,801	0	0	0	0	0	0	0	0	40,733,102,801
54	27,835,008,188	0	0	0	0	0	0	0	0	27,835,008,188
55	1,887,778,693	6,121,606,006	0	0	0	382,776,758	14,684,422	621,235,486	7,140,302,672	9,028,081,365
56	3,412,984,168	0	0	0	0	0	0	109,673,833	109,673,833	3,522,658,001
57	-1,873,414	0	0	0	0	0	0	0	0	-1,873,414
58	-291,905,098	0	0	0	0	0	0	0	0	-291,905,098
59	8,491,555,854	0	0	0	0	0	0	0	0	8,491,555,854
60	782,720,940	530,643,123	0	0	0	136,678,202	27,931,042	-1,486,249,481	-790,997,114	-8,276,174
61	0	0	0	0	0	0	0	0	0	0
62	15,113,083,669	6,619,845,609	0	0	0	0	221,899,176	4,111,868,109	10,953,612,894	26,066,696,563
63	97,962,455,801	13,272,094,738	0	0	0	519,454,959	264,514,640	3,356,527,948	17,412,592,285	115,375,048,086
64	190,889,516,431	59,376,613,522	12,745,727,670	1,906,716,029	0	28,632,003,951	902,675,550	18,942,240,193	122,505,976,915	313,395,493,345

5.1.3 46 sector inverse Leontief matrices for 1994/95 and 1997/98

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
217	Inverse Leontief $(I-A)^{-1}$ of the 1994-95 New Zealand Input-Output Matrix (46 sector transaction matrix)															
218		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
219	1	1.13939	0.10828	0.01573	0.00766	0.09615	0.00459	0.00473	0.00065	0.00199	0.42054	0.08291	0.03566	0.02206	0.29233	0.00761
220	2	0.02543	1.02122	0.00807	0.01211	0.02100	0.00133	0.00149	0.00032	0.00107	0.05334	0.55376	0.01299	0.00880	0.03320	0.00207
221	3	0.00710	0.00557	1.01966	0.01363	0.00809	0.00099	0.00105	0.00020	0.00059	0.00605	0.00610	0.03306	0.04932	0.00395	0.00115
222	4	0.07763	0.04302	0.12443	1.03069	0.06380	0.00187	0.00837	0.00012	0.00032	0.03365	0.02597	0.00924	0.00932	0.02205	0.00211
223	5	0.02382	0.01507	0.00601	0.00262	1.13171	0.00098	0.00191	0.00019	0.00055	0.06335	0.01599	0.04217	0.02702	0.01785	0.00157
224	6	0.00336	0.00280	0.00232	0.00632	0.00994	1.00133	0.00065	0.00013	0.00031	0.00279	0.00520	0.10741	0.00456	0.00242	0.00045
225	7	0.00400	0.00294	0.01074	0.00591	0.00390	0.00158	1.49371	0.00107	0.00391	0.00572	0.00569	0.00588	0.00752	0.00364	0.24237
226	8	0.00987	0.00911	0.00885	0.00608	0.00744	0.00211	0.00427	1.23099	0.00398	0.00597	0.00668	0.00320	0.00372	0.00500	0.00407
227	9	0.00426	0.00375	0.00391	0.00429	0.00320	0.00109	0.00458	0.01908	1.04759	0.00493	0.00668	0.00286	0.00678	0.00281	0.00313
228	10	0.00296	0.00313	0.00196	0.00278	0.01288	0.00308	0.00175	0.00067	0.00215	1.19148	0.00509	0.02793	0.00653	0.05455	0.00331
229	11	0.00132	0.00114	0.00104	0.00117	0.00134	0.00109	0.00076	0.00032	0.00125	0.00175	1.02548	0.00932	0.00453	0.00145	0.00148
230	12	0.00574	0.01680	0.00235	0.00404	0.02767	0.01038	0.00587	0.00105	0.00237	0.01332	0.04722	1.15466	0.04430	0.00495	0.00352
231	13	0.00080	0.00068	0.00061	0.00092	0.00100	0.00080	0.00043	0.00026	0.00112	0.00113	0.00110	0.00208	1.06023	0.00093	0.00107
232	14	0.00803	0.00350	0.00452	0.00773	0.00345	0.01295	0.00159	0.00080	0.00287	0.00848	0.00346	0.00971	0.01203	1.29756	0.01849
233	15	0.01049	0.00795	0.02228	0.00542	0.00651	0.00428	0.00449	0.00307	0.01322	0.00951	0.00883	0.00799	0.01148	0.00760	1.20499
234	16	0.00823	0.00683	0.04620	0.02265	0.00828	0.00566	0.00502	0.00365	0.00970	0.02733	0.02356	0.03529	0.04381	0.01543	0.02455
235	17	0.00994	0.00788	0.01670	0.01464	0.01000	0.00752	0.00713	0.00767	0.01343	0.02375	0.02464	0.02370	0.02663	0.01280	0.01344
236	18	0.01563	0.01898	0.01958	0.01302	0.01151	0.00668	0.00863	0.00376	0.01775	0.03253	0.02916	0.03210	0.03667	0.02233	0.02291
237	19	0.09726	0.08988	0.08779	0.06027	0.07320	0.01986	0.04228	0.00750	0.03610	0.05750	0.06534	0.02979	0.03312	0.04798	0.03869
238	20	0.00814	0.00624	0.00808	0.01218	0.00548	0.00290	0.00214	0.00284	0.01002	0.00650	0.00966	0.00836	0.06076	0.00468	0.01171
239	21	0.00550	0.00494	0.00394	0.00374	0.00417	0.00301	0.00270	0.00140	0.00700	0.00589	0.00501	0.00558	0.00994	0.00511	0.00796
240	22	0.02261	0.02393	0.01118	0.01221	0.01395	0.00841	0.00856	0.00752	0.02996	0.01722	0.01997	0.01945	0.03879	0.01146	0.03427
241	23	0.00673	0.00589	0.00708	0.01405	0.00545	0.00742	0.01284	0.00533	0.03952	0.01335	0.01186	0.01261	0.01057	0.00817	0.01689
242	24	0.00470	0.00347	0.00346	0.00412	0.00359	0.03084	0.00467	0.00181	0.00585	0.00495	0.00457	0.00778	0.00616	0.00357	0.00572
243	25	0.00036	0.00030	0.00037	0.00037	0.00030	0.00023	0.00021	0.00018	0.00035	0.00059	0.00044	0.00053	0.00071	0.00273	0.00044
244	28	0.00073	0.00068	0.00092	0.00074	0.00078	0.00041	0.00051	0.00023	0.00084	0.01266	0.00294	0.00573	0.00984	0.00421	0.00134
245	29	0.08551	0.06486	0.06012	0.03064	0.05231	0.02716	0.01908	0.02584	0.10822	0.06072	0.05012	0.03502	0.03057	0.04614	0.04778
246	30	0.10005	0.08194	0.08020	0.06982	0.08550	0.04685	0.04970	0.01765	0.08778	0.12490	0.09078	0.11116	0.20301	0.11284	0.11143
247	31	0.00716	0.00498	0.00523	0.00829	0.00673	0.00591	0.00365	0.00260	0.01194	0.00953	0.00773	0.00949	0.01380	0.00848	0.01034
248	32	0.04827	0.01879	0.02370	0.01954	0.02523	0.02199	0.07985	0.02829	0.08220	0.05050	0.04312	0.05118	0.04979	0.03121	0.06166
249	33	0.00998	0.00827	0.00779	0.00919	0.00990	0.01004	0.01996	0.00958	0.01471	0.01855	0.01450	0.01592	0.01873	0.01026	0.02371
250	34	0.00519	0.00422	0.00767	0.00482	0.00896	0.26609	0.00348	0.00430	0.01008	0.00934	0.01185	0.05119	0.01095	0.00711	0.01051
251	35	0.00276	0.00228	0.00326	0.00372	0.00341	0.00411	0.00328	0.00183	0.00474	0.00525	0.00359	0.00543	0.00550	0.00489	0.00583
252	36	0.01843	0.01504	0.01638	0.01586	0.01977	0.01038	0.01152	0.00844	0.02078	0.02699	0.01957	0.02377	0.02592	0.02244	0.02381
253	37	0.05901	0.05669	0.05660	0.05277	0.06108	0.03853	0.04687	0.04430	0.04447	0.07355	0.07350	0.07972	0.09022	0.06685	0.06526
254	38	0.00645	0.00648	0.00605	0.00808	0.00815	0.00397	0.00393	0.00439	0.00536	0.00896	0.00713	0.01021	0.00828	0.00667	0.00644
255	39	0.00712	0.00588	0.00484	0.00508	0.00680	0.00403	0.00286	0.00472	0.00366	0.00698	0.00569	0.00498	0.00426	0.00484	0.00516
256	40	0.02371	0.03156	0.02532	0.01038	0.02802	0.00961	0.00910	0.00586	0.01265	0.02928	0.02519	0.02008	0.02085	0.02571	0.02536
257	41	0.05769	0.03841	0.05450	0.08948	0.06090	0.04749	0.04180	0.06656	0.07288	0.09490	0.05049	0.07012	0.06236	0.06516	0.06121
258	42	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
259	43	0.00070	0.00061	0.00037	0.00032	0.00066	0.00020	0.00014	0.00012	0.00029	0.00087	0.00048	0.00062	0.00079	0.00046	0.00030
260	44	0.00205	0.00234	0.00058	0.00044	0.00221	0.00030	0.00029	0.00022	0.00085	0.00142	0.00154	0.00060	0.00058	0.00097	0.00048
261	45	0.00734	0.01186	0.01194	0.00495	0.01469	0.00302	0.00289	0.00286	0.00379	0.01249	0.00904	0.00828	0.00911	0.00601	0.00501
262	46	0.02641	0.03534	0.02350	0.00994	0.02141	0.00491	0.01142	0.00390	0.01028	0.01961	0.02712	0.01081	0.01538	0.01377	0.01044
263	47	0.00348	0.00378	0.00323	0.00234	0.00436	0.00264	0.00204	0.00221	0.00511	0.00481	0.00339	0.00329	0.00329	0.00383	0.00376
264	48	0.00302	0.00243	0.00255	0.00269	0.00428	0.00096	0.00140	0.00072	0.00237	0.00450	0.00261	0.00247	0.00312	0.00255	0.00171

	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
217																	
218	16	17	18	19	20	21	22	23	24	25	28	29	30	31	32	33	34
219	0.00320	0.00226	0.00569	0.00365	0.00238	0.00198	0.00326	0.00319	0.00216	0.00595	0.00254	0.00357	0.00453	0.04678	0.00282	0.00290	0.00368
220	0.00133	0.00104	0.00198	0.00128	0.00128	0.00129	0.00151	0.00148	0.00142	0.00192	0.00124	0.00163	0.00558	0.01644	0.00152	0.00131	0.00207
221	0.00074	0.00061	0.00084	0.00051	0.00071	0.00060	0.00078	0.00086	0.00065	0.00152	0.00094	0.00084	0.00206	0.02142	0.00076	0.00087	0.00187
222	0.00114	0.00044	0.00090	0.00043	0.00040	0.00033	0.00048	0.00053	0.00038	0.00079	0.00049	0.00063	0.00092	0.00715	0.00043	0.00051	0.00066
223	0.00096	0.00071	0.00520	0.00076	0.00065	0.00050	0.00080	0.00088	0.00060	0.00124	0.00073	0.00087	0.00124	0.01500	0.00078	0.00086	0.00131
224	0.00040	0.00029	0.00097	0.00029	0.00031	0.00024	0.00039	0.00045	0.00026	0.00413	0.00056	0.00040	0.00040	0.01290	0.00033	0.00038	0.00148
225	0.13490	0.01938	0.00466	0.00242	0.00659	0.00314	0.00577	0.00847	0.00717	0.00640	0.00395	0.02383	0.00591	0.00396	0.00248	0.00758	0.00260
226	0.00305	0.00166	0.00973	0.11212	0.00303	0.00341	0.00222	0.00287	0.00157	0.00339	0.00240	0.00497	0.00448	0.00217	0.00783	0.00225	0.00289
227	0.00185	0.00111	0.00478	0.02801	0.08433	0.06436	0.00717	0.00343	0.00288	0.04980	0.00505	0.01079	0.00309	0.00226	0.00295	0.00333	0.00180
228	0.00237	0.00181	0.00329	0.00643	0.00207	0.00181	0.00219	0.00261	0.00169	0.00708	0.00305	0.00268	0.00269	0.10756	0.00278	0.00259	0.00557
229	0.00130	0.00094	0.00156	0.00129	0.00138	0.00162	0.00152	0.00147	0.00174	0.00156	0.00133	0.00177	0.00827	0.01669	0.00167	0.00106	0.00248
230	0.00319	0.00211	0.00600	0.00248	0.00235	0.00186	0.00328	0.00376	0.00201	0.00273	0.00366	0.00301	0.00307	0.10491	0.00247	0.00275	0.01108
231	0.00098	0.00086	0.00099	0.00067	0.00099	0.00097	0.00098	0.00136	0.00088	0.00115	0.00133	0.00123	0.00230	0.07753	0.00111	0.00116	0.00167
232	0.00377	0.00293	0.00601	0.00375	0.00353	0.00307	0.00654	0.00529	0.00327	0.01041	0.00304	0.00738	0.00566	0.00544	0.00381	0.00323	0.00230
233	0.03113	0.01138	0.00798	0.00539	0.01930	0.00944	0.02008	0.03017	0.02938	0.01430	0.00945	0.10772	0.00769	0.00908	0.00602	0.02946	0.00855
234	1.21745	0.16044	0.02662	0.01066	0.02375	0.00925	0.01430	0.02087	0.00994	0.03102	0.01520	0.01985	0.02633	0.01658	0.00958	0.01395	0.00679
235	0.04465	1.15350	0.01820	0.00847	0.01665	0.01013	0.01500	0.02286	0.01230	0.01425	0.02250	0.02118	0.02395	0.02128	0.01439	0.02645	0.01075
236	0.01900	0.03101	1.05642	0.01868	0.01552	0.00966	0.02155	0.02399	0.02145	0.04259	0.01026	0.03323	0.01971	0.01607	0.02857	0.01482	0.00874
237	0.02892	0.01544	0.09725	1.14151	0.02816	0.03095	0.01932	0.02638	0.01259	0.03146	0.02079	0.04557	0.02022	0.01975	0.07670	0.02082	0.02611
238	0.00301	0.00213	0.00485	0.00422	1.16307	0.00723	0.01283	0.00609	0.01135	0.00685	0.05026	0.10008	0.00381	0.01141	0.00386	0.02580	0.00675
239	0.00491	0.00317	0.00515	0.00628	0.00931	1.08612	0.08797	0.03416	0.02557	0.03305	0.00758	0.01770	0.03353	0.00450	0.00580	0.00582	0.00331
240	0.00918	0.00547	0.01536	0.00709	0.03294	0.03361	1.08305	0.04602	0.02208	0.01873	0.03344	0.10568	0.00842	0.01379	0.00647	0.02875	0.00964
241	0.02651	0.00977	0.00719	0.00941	0.01623	0.01480	0.01997	1.07869	0.01620	0.01044	0.01045	0.03093	0.00997	0.00792	0.01256	0.01250	0.00945
242	0.00516	0.00311	0.00294	0.00252	0.00490	0.00471	0.00503	0.00560	1.26431	0.00389	0.00316	0.00471	0.01284	0.00349	0.04998	0.00385	0.01669
243	0.00034	0.00220	0.00049	0.00024	0.00052	0.00028	0.00043	0.00049	0.00034	1.01145	0.00054	0.00066	0.00062	0.00040	0.00046	0.00056	0.00026
244	0.01095	0.00177	0.00168	0.00163	0.00767	0.00148	0.00222	0.00127	0.00106	0.00088	1.45278	0.00183	0.00128	0.00424	0.00313	0.00188	0.00062
245	0.02250	0.01875	0.02417	0.03215	0.08244	0.05783	0.02825	0.02786	0.01635	0.03732	0.06766	1.28155	0.02927	0.04552	0.03382	0.32350	0.07751
246	0.08774	0.06157	0.08444	0.11040	0.10577	0.15340	0.13872	0.11886	0.14505	0.12654	0.06548	0.14085	1.10063	0.09701	0.13199	0.06804	0.05784
247	0.00949	0.00913	0.00997	0.00562	0.00976	0.00901	0.00932	0.01378	0.00713	0.01151	0.01295	0.01153	0.01152	1.01628	0.01087	0.01218	0.00947
248	0.06394	0.03745	0.02636	0.01900	0.03948	0.02264	0.02623	0.02448	0.01428	0.02840	0.01572	0.02459	0.03633	0.01967	1.12414	0.01961	0.03870
249	0.02056	0.00947	0.01190	0.00654	0.01633	0.01265	0.01501	0.01262	0.00936	0.01259	0.01180	0.01089	0.01794	0.00829	0.03454	1.03332	0.02157
250	0.03692	0.00927	0.00791	0.00787	0.01650	0.01443	0.00798	0.00751	0.00626	0.00931	0.00492	0.00675	0.01442	0.00968	0.01497	0.00492	1.11631
251	0.00749	0.00452	0.00458	0.00243	0.00465	0.00365	0.00478	0.00620	0.00565	0.00620	0.00391	0.00453	0.00761	0.00334	0.01042	0.02906	0.00725
252	0.01881	0.03224	0.01961	0.01200	0.02134	0.01660	0.02260	0.03018	0.01801	0.02252	0.01897	0.02909	0.04014	0.03076	0.03361	0.06713	0.01667
253	0.07113	0.06572	0.06218	0.04023	0.06022	0.05823	0.06661	0.06357	0.05820	0.05746	0.02869	0.08937	0.08487	0.06755	0.06701	0.05307	0.04442
254	0.00772	0.00818	0.00902	0.00537	0.00632	0.00542	0.00806	0.00817	0.00750	0.00612	0.00702	0.01227	0.01176	0.00738	0.00792	0.01117	0.00501
255	0.00493	0.00439	0.00372	0.00341	0.00420	0.00336	0.00385	0.00409	0.00315	0.00454	0.00501	0.00477	0.00548	0.00510	0.00754	0.00538	0.00293
256	0.01668	0.02393	0.02098	0.01174	0.02178	0.01538	0.02704	0.02652	0.01892	0.02968	0.02112	0.02152	0.04433	0.04279	0.02459	0.03542	0.02043
257	0.03217	0.07505	0.07059	0.04192	0.07995	0.06116	0.06528	0.07892	0.05588	0.07918	0.09394	0.09376	0.07405	0.07379	0.07304	0.13135	0.08016
258	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
259	0.00025	0.00091	0.00049	0.00026	0.00033	0.00054	0.00032	0.00062	0.00024	0.00068	0.00326	0.00042	0.00043	0.00046	0.00029	0.00123	0.00053
260	0.00045	0.00060	0.00050	0.00027	0.00046	0.00057	0.00043	0.00058	0.00033	0.00052	0.00307	0.00059	0.00064	0.00066	0.00049	0.00132	0.00053
261	0.00461	0.00529	0.00784	0.00315	0.00529	0.00391	0.00478	0.00834	0.00451	0.00499	0.00898	0.00676	0.00726	0.00812	0.00529	0.00905	0.00428
262	0.00999	0.01095	0.00742	0.00567	0.01103	0.00840	0.00773	0.01037	0.00903	0.00992	0.03359	0.01610	0.01254	0.02038	0.02846	0.01297	0.00747
263	0.00242	0.00413	0.00314	0.00194	0.00367	0.00268	0.00324	0.00370	0.00256	0.00392	0.00486	0.00595	0.00443	0.00416	0.00384	0.01953	0.00606
264	0.00313	0.00252	0.00128	0.00112	0.00317	0.00159	0.00139	0.00136	0.00091	0.00133	0.24237	0.02001	0.00155	0.00252	0.00435	0.00674	0.00184

	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
217														
218	35	36	37	38	39	40	41	42	43	44	45	46	47	48
219	0.00631	0.00371	0.00219	0.00184	0.00219	0.00149	0.00276	0.00252	0.00160	0.00485	0.00708	0.00292	0.00285	0.00222
220	0.00330	0.00179	0.00098	0.00084	0.00100	0.00062	0.00119	0.00056	0.00063	0.00179	0.00256	0.00135	0.00127	0.00118
221	0.00310	0.00122	0.00082	0.00062	0.00076	0.00044	0.00095	0.00019	0.00047	0.00161	0.00361	0.00085	0.00076	0.00106
222	0.00113	0.00059	0.00062	0.00033	0.00042	0.00040	0.00055	0.00026	0.00123	0.00124	0.00990	0.00050	0.00067	0.00055
223	0.00205	0.00129	0.00074	0.00060	0.00070	0.00043	0.00088	0.00028	0.00095	0.00116	0.00332	0.00096	0.00094	0.00069
224	0.00242	0.00022	0.00030	0.00021	0.00028	0.00017	0.00043	0.00009	0.00031	0.00105	0.00144	0.00037	0.00093	0.00080
225	0.00245	0.00143	0.00224	0.00282	0.00278	0.00261	0.00448	0.00407	0.00391	0.00347	0.00515	0.00447	0.00407	0.00284
226	0.00302	0.00156	0.00059	0.00070	0.00086	0.00077	0.00135	0.00063	0.00145	0.00145	0.00303	0.00312	0.00160	0.00346
227	0.00152	0.00154	0.00053	0.00057	0.00069	0.00116	0.00101	0.00122	0.00098	0.00184	0.00190	0.00175	0.00177	0.00236
228	0.01211	0.00146	0.00172	0.00144	0.00182	0.00113	0.00229	0.00091	0.00144	0.00501	0.00559	0.00243	0.00178	0.00324
229	0.00411	0.00070	0.00059	0.00048	0.00065	0.00043	0.00090	0.00041	0.00051	0.00175	0.00179	0.00116	0.00100	0.00138
230	0.01706	0.00152	0.00222	0.00156	0.00202	0.00122	0.00348	0.00057	0.00237	0.00799	0.01226	0.00271	0.00323	0.00429
231	0.00474	0.00079	0.00097	0.00082	0.00096	0.00062	0.00122	0.00023	0.00068	0.00181	0.00446	0.00124	0.00087	0.00132
232	0.00260	0.00164	0.00172	0.00118	0.00165	0.00199	0.00331	0.00943	0.00144	0.00813	0.01293	0.00351	0.00450	0.00178
233	0.00588	0.00344	0.00380	0.00366	0.00468	0.00806	0.00669	0.01659	0.01103	0.00478	0.01050	0.01361	0.00966	0.00694
234	0.00957	0.00536	0.01240	0.01850	0.01609	0.00849	0.02782	0.00664	0.01468	0.01109	0.01833	0.01450	0.01153	0.01100
235	0.02289	0.01326	0.02151	0.04925	0.02797	0.02320	0.09806	0.00351	0.03116	0.01788	0.04054	0.02288	0.02689	0.02236
236	0.01109	0.00847	0.00461	0.00531	0.00532	0.00538	0.01492	0.00601	0.00981	0.01911	0.01904	0.04638	0.01480	0.00791
237	0.02896	0.01479	0.00525	0.00654	0.00798	0.00707	0.01250	0.00554	0.01345	0.01328	0.02691	0.02848	0.01450	0.02478
238	0.00457	0.00241	0.00235	0.00225	0.00307	0.00824	0.00357	0.01077	0.00502	0.00356	0.00701	0.00532	0.00712	0.00572
239	0.00400	0.00204	0.00128	0.00122	0.00156	0.00220	0.00264	0.00297	0.00197	0.00216	0.00399	0.00483	0.00366	0.00261
240	0.00654	0.00393	0.00366	0.00327	0.00436	0.01213	0.00702	0.01962	0.00774	0.00508	0.01610	0.01442	0.01353	0.00968
241	0.00720	0.00744	0.00397	0.00356	0.00384	0.00479	0.01084	0.00361	0.00454	0.01044	0.00789	0.01895	0.00906	0.01008
242	0.03071	0.00261	0.00138	0.00134	0.00162	0.00124	0.00309	0.00093	0.00195	0.00199	0.00403	0.02691	0.02486	0.00179
243	0.00041	0.00027	0.00048	0.00058	0.00053	0.00028	0.00189	0.00013	0.00119	0.00076	0.00303	0.00112	0.00039	0.00041
244	0.00081	0.00210	0.00041	0.00079	0.00055	0.00061	0.00070	0.01437	0.00271	0.00242	0.00131	0.00412	0.00138	0.00565
245	0.04273	0.02202	0.02443	0.02382	0.03367	0.07822	0.02723	0.06487	0.04739	0.03411	0.07057	0.03681	0.07439	0.06435
246	0.07543	0.04555	0.02479	0.02360	0.03092	0.02477	0.05139	0.03460	0.02851	0.04157	0.06846	0.08053	0.04753	0.04252
247	0.02979	0.00891	0.01052	0.00983	0.01091	0.00708	0.01378	0.00196	0.00759	0.01746	0.02565	0.01335	0.00907	0.01227
248	0.01864	0.01455	0.00902	0.01031	0.01055	0.00666	0.01962	0.00419	0.02279	0.00721	0.01875	0.01048	0.01099	0.00923
249	0.07565	0.00523	0.00555	0.00440	0.00767	0.00293	0.00950	0.00193	0.00591	0.00716	0.01205	0.00772	0.00557	0.00519
250	0.00834	0.00857	0.00274	0.00308	0.00328	0.00219	0.00562	0.00124	0.00201	0.00272	0.00452	0.00426	0.00567	0.00254
251	1.07505	0.00719	0.00428	0.00310	0.00436	0.00276	0.00637	0.00080	0.00219	0.00486	0.00765	0.00418	0.00707	0.00404
252	0.02592	1.05587	0.04137	0.06453	0.05447	0.01770	0.04694	0.00498	0.01400	0.02186	0.04315	0.04470	0.03214	0.02505
253	0.05366	0.05299	1.24420	0.16020	0.25131	0.05012	0.07044	0.04853	0.01362	0.02597	0.04481	0.04882	0.04428	0.03473
254	0.00769	0.00634	0.04859	1.05884	0.22175	0.01322	0.02692	0.00416	0.00280	0.00409	0.00726	0.00621	0.02227	0.00655
255	0.00546	0.00835	0.00665	0.00603	1.02614	0.00275	0.00560	0.00679	0.00166	0.00295	0.00477	0.00419	0.00353	0.00678
256	0.01862	0.09162	0.03602	0.03278	0.03591	1.11006	0.03254	0.00449	0.00752	0.01684	0.03833	0.03381	0.04097	0.02350
257	0.12543	0.05737	0.10659	0.10600	0.09533	0.07245	1.12501	0.01518	0.02896	0.05082	0.11167	0.07734	0.08779	0.13180
258	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000	1.00000	0.00000	0.00000	0.00000	0.00000	0.00000	0.00000
259	0.00359	0.00078	0.00026	0.00031	0.00036	0.00026	0.00062	0.00009	1.00414	0.00126	0.00065	0.00040	0.00422	0.00144
260	0.01214	0.00094	0.00053	0.00045	0.00246	0.00037	0.00062	0.00013	0.00128	1.01802	0.00300	0.00044	0.01442	0.00052
261	0.01014	0.00633	0.03807	0.00765	0.01147	0.00970	0.01773	0.00210	0.00234	0.00444	1.13294	0.00632	0.00855	0.00659
262	0.01101	0.02127	0.00756	0.00780	0.01408	0.00923	0.01456	0.00271	0.01278	0.02572	0.03490	1.03498	0.01380	0.01470
263	0.02107	0.00713	0.00443	0.00418	0.00463	0.00418	0.00495	0.00086	0.00394	0.00472	0.00606	0.00447	1.00982	0.00339
264	0.00294	0.00180	0.00143	0.00138	0.00160	0.00449	0.00209	0.00350	0.00170	0.00179	0.01345	0.01576	0.00248	1.20104

	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
218	Inverse Leontief $(I-A)^{-1}$ of the 1997-98 New Zealand Input-Output Matrix (46 sector transaction matrix)																
219		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
220	1	1.1738	0.1216	0.0157	0.0111	0.1045	0.0047	0.0056	0.0024	0.0024	0.4266	0.0893	0.0421	0.0235	0.3281	0.0078	0.0039
221	2	0.0449	1.0374	0.0118	0.0245	0.0322	0.0032	0.0029	0.0024	0.0028	0.0773	0.6173	0.0273	0.0166	0.0514	0.0044	0.0034
222	3	0.0147	0.0101	1.0273	0.0217	0.0168	0.0020	0.0019	0.0012	0.0012	0.0117	0.0107	0.0585	0.0965	0.0083	0.0021	0.0016
223	4	0.0778	0.0434	0.1084	1.0389	0.0652	0.0021	0.0074	0.0005	0.0005	0.0343	0.0279	0.0123	0.0138	0.0247	0.0023	0.0013
224	5	0.0314	0.0208	0.0064	0.0045	1.1509	0.0012	0.0023	0.0008	0.0008	0.0731	0.0190	0.0487	0.0305	0.0235	0.0021	0.0013
225	6	0.0039	0.0024	0.0022	0.0084	0.0098	1.0012	0.0006	0.0004	0.0003	0.0027	0.0033	0.0961	0.0040	0.0026	0.0004	0.0004
226	7	0.0066	0.0049	0.0126	0.0103	0.0056	0.0024	1.5952	0.0047	0.0057	0.0078	0.0069	0.0082	0.0106	0.0068	0.3081	0.1703
227	8	0.0078	0.0073	0.0055	0.0052	0.0051	0.0012	0.0026	1.1980	0.0021	0.0043	0.0051	0.0022	0.0024	0.0043	0.0025	0.0019
228	9	0.0048	0.0043	0.0035	0.0049	0.0032	0.0011	0.0038	0.0500	1.0425	0.0047	0.0058	0.0028	0.0060	0.0034	0.0029	0.0018
229	10	0.0047	0.0045	0.0027	0.0050	0.0171	0.0044	0.0025	0.0029	0.0030	1.2611	0.0059	0.0424	0.0088	0.0779	0.0044	0.0034
230	11	0.0045	0.0038	0.0028	0.0046	0.0040	0.0036	0.0021	0.0029	0.0037	0.0051	1.0430	0.0253	0.0111	0.0056	0.0043	0.0040
231	12	0.0050	0.0105	0.0021	0.0047	0.0322	0.0095	0.0052	0.0029	0.0022	0.0108	0.0272	1.1356	0.0413	0.0050	0.0034	0.0031
232	13	0.0008	0.0007	0.0005	0.0010	0.0009	0.0008	0.0004	0.0007	0.0010	0.0010	0.0009	0.0020	1.0462	0.0011	0.0009	0.0009
233	14	0.0058	0.0025	0.0025	0.0051	0.0022	0.0084	0.0008	0.0013	0.0016	0.0044	0.0021	0.0046	0.0054	1.1840	0.0112	0.0023
234	15	0.0138	0.0107	0.0212	0.0080	0.0079	0.0053	0.0046	0.0111	0.0153	0.0111	0.0100	0.0094	0.0136	0.0113	1.1980	0.0303
235	16	0.0113	0.0092	0.0424	0.0322	0.0101	0.0064	0.0054	0.0122	0.0109	0.0282	0.0210	0.0386	0.0485	0.0234	0.0271	1.2580
236	17	0.0112	0.0090	0.0139	0.0177	0.0098	0.0074	0.0065	0.0216	0.0128	0.0213	0.0189	0.0232	0.0255	0.0163	0.0131	0.0473
237	18	0.0166	0.0192	0.0175	0.0160	0.0117	0.0071	0.0085	0.0116	0.0184	0.0308	0.0249	0.0334	0.0378	0.0311	0.0235	0.0219
238	19	0.1373	0.1293	0.0974	0.0910	0.0903	0.0205	0.0459	0.0228	0.0357	0.0755	0.0895	0.0373	0.0405	0.0753	0.0428	0.0324
239	20	0.0097	0.0076	0.0073	0.0142	0.0059	0.0034	0.0022	0.0091	0.0106	0.0070	0.0088	0.0081	0.0512	0.0064	0.0114	0.0033
240	21	0.0067	0.0060	0.0039	0.0050	0.0045	0.0031	0.0027	0.0045	0.0072	0.0062	0.0053	0.0059	0.0105	0.0070	0.0082	0.0053
241	22	0.0262	0.0275	0.0109	0.0169	0.0144	0.0094	0.0087	0.0232	0.0309	0.0188	0.0218	0.0204	0.0433	0.0156	0.0352	0.0101
242	23	0.0098	0.0089	0.0078	0.0123	0.0077	0.0083	0.0108	0.0205	0.0399	0.0142	0.0118	0.0142	0.0133	0.0132	0.0194	0.0267
243	24	0.0051	0.0035	0.0028	0.0045	0.0032	0.0244	0.0045	0.0057	0.0058	0.0047	0.0039	0.0067	0.0058	0.0043	0.0057	0.0053
244	25	0.0002	0.0002	0.0002	0.0003	0.0002	0.0001	0.0001	0.0003	0.0002	0.0003	0.0002	0.0003	0.0004	0.0021	0.0003	0.0002
245	28	0.0013	0.0012	0.0012	0.0014	0.0012	0.0006	0.0007	0.0010	0.0012	0.0150	0.0032	0.0076	0.0130	0.0064	0.0018	0.0138
246	29	0.1092	0.0851	0.0593	0.0468	0.0601	0.0357	0.0218	0.0912	0.1228	0.0721	0.0633	0.0428	0.0380	0.0677	0.0546	0.0279
247	30	0.1310	0.1090	0.0826	0.1031	0.0974	0.0540	0.0539	0.0617	0.0989	0.1374	0.1012	0.1235	0.2201	0.1659	0.1245	0.1024
248	31	0.0085	0.0061	0.0050	0.0107	0.0071	0.0062	0.0035	0.0079	0.0120	0.0094	0.0073	0.0094	0.0135	0.0114	0.0106	0.0100
249	32	0.0593	0.0244	0.0240	0.0288	0.0286	0.0251	0.0802	0.0936	0.0868	0.0545	0.0392	0.0561	0.0539	0.0443	0.0683	0.0719
250	33	0.0147	0.0123	0.0092	0.0160	0.0130	0.0136	0.0228	0.0380	0.0186	0.0225	0.0161	0.0201	0.0231	0.0178	0.0289	0.0254
251	34	0.0082	0.0064	0.0089	0.0087	0.0118	0.3679	0.0045	0.0168	0.0138	0.0120	0.0124	0.0632	0.0143	0.0118	0.0136	0.0465
252	35	0.0037	0.0031	0.0034	0.0055	0.0039	0.0047	0.0035	0.0063	0.0055	0.0057	0.0037	0.0060	0.0061	0.0074	0.0066	0.0084
253	36	0.0339	0.0281	0.0237	0.0330	0.0312	0.0174	0.0177	0.0411	0.0336	0.0422	0.0297	0.0386	0.0416	0.0474	0.0383	0.0323
254	37	0.0821	0.0785	0.0605	0.0823	0.0730	0.0466	0.0530	0.1613	0.0559	0.0882	0.0831	0.0973	0.1089	0.1031	0.0792	0.0877
255	38	0.0061	0.0060	0.0044	0.0081	0.0063	0.0033	0.0031	0.0110	0.0045	0.0071	0.0057	0.0080	0.0068	0.0071	0.0053	0.0064
256	39	0.0077	0.0065	0.0042	0.0064	0.0063	0.0038	0.0027	0.0139	0.0036	0.0067	0.0056	0.0049	0.0042	0.0060	0.0050	0.0049
257	40	0.0259	0.0342	0.0212	0.0137	0.0262	0.0101	0.0087	0.0178	0.0129	0.0282	0.0260	0.0206	0.0212	0.0332	0.0252	0.0179
258	41	0.0684	0.0472	0.0510	0.1166	0.0625	0.0505	0.0411	0.2040	0.0751	0.0936	0.0499	0.0734	0.0651	0.0882	0.0641	0.0360
259	42	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
260	43	0.0015	0.0015	0.0006	0.0010	0.0010	0.0007	0.0003	0.0010	0.0007	0.0018	0.0012	0.0017	0.0024	0.0014	0.0009	0.0006
261	44	0.0098	0.0106	0.0059	0.0058	0.0096	0.0027	0.0030	0.0075	0.0076	0.0094	0.0083	0.0051	0.0068	0.0084	0.0041	0.0042
262	45	0.0094	0.0143	0.0108	0.0071	0.0152	0.0035	0.0031	0.0095	0.0044	0.0138	0.0106	0.0100	0.0105	0.0089	0.0059	0.0056
263	46	0.0284	0.0373	0.0194	0.0143	0.0201	0.0058	0.0114	0.0134	0.0115	0.0208	0.0282	0.0125	0.0166	0.0181	0.0116	0.0119
264	47	0.0005	0.0005	0.0003	0.0004	0.0005	0.0003	0.0002	0.0008	0.0006	0.0005	0.0004	0.0004	0.0004	0.0006	0.0004	0.0003
265	48	0.0030	0.0024	0.0020	0.0031	0.0036	0.0010	0.0012	0.0020	0.0021	0.0041	0.0023	0.0024	0.0031	0.0030	0.0016	0.0031

	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
218																		
219	17	18	19	20	21	22	23	24	25	28	29	30	31	32	33	34	35	36
220	0.0028	0.0073	0.0058	0.0030	0.0028	0.0036	0.0034	0.0032	0.0083	0.0031	0.0042	0.0059	0.0573	0.0035	0.0032	0.0043	0.0077	0.0032
221	0.0027	0.0050	0.0047	0.0036	0.0041	0.0039	0.0035	0.0051	0.0052	0.0034	0.0043	0.0152	0.0398	0.0040	0.0029	0.0052	0.0085	0.0025
222	0.0014	0.0020	0.0016	0.0016	0.0015	0.0017	0.0017	0.0018	0.0028	0.0019	0.0018	0.0048	0.0337	0.0017	0.0016	0.0032	0.0050	0.0019
223	0.0006	0.0013	0.0008	0.0006	0.0006	0.0007	0.0007	0.0007	0.0012	0.0007	0.0009	0.0016	0.0095	0.0007	0.0006	0.0009	0.0015	0.0006
224	0.0011	0.0074	0.0014	0.0010	0.0008	0.0011	0.0011	0.0011	0.0021	0.0010	0.0012	0.0018	0.0187	0.0011	0.0011	0.0015	0.0025	0.0012
225	0.0003	0.0010	0.0004	0.0003	0.0003	0.0004	0.0004	0.0003	0.0044	0.0005	0.0004	0.0004	0.0109	0.0003	0.0003	0.0011	0.0018	0.0001
226	0.0276	0.0071	0.0047	0.0101	0.0054	0.0081	0.0099	0.0111	0.0104	0.0056	0.0337	0.0079	0.0057	0.0037	0.0106	0.0035	0.0034	0.0015
227	0.0011	0.0067	0.0688	0.0019	0.0024	0.0014	0.0017	0.0011	0.0027	0.0013	0.0028	0.0020	0.0016	0.0042	0.0012	0.0015	0.0016	0.0006
228	0.0011	0.0049	0.0256	0.0819	0.0634	0.0069	0.0032	0.0030	0.0459	0.0045	0.0102	0.0030	0.0023	0.0026	0.0031	0.0015	0.0014	0.0011
229	0.0027	0.0054	0.0112	0.0032	0.0030	0.0032	0.0034	0.0028	0.0125	0.0044	0.0038	0.0037	0.1368	0.0040	0.0034	0.0072	0.0154	0.0014
230	0.0030	0.0050	0.0058	0.0045	0.0056	0.0047	0.0041	0.0070	0.0054	0.0043	0.0054	0.0228	0.0470	0.0051	0.0030	0.0069	0.0116	0.0015
231	0.0022	0.0064	0.0031	0.0024	0.0021	0.0033	0.0034	0.0023	0.0032	0.0033	0.0029	0.0029	0.0920	0.0023	0.0022	0.0085	0.0122	0.0010
232	0.0008	0.0010	0.0009	0.0010	0.0010	0.0009	0.0011	0.0010	0.0012	0.0012	0.0011	0.0019	0.0655	0.0010	0.0009	0.0014	0.0042	0.0005
233	0.0017	0.0038	0.0029	0.0021	0.0019	0.0036	0.0030	0.0023	0.0076	0.0017	0.0052	0.0029	0.0030	0.0023	0.0020	0.0013	0.0013	0.0007
234	0.0128	0.0095	0.0085	0.0239	0.0128	0.0220	0.0269	0.0345	0.0187	0.0109	0.1191	0.0085	0.0106	0.0073	0.0331	0.0093	0.0069	0.0029
235	0.1863	0.0331	0.0159	0.0285	0.0125	0.0166	0.0210	0.0141	0.0402	0.0166	0.0234	0.0282	0.0182	0.0113	0.0145	0.0069	0.0100	0.0044
236	1.1571	0.0195	0.0119	0.0176	0.0116	0.0150	0.0195	0.0150	0.0165	0.0213	0.0206	0.0221	0.0201	0.0144	0.0225	0.0091	0.0199	0.0091
237	0.0358	1.0608	0.0261	0.0172	0.0119	0.0223	0.0235	0.0282	0.0595	0.0105	0.0346	0.0198	0.0161	0.0308	0.0147	0.0082	0.0104	0.0064
238	0.0190	0.1191	1.2296	0.0323	0.0398	0.0224	0.0280	0.0174	0.0467	0.0221	0.0476	0.0227	0.0269	0.0728	0.0206	0.0244	0.0272	0.0107
239	0.0025	0.0055	0.0059	1.1611	0.0086	0.0126	0.0060	0.0132	0.0078	0.0448	0.0975	0.0040	0.0102	0.0043	0.0259	0.0066	0.0047	0.0019
240	0.0036	0.0060	0.0088	0.0108	1.0927	0.0867	0.0331	0.0256	0.0345	0.0079	0.0186	0.0326	0.0048	0.0063	0.0061	0.0032	0.0041	0.0017
241	0.0066	0.0187	0.0111	0.0383	0.0408	1.0830	0.0469	0.0277	0.0223	0.0339	0.1096	0.0095	0.0143	0.0077	0.0305	0.0099	0.0074	0.0033
242	0.0125	0.0103	0.0160	0.0190	0.0186	0.0243	1.1169	0.0233	0.0190	0.0143	0.0340	0.0121	0.0096	0.0142	0.0137	0.0094	0.0134	0.0087
243	0.0034	0.0032	0.0033	0.0050	0.0052	0.0053	0.0049	1.2068	0.0043	0.0029	0.0044	0.0097	0.0031	0.0527	0.0031	0.0125	0.0280	0.0016
244	0.0014	0.0003	0.0002	0.0003	0.0002	0.0003	0.0003	0.0003	1.0121	0.0003	0.0004	0.0004	0.0002	0.0003	0.0003	0.0001	0.0002	0.0001
245	0.0026	0.0027	0.0034	0.0105	0.0025	0.0032	0.0019	0.0020	0.0015	1.5546	0.0025	0.0017	0.0056	0.0044	0.0024	0.0008	0.0011	0.0021
246	0.0245	0.0327	0.0517	0.1014	0.0762	0.0350	0.0334	0.0240	0.0507	0.0767	1.3138	0.0342	0.0534	0.0405	0.3433	0.0808	0.0490	0.0184
247	0.0765	0.1099	0.1887	0.1301	0.2004	0.1619	0.1255	0.2367	0.1665	0.0744	0.1624	1.1097	0.1077	0.1538	0.0739	0.0598	0.0803	0.0372
248	0.0100	0.0115	0.0083	0.0110	0.0109	0.0101	0.0129	0.0090	0.0134	0.0130	0.0119	0.0112	1.0154	0.0110	0.0109	0.0087	0.0262	0.0065
249	0.0460	0.0335	0.0283	0.0475	0.0295	0.0312	0.0263	0.0207	0.0386	0.0185	0.0290	0.0399	0.0227	1.1389	0.0212	0.0374	0.0207	0.0123
250	0.0137	0.0178	0.0125	0.0228	0.0184	0.0197	0.0160	0.0149	0.0204	0.0175	0.0149	0.0220	0.0112	0.0439	1.0371	0.0234	0.0872	0.0054
251	0.0133	0.0118	0.0127	0.0228	0.0212	0.0110	0.0091	0.0114	0.0150	0.0067	0.0092	0.0182	0.0123	0.0201	0.0062	1.1525	0.0108	0.0081
252	0.0056	0.0058	0.0040	0.0058	0.0049	0.0057	0.0064	0.0068	0.0083	0.0047	0.0053	0.0082	0.0038	0.0120	0.0293	0.0071	1.0765	0.0057
253	0.0564	0.0357	0.0277	0.0377	0.0317	0.0383	0.0444	0.0373	0.0428	0.0313	0.0475	0.0617	0.0486	0.0557	0.0945	0.0237	0.0386	1.0632
254	0.0874	0.0839	0.0699	0.0809	0.0839	0.0851	0.0746	0.1048	0.0808	0.0366	0.1119	0.0997	0.0818	0.0853	0.0601	0.0486	0.0612	0.0474
255	0.0072	0.0080	0.0061	0.0057	0.0053	0.0068	0.0064	0.0089	0.0060	0.0056	0.0099	0.0089	0.0060	0.0067	0.0078	0.0037	0.0056	0.0037
256	0.0046	0.0041	0.0049	0.0044	0.0039	0.0039	0.0038	0.0039	0.0051	0.0048	0.0047	0.0050	0.0049	0.0075	0.0045	0.0026	0.0049	0.0055
257	0.0259	0.0231	0.0163	0.0235	0.0182	0.0279	0.0250	0.0242	0.0347	0.0215	0.0223	0.0416	0.0413	0.0253	0.0310	0.0176	0.0170	0.0627
258	0.0849	0.0826	0.0630	0.0904	0.0751	0.0717	0.0768	0.0786	0.0980	0.0954	0.0987	0.0743	0.0753	0.0793	0.1203	0.0724	0.1171	0.0418
259	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
260	0.0017	0.0013	0.0008	0.0010	0.0014	0.0010	0.0014	0.0008	0.0027	0.0025	0.0010	0.0012	0.0013	0.0009	0.0035	0.0017	0.0117	0.0019
261	0.0098	0.0059	0.0041	0.0051	0.0065	0.0042	0.0053	0.0036	0.0063	0.0534	0.0064	0.0052	0.0058	0.0055	0.0124	0.0043	0.0444	0.0057
262	0.0067	0.0100	0.0053	0.0068	0.0054	0.0059	0.0084	0.0072	0.0070	0.0098	0.0078	0.0081	0.0095	0.0063	0.0090	0.0044	0.0102	0.0057
263	0.0130	0.0095	0.0093	0.0134	0.0112	0.0092	0.0116	0.0127	0.0128	0.0390	0.0176	0.0135	0.0234	0.0307	0.0123	0.0078	0.0117	0.0163
264	0.0005	0.0004	0.0003	0.0005	0.0004	0.0004	0.0004	0.0004	0.0005	0.0006	0.0007	0.0005	0.0005	0.0005	0.0020	0.0006	0.0022	0.0006
265	0.0025	0.0014	0.0015	0.0032	0.0017	0.0014	0.0013	0.0011	0.0015	0.2080	0.0158	0.0014	0.0024	0.0041	0.0055	0.0015	0.0026	0.0012

	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV
218												
219	37	38	39	40	41	42	43	44	45	46	47	48
220	0.0022	0.0023	0.0029	0.0021	0.0029	0.0021	0.0017	0.0032	0.0063	0.0037	0.0031	0.0031
221	0.0019	0.0019	0.0025	0.0016	0.0025	0.0009	0.0013	0.0026	0.0053	0.0034	0.0029	0.0037
222	0.0014	0.0013	0.0017	0.0010	0.0016	0.0003	0.0007	0.0018	0.0049	0.0020	0.0014	0.0022
223	0.0007	0.0005	0.0006	0.0005	0.0007	0.0002	0.0012	0.0009	0.0098	0.0007	0.0008	0.0008
224	0.0009	0.0009	0.0011	0.0006	0.0011	0.0003	0.0012	0.0009	0.0037	0.0014	0.0012	0.0010
225	0.0002	0.0002	0.0003	0.0002	0.0003	0.0001	0.0002	0.0005	0.0010	0.0004	0.0009	0.0008
226	0.0027	0.0045	0.0045	0.0043	0.0058	0.0037	0.0046	0.0030	0.0070	0.0066	0.0060	0.0045
227	0.0003	0.0005	0.0006	0.0005	0.0008	0.0003	0.0007	0.0005	0.0016	0.0018	0.0009	0.0018
228	0.0005	0.0006	0.0008	0.0013	0.0009	0.0008	0.0008	0.0011	0.0017	0.0017	0.0018	0.0023
229	0.0020	0.0021	0.0028	0.0018	0.0029	0.0009	0.0017	0.0041	0.0065	0.0038	0.0025	0.0050
230	0.0016	0.0016	0.0022	0.0016	0.0025	0.0008	0.0013	0.0032	0.0053	0.0037	0.0030	0.0050
231	0.0017	0.0015	0.0020	0.0013	0.0029	0.0004	0.0018	0.0041	0.0077	0.0028	0.0030	0.0040
232	0.0007	0.0008	0.0009	0.0006	0.0010	0.0001	0.0005	0.0010	0.0037	0.0013	0.0008	0.0013
233	0.0008	0.0007	0.0010	0.0021	0.0016	0.0063	0.0007	0.0029	0.0062	0.0020	0.0025	0.0011
234	0.0039	0.0048	0.0063	0.0107	0.0074	0.0118	0.0103	0.0034	0.0116	0.0155	0.0118	0.0092
235	0.0119	0.0239	0.0204	0.0108	0.0282	0.0048	0.0132	0.0073	0.0196	0.0177	0.0128	0.0132
236	0.0181	0.0554	0.0297	0.0254	0.0878	0.0024	0.0249	0.0103	0.0360	0.0249	0.0253	0.0229
237	0.0043	0.0066	0.0064	0.0068	0.0145	0.0041	0.0079	0.0092	0.0186	0.0405	0.0155	0.0087
238	0.0053	0.0081	0.0099	0.0089	0.0128	0.0043	0.0120	0.0084	0.0273	0.0301	0.0156	0.0262
239	0.0022	0.0027	0.0038	0.0098	0.0036	0.0071	0.0044	0.0023	0.0070	0.0056	0.0079	0.0067
240	0.0013	0.0015	0.0020	0.0028	0.0028	0.0021	0.0019	0.0016	0.0043	0.0052	0.0041	0.0033
241	0.0037	0.0042	0.0056	0.0158	0.0074	0.0137	0.0067	0.0036	0.0168	0.0156	0.0154	0.0121
242	0.0052	0.0053	0.0069	0.0069	0.0161	0.0030	0.0080	0.0141	0.0167	0.0261	0.0177	0.0186
243	0.0011	0.0014	0.0017	0.0013	0.0028	0.0006	0.0017	0.0010	0.0036	0.0195	0.0201	0.0018
244	0.0003	0.0004	0.0004	0.0002	0.0010	0.0001	0.0006	0.0003	0.0020	0.0007	0.0002	0.0003
245	0.0005	0.0014	0.0009	0.0011	0.0009	0.0129	0.0031	0.0020	0.0017	0.0057	0.0019	0.0082
246	0.0251	0.0314	0.0444	0.0982	0.0306	0.0484	0.0443	0.0234	0.0763	0.0450	0.0891	0.0805
247	0.0254	0.0305	0.0404	0.0342	0.0545	0.0266	0.0287	0.0290	0.0750	0.0927	0.0562	0.0539
248	0.0093	0.0106	0.0123	0.0085	0.0128	0.0014	0.0064	0.0104	0.0236	0.0164	0.0095	0.0133
249	0.0099	0.0142	0.0148	0.0096	0.0212	0.0034	0.0233	0.0052	0.0216	0.0133	0.0133	0.0124
250	0.0073	0.0119	0.0174	0.0098	0.0131	0.0019	0.0072	0.0064	0.0163	0.0120	0.0095	0.0100
251	0.0035	0.0047	0.0054	0.0036	0.0070	0.0012	0.0024	0.0022	0.0058	0.0063	0.0077	0.0038
252	0.0043	0.0038	0.0059	0.0038	0.0067	0.0007	0.0023	0.0033	0.0081	0.0054	0.0079	0.0051
253	0.0583	0.1136	0.0993	0.0345	0.0705	0.0057	0.0201	0.0210	0.0659	0.0797	0.0512	0.0438
254	1.2760	0.2047	0.3330	0.0736	0.0812	0.0399	0.0151	0.0196	0.0531	0.0620	0.0554	0.0487
255	0.0366	1.0497	0.1834	0.0127	0.0214	0.0024	0.0019	0.0020	0.0056	0.0055	0.0178	0.0059
256	0.0055	0.0058	1.0299	0.0026	0.0052	0.0045	0.0014	0.0017	0.0043	0.0042	0.0032	0.0072
257	0.0320	0.0337	0.0399	1.1388	0.0309	0.0032	0.0068	0.0100	0.0362	0.0345	0.0400	0.0290
258	0.0976	0.1158	0.1047	0.0768	1.1205	0.0112	0.0273	0.0321	0.1087	0.0885	0.0891	0.1446
259	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
260	0.0007	0.0010	0.0013	0.0006	0.0017	0.0001	1.0022	0.0019	0.0017	0.0024	0.0062	0.0056
261	0.0039	0.0045	0.0130	0.0047	0.0069	0.0010	0.0078	1.0442	0.0168	0.0103	0.0588	0.0102
262	0.0359	0.0089	0.0142	0.0120	0.0181	0.0016	0.0023	0.0030	1.1450	0.0079	0.0095	0.0080
263	0.0075	0.0095	0.0174	0.0119	0.0152	0.0022	0.0128	0.0170	0.0363	1.0406	0.0165	0.0166
264	0.0005	0.0005	0.0006	0.0005	0.0006	0.0001	0.0004	0.0003	0.0007	0.0005	1.0011	0.0004
265	0.0011	0.0014	0.0016	0.0043	0.0018	0.0024	0.0014	0.0010	0.0109	0.0142	0.0023	1.1915

5.2 Details of calculations of national sectoral ecological service inputs requirements

5.2.1 Water inputs, water discharge and water pollutants

The details behind the water input, discharge data and water pollutants are recorded in the EcoLink Water Account Technical Report (McDonald & Patterson, 1999). Essentially, the data are based on water abstraction (for surface and ground water) and discharge consents allocated by the three regional councils (Northland Regional Council, Auckland Regional Council and Environment Waikato) to the 48 sectors over the two periods (1994/95 and 1997/98). National estimates are calculated using the regional data. First, the three regions' ecosystem service requirements are summed. This total is then multiplied by the following ratio:

$$s_{ri} = \frac{v_{nzi}}{v_{ri}}$$

Equation A5- 1

Where:

s_{ri} = the scalar for three-region sum r for sector i

v_{nzi} = the value added for sector i for New Zealand as a whole

v_{ri} = the value added for sector i in the thee regions r

Sensitivity analysis showed that the difference between use of value added and employment scalars is marginal.

The resulting eco-efficiency indicators related to water use and discharge are shown in Appendix 5.3 below.

5.2.2 Land data

National land estimates (in ha) were estimated by McDonald (forthcoming) for 1997/98 only. It was assumed that the sectoral land use remained constant between 1994/95 and 1997/98.

5.2.3 Energy data

Energy data is not readily available to a 48 sector breakdown. The most disaggregated energy data set available is the EECA database. This database contains, inter alia, delivered energy data for the 1994/95 year (in TJ/yr) broken down to 33 sectors. The following table outlines the approach to disaggregating each of the sectors to provide a compatible 48-sector breakdown.

Table A5-2: Details of disaggregation process for energy sectors

33 sector number	33 Sector Name	48 sector number	48 sector name	Comment
1	Agriculture	1	Mixed livestock	An assessment of energy requirements in agriculture was made in 1985 (Patterson & Earle. 1985). Since then, there has been no comprehensive analysis of energy use in agriculture. Delivered energy to agriculture was obtained from page 8 of Patterson and Earle (1985). This contained information on 'fuel', electricity and 'other' energy types. 'Fuel' use was broken down using the proportions of fuel use from the EECA database. The EECA database showed that the agricultural sector used aviation gasoline (1% of total fuel use), diesel (61%) and petrol (38%). 'Other' was assumed to be natural gas use. Using the estimates for avgas. diesel. petrol, electricity and gas, it was possible to work out a sectoral split of energy types. This was then used to allocate the agricultural sector energy use data (from the EECA database) to the 5 subsectors.
1		2	Dairy farming	
1		3	Horticulture	
1		4	Services to Agriculture	
1		5	All other farming	
2	Fishing and Hunting	6	Fishing and Hunting	
3	Forestry and Logging	7	Forestry & Logging	
4	Mining and Quarrying	8	Oil and Gas Exploration	In the absence of other data, the Other Mining sector was disaggregated using value added proportions. That is, each subsector ('oil and gas exploration' and 'other mining') energy use was assumed to be the same as the proportion of value added.
4		9	Other mining	
5	Slaughtering and Meat Processing	10	Meat Products	
6	Dairy Products	11	Dairy Products	
7	Other Food Processing Sectors	12	Manufacture of other food	An assessment of energy requirements in the food processing system was made by Patterson in 1993. Since then, there has been no comprehensive analysis of energy use in this sector. Patterson's assessment was based on 1991/92 data. The proportions from Patterson's work were used to disaggregate the EECA database 'other food processing' sector to the necessary level.
7		13	Beverage Manufacture	
8	Textile, Apparel	14	Textile	

	and Leathergoods		Manufacture	
9	Wood Processing and Wood Products	15	Wood & Wood Products	
10	Paper and Paper Products, Printing and Publishing	16	Paper Manufacturing	Data from the Energy Efficiency and Conservation Authority's Energy Wise Monitoring Quarterly, issue 10 (Forestry sector study) were used (Energy Efficiency and Conservation Authority, 1998) to disaggregate paper products and printing sectors.
10		17	Printing & Publishing	
11	Chemicals, Related Products and Plastics	18	Other Chemicals	In the absence of other data, value added was used for disaggregation.
11		19	Basic Chemicals	
12	Concrete, Clay, Glass and Related Minerals Manufacture	20	Non-metallic Minerals	
13	Basic Metal Industries	21	Basic Metal Industries	
14	Fabricated Metal Products, Machinery and Equipment	22	Fabricated Metals	In the absence of other data, value added was used for disaggregation.
14		23	Equipment Manufacture	
14		24	Transport Equipment	
15	Other Manufacturing Industries	25	Other Manufacturing	
	Not included	26	Electricity Generation &	
	Not included	27	Gas Treatment & Distribution	
33	Water Works and Supply	28	Water works	
16	Construction	29	Construction	
17	Wholesale Trade - Food	30	Trade	
18	Retail Trade - Food	31	Accommodation	
19	Motels, Hotels & Guest Houses	31		
20	Wholesale and Retail Trade - Non Food	31		
21	Transport and Storage	32	Road Transport	Energy use by transport mode is available from the EECA database.
21		33	Services to Transport	
21		34	Water Transport	
21		35	Air Transport	

22	Communication	36	Communications	
23	Financing, Insurance, Real Estate and Business Services	37	Finance	In the absence of other data, value added was used for disaggregation.
23		38	Finance services	
23		39	Insurance	
23		40	Real Estate	
24	Sanitary and Cleaning Services	41	Business Services	
32	Household	42	Dwelling ownership	
25	Education Services: Pre-School, Primary and Secondary	43	Education	
26	Education Services: Tertiary Education			
27	Health and Welfare Services	44	Community Services	In the absence of other data, value added was used for disaggregation.
28	Other Social and Related Community Services			
27		45	Recreation Services	
27		46	Personal Services	
29	Central Government Administration	47	Central Government	
31	Central Government Defence Services			
30	Local Government Administration	48	Local Government	

The 1994/95 data was extrapolated to 1997/98 using the sectoral value-added growth rates.

5.2.4 Energy-related air pollutants

Energy-related air pollutants were calculated by multiplying sectoral energy use data by relevant emission factors. Emission factors were obtained from Annex A of the Ministry of Commerce publication 'Energy Greenhouse Gas Emissions: 1990-1998' (Ministry of Commerce, 1999). These emission factors are in turn based on Baines (1993). Note that emission estimates in this present research differ somewhat from other published estimates. This is primarily because this study does not include the household sector (i.e. the input-output table is open with respect to the household sector) energy use. Furthermore, household transport energy use is not included in this analysis.

5.2.5 Mineral inputs

Mineral extraction data for gold, silver, coal and iron sand was obtained from the Crown Minerals section of the Ministry of Economic Development. The iron sand information was verified against data provided by BHP New Zealand Steel Mining.

5.3 Eco-efficiency profile for New Zealand

	A	B	C	D	E	G	H	I	J	K	L	M	N	O	P	Q
7						1	2	3	4	5	6	7	8	9	10	11
8						Mixed livestock	Dairy farming	Horticulture	Services to Agriculture	All other farming	Fishing and Hunting	Forestry & Logging	Oil and Gas Exploration	Other mining	Meat Products	Dairy Products
10	1994/95	Water in	Ground Water Takes		$m^3/\$$	8.6E-06	1.8E-03	3.3E-02	4.2E-04	7.9E-03	4.3E-04	3.7E-04	0.0E+00	1.1E-01	1.9E-03	5.2E-03
11	1994/95		Surface Water Takes		$m^3/\$$	2.4E-05	9.7E-03	3.0E-02	1.6E-04	3.2E-02	1.2E-01	4.3E-05	0.0E+00	1.0E-01	1.8E-02	1.9E-02
12	1994/95		Total Water Takes		$m^3/\$$	3.3E-05	1.2E-02	6.3E-02	5.8E-04	4.0E-02	1.2E-01	4.1E-04	0.0E+00	2.1E-01	2.0E-02	2.4E-02
13	1994/95	Land IN	Total land		ha/$	2.9E-03	7.1E-04	1.8E-04	3.6E-07	8.7E-04	8.1E-06	6.4E-04	5.5E-06	7.5E-05	5.4E-07	2.0E-07
14	1994/95	Energy IN	Aviation Fuel		GJ/$	0.0E+00	0.0E+00	0.0E+00	1.6E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
15	1994/95		Black Liquor		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
16	1994/95		Coal		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.2E-04	3.6E-04	4.9E-04	1.7E-03
17	1994/95		Diesel		GJ/$	1.2E-03	8.9E-04	3.4E-04	5.8E-05	2.0E-03	6.5E-03	3.6E-04	1.3E-03	7.3E-04	1.0E-05	1.6E-04
18	1994/95		Electricity		GJ/$	1.1E-04	5.7E-04	1.6E-04	6.0E-04	4.3E-04	7.1E-05	0.0E+00	8.9E-04	5.2E-04	2.7E-04	4.6E-04
19	1994/95		Fuel Oil		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E-03	0.0E+00	3.4E-04	2.0E-04	8.5E-06	3.9E-05
20	1994/95		Geothermal		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
21	1994/95		LPG		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-05	3.1E-06
22	1994/95		Natural Gas		GJ/$	1.9E-06	4.3E-06	1.4E-06	4.0E-04	4.9E-06	0.0E+00	0.0E+00	1.9E-05	1.1E-05	1.7E-04	1.4E-03
23	1994/95		Petrol		GJ/$	7.2E-04	5.4E-04	2.1E-04	9.4E-05	1.2E-03	1.2E-05	1.6E-04	1.8E-04	1.0E-04	5.3E-05	2.2E-07
24	1994/95		Wood		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	1994/95		Total		GJ/$	2.0E-03	2.0E-03	7.2E-04	1.3E-03	3.7E-03	8.3E-03	5.2E-04	3.3E-03	1.9E-03	1.0E-03	3.8E-03
26	1994/95	Minerals I	Gold		g/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.5E-02	0.0E+00	0.0E+00
27	1994/95		Silver		g/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E-02	0.0E+00	0.0E+00
28	1994/95		Coal		tonne/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.3E-03	0.0E+00	0.0E+00
29	1994/95		Ironsand		tonne/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.9E-03	0.0E+00	0.0E+00
30	1994/95	Water dis(	Discharges Into Water		$m^3/\$$	0.0E+00	5.8E-03	1.8E-03	3.5E-04	3.5E-03	1.2E-01	0.0E+00	0.0E+00	6.2E-01	1.9E-02	1.2E-02
31	1994/95		Discharges Onto Land		$m^3/\$$	0.0E+00	2.1E-03	1.1E-06	6.5E-05	4.5E-03	3.7E-04	1.5E-06	0.0E+00	1.1E-02	1.9E-03	4.8E-03
32	1994/95		Total Discharges		$m^3/\$$	0.0E+00	7.9E-03	1.8E-03	4.2E-04	8.0E-03	1.2E-01	1.5E-06	0.0E+00	6.3E-01	2.1E-02	1.7E-02
33	1994/95	Water Pol	Into Water	Ammonia (NH4 - kg)	kg/$	0.0E+00	4.1E-04	0.0E+00	2.3E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.9E-04	4.7E-09
34	1994/95		Into Water	Biochemical Oxygen Demand ·	kg/$	0.0E+00	4.4E-04	0.0E+00	1.7E-06	2.4E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-04	3.3E-08
35	1994/95		Into Water	Dissolved Reactive Phosphoro	kg/$	0.0E+00	5.5E-05	0.0E+00	2.3E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.7E-09
36	1994/95		Into Water	Nitrate (NO3 - kg)	kg/$	0.0E+00	1.0E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-04	0.0E+00
37	1994/95		Into Water	Total Kjeldahl Nitrogen (TKN	kg/$	0.0E+00	0.0E+00	0.0E+00	2.4E-06	7.8E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E-04	4.7E-08
38	1994/95		Into Water	Total Phosphorus (TP - kg)	kg/$	0.0E+00	1.3E-04	0.0E+00	2.8E-07	2.7E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.2E-05	4.7E-09
39	1994/95		Onto Land	Ammonia (NH4 - kg)	kg/$	0.0E+00	1.7E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-04	2.8E-08
40	1994/95		Onto Land	Biochemical Oxygen Demand ·	kg/$	0.0E+00	1.8E-04	0.0E+00	0.0E+00	2.7E-04	0.0E+00	0.0E+00	0.0E+00	9.2E-08	9.4E-05	2.4E-07
41	1994/95		Onto Land	Dissolved Reactive Phosphoro	kg/$	0.0E+00	2.3E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E-08	3.6E-08	3.3E-08
42	1994/95		Onto Land	Nitrate (NO3 - kg)	kg/$	0.0E+00	4.2E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.4E-05	0.0E+00
43	1994/95		Onto Land	Total Kjeldahl Nitrogen (TKN	kg/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.7E-05	0.0E+00	0.0E+00	0.0E+00	1.2E-07	1.7E-04	3.4E-07
44	1994/95		Onto Land	Total Phosphorus (TP - kg)	kg/$	0.0E+00	5.4E-05	0.0E+00	0.0E+00	3.1E-04	0.0E+00	0.0E+00	0.0E+00	2.3E-08	1.9E-05	4.2E-08
45	1994/95		Total	Ammonia (NH4 - kg)	kg/$	0.0E+00	5.8E-04	0.0E+00	2.3E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.3E-04	3.3E-08
46	1994/95		Total	Biochemical Oxygen Demand ·	kg/$	0.0E+00	6.2E-04	0.0E+00	1.7E-06	5.2E-04	0.0E+00	0.0E+00	0.0E+00	9.2E-08	3.0E-04	2.8E-07
47	1994/95		Total	Dissolved Reactive Phosphoro	kg/$	0.0E+00	7.8E-05	0.0E+00	2.3E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E-08	3.6E-08	3.7E-08
48	1994/95		Total	Nitrate (NO3 - kg)	kg/$	0.0E+00	1.4E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E-04	0.0E+00
49	1994/95		Total	Total Kjeldahl Nitrogen (TKN	kg/$	0.0E+00	0.0E+00	0.0E+00	2.4E-06	1.7E-04	0.0E+00	0.0E+00	0.0E+00	1.2E-07	5.5E-04	3.9E-07
50	1994/95		Total	Total Phosphorus (TP - kg)	kg/$	0.0E+00	1.8E-04	0.0E+00	2.8E-07	5.8E-04	0.0E+00	0.0E+00	0.0E+00	2.3E-08	6.1E-05	4.7E-08
51	1994/95	air polluti	Carbon Dioxide	Total	tonne/$	1.3E-04	1.2E-04	4.3E-05	6.2E-05	2.4E-04	5.7E-04	3.5E-05	2.1E-04	1.2E-04	6.9E-05	2.6E-04
52	1994/95		Methane	Total	tonne/$	5.9E-08	4.4E-08	1.7E-08	7.2E-09	1.0E-07	1.1E-07	1.4E-08	3.6E-08	2.1E-08	8.0E-09	1.7E-08
53	1994/95		Nitrous Oxide	Total	tonne/$	6.3E-09	7.2E-09	2.5E-09	3.8E-09	1.2E-08	2.3E-08	1.6E-09	1.2E-08	7.1E-09	3.8E-09	1.1E-08
54	1994/95	Water in	Ground Water Takes		$m^3/\$$	1.4E-03	1.2E-03	2.2E-03	1.6E-03	2.2E-03	4.6E-04	1.0E-03	2.2E-03	5.7E-03	6.6E-03	3.7E-03
55	1994/95		Surface Water Takes		$m^3/\$$	3.6E-03	3.0E-03	4.5E-03	3.7E-03	7.9E-03	1.2E-03	1.6E-03	2.5E-03	6.6E-03	2.3E-02	1.2E-02
56	1994/95		Total Water Takes		$m^3/\$$	5.0E-03	4.2E-03	6.7E-03	5.3E-03	1.0E-02	1.7E-03	2.6E-03	4.7E-03	1.2E-02	2.9E-02	1.6E-02
57	1994/96	Land IN	Total land		ha/$	4.4E-04	3.4E-04	6.9E-05	4.1E-05	4.1E-04	1.7E-05	3.3E-04	6.4E-06	1.5E-05	1.3E-03	6.5E-04
58	1994/95	Energy IN	Aviation Fuel		GJ/$	2.4E-05	1.6E-05	3.2E-05	1.8E-05	2.3E-05	1.5E-05	1.3E-05	7.1E-06	1.9E-05	2.5E-05	1.8E-05

	A	B	C	D	E	G	H	I	J	K	L	M	N	O	P	Q
59	1994/95		Black Liquor		GJ/$	5.8E-05	4.8E-05	3.3E-04	1.6E-04	5.9E-05	4.0E-05	3.5E-05	2.6E-05	6.9E-05	1.9E-04	1.7E-04
60	1994/95		Coal		GJ/$	1.2E-04	1.0E-04	1.2E-04	1.1E-04	9.7E-05	5.7E-05	5.3E-05	1.8E-04	1.4E-04	2.2E-04	1.7E-04
61	1994/95		Diesel		GJ/$	8.0E-04	4.5E-04	3.7E-04	3.1E-04	7.8E-04	8.9E-04	9.6E-04	5.9E-04	8.9E-04	1.2E-03	1.2E-03
62	1994/95		Electricity		GJ/$	3.5E-04	2.9E-04	4.3E-04	2.8E-04	3.5E-04	1.4E-04	1.5E-04	3.0E-04	2.8E-04	5.4E-04	6.9E-04
63	1994/95		Fuel Oil		GJ/$	2.8E-05	2.5E-05	4.0E-05	3.4E-05	4.2E-05	2.8E-04	1.4E-05	9.1E-05	3.5E-05	3.9E-05	4.5E-05
64	1994/95		Geothermal		GJ/$	1.9E-05	1.6E-05	1.0E-04	5.1E-05	1.9E-05	1.3E-05	1.1E-05	8.3E-06	2.2E-05	6.2E-05	5.3E-05
65	1994/95		LPG		GJ/$	5.2E-05	2.3E-05	2.8E-05	2.4E-05	3.0E-05	2.4E-05	7.9E-05	2.9E-05	8.5E-05	5.8E-05	4.9E-05
66	1994/95		Natural Gas		GJ/$	1.6E-04	1.3E-04	2.3E-04	1.4E-04	1.4E-04	6.9E-05	8.6E-05	4.3E-05	1.3E-04	2.1E-04	2.2E-04
67	1994/95		Petrol		GJ/$	6.2E-04	3.5E-04	3.0E-04	2.5E-04	5.4E-04	2.2E-04	7.3E-04	2.8E-04	7.1E-04	9.3E-04	8.1E-04
68	1994/95		Wood		GJ/$	2.1E-05	1.6E-05	7.6E-05	3.3E-05	1.7E-05	1.1E-05	1.1E-05	7.3E-06	2.5E-05	4.3E-05	3.7E-05
69	1994/95		Total		GJ/$	2.2E-03	1.5E-03	2.1E-03	1.4E-03	2.1E-03	1.8E-03	2.1E-03	1.6E-03	2.4E-03	3.6E-03	3.4E-03
70	1994/95	Minerals I	Gold		g/$	6.2E-05	5.5E-05	5.7E-05	6.2E-05	4.7E-05	1.6E-05	6.7E-05	2.8E-04	6.9E-04	7.2E-05	9.7E-05
71	1994/95		Silver		g/$	1.6E-04	1.4E-04	1.5E-04	1.6E-04	1.2E-04	4.1E-05	1.7E-04	7.2E-04	1.8E-03	1.9E-04	2.5E-04
72	1994/95		Coal		tonne/$	1.8E-05	1.6E-05	1.7E-05	1.8E-05	1.4E-05	4.7E-06	2.0E-05	8.2E-05	2.0E-04	2.1E-05	2.9E-05
73	1994/95		Ironsand		tonne/$	1.3E-05	1.1E-05	1.2E-05	1.3E-05	9.4E-06	3.2E-06	1.4E-05	5.6E-05	1.4E-04	1.5E-05	2.0E-05
74	1994/95	Water dis	Discharges Into Water		$m^3/\$$	1.4E-02	1.7E-02	1.4E-02	8.8E-03	1.3E-02	3.3E-03	7.7E-03	1.4E-02	3.4E-02	1.7E-02	2.0E-02
75	1994/95		Discharges Onto Land		$m^3/\$$	4.4E-04	4.4E-04	3.1E-04	2.0E-04	9.0E-04	8.6E-05	1.7E-04	2.5E-04	6.4E-04	1.6E-03	1.8E-03
76	1994/95		Total Discharges		$m^3/\$$	1.4E-02	1.7E-02	1.5E-02	9.0E-03	1.4E-02	3.4E-03	7.8E-03	1.4E-02	3.5E-02	1.9E-02	2.2E-02
77	1994/95	Water Pol	Into Water	Ammonia (NH4 - kg)	kg/$	3.9E-05	4.7E-05	2.9E-05	1.6E-05	3.5E-05	6.6E-06	1.3E-05	4.4E-06	1.2E-05	1.0E-04	2.6E-04
78	1994/95		Into Water	Biochemical Oxygen Demand	kg/$	2.4E-04	3.1E-04	2.1E-04	9.1E-05	2.3E-04	4.3E-05	9.8E-05	3.3E-05	8.9E-05	2.5E-04	4.8E-04
79	1994/95		Into Water	Dissolved Reactive Phosphoro	kg/$	3.4E-05	4.4E-05	2.9E-05	1.3E-05	2.7E-05	6.1E-06	1.4E-05	4.8E-06	1.3E-05	2.8E-05	6.4E-05
80	1994/95		Into Water	Nitrate (NO3 - kg)	kg/$	1.3E-06	1.5E-06	9.8E-07	8.3E-07	3.2E-06	7.6E-07	6.4E-07	2.3E-07	7.0E-07	4.1E-05	2.3E-06
81	1994/95		Into Water	Total Kjeldahl Nitrogen (TKN	kg/$	3.2E-04	4.2E-04	2.8E-04	1.2E-04	2.7E-04	6.0E-05	1.4E-04	4.7E-05	1.2E-04	3.2E-04	3.3E-04
82	1994/95		Into Water	Total Phosphorus (TP - kg)	kg/$	4.8E-05	5.9E-05	3.7E-05	1.7E-05	7.1E-05	7.8E-06	1.7E-05	5.8E-06	1.5E-05	6.2E-05	1.2E-04
83	1994/95		Onto Land	Ammonia (NH4 - kg)	kg/$	5.3E-06	4.8E-06	2.1E-06	2.6E-06	5.7E-06	7.4E-07	7.2E-07	2.3E-07	6.9E-07	3.5E-05	9.5E-05
84	1994/95		Onto Land	Biochemical Oxygen Demand	kg/$	1.6E-05	1.4E-05	7.3E-06	4.9E-06	4.5E-05	1.7E-06	2.9E-06	8.6E-07	2.4E-06	4.8E-05	1.1E-04
85	1994/95		Onto Land	Dissolved Reactive Phosphoro	kg/$	1.2E-06	1.4E-06	7.6E-07	5.2E-07	1.0E-06	1.5E-07	3.2E-07	1.1E-07	2.8E-07	1.7E-06	1.3E-05
86	1994/95		Onto Land	Nitrate (NO3 - kg)	kg/$	3.0E-07	3.2E-07	2.0E-07	2.7E-07	1.2E-06	2.9E-07	1.7E-07	6.4E-08	2.1E-07	1.8E-05	7.2E-07
87	1994/95		Onto Land	Total Kjeldahl Nitrogen (TKN	kg/$	8.9E-06	1.0E-05	6.5E-06	3.1E-06	1.9E-05	1.8E-06	3.2E-06	1.1E-06	2.9E-06	4.3E-05	8.8E-06
88	1994/95		Onto Land	Total Phosphorus (TP - kg)	kg/$	9.5E-06	6.9E-06	3.0E-06	1.8E-06	4.3E-05	5.8E-07	1.0E-06	2.1E-07	5.8E-07	2.7E-05	3.6E-05
89	1994/95		Total	Ammonia (NH4 - kg)	kg/$	4.4E-05	5.2E-05	3.1E-05	1.9E-05	4.1E-05	7.4E-06	1.4E-05	4.7E-06	1.3E-05	1.3E-04	3.5E-04
90	1994/95		Total	Biochemical Oxygen Demand	kg/$	2.6E-04	3.3E-04	2.1E-04	9.6E-05	2.7E-04	4.5E-05	1.0E-04	3.4E-05	9.1E-05	3.0E-04	5.9E-04
91	1994/95		Total	Dissolved Reactive Phosphoro	kg/$	3.5E-05	4.6E-05	3.0E-05	1.3E-05	2.8E-05	6.3E-06	1.4E-05	4.9E-06	1.3E-05	2.9E-05	7.7E-05
92	1994/95		Total	Nitrate (NO3 - kg)	kg/$	1.6E-06	1.8E-06	1.2E-06	1.1E-06	4.5E-06	1.1E-06	8.1E-07	3.0E-07	9.1E-07	5.9E-05	3.0E-06
93	1994/95		Total	Total Kjeldahl Nitrogen (TKN	kg/$	3.3E-04	4.3E-04	2.9E-04	1.2E-04	2.9E-04	6.2E-05	1.4E-04	4.8E-05	1.3E-04	3.6E-04	3.4E-04
94	1994/95		Total	Total Phosphorus (TP - kg)	kg/$	5.8E-05	6.5E-05	4.0E-05	1.9E-05	1.1E-04	8.4E-06	1.9E-05	6.0E-06	1.6E-05	8.9E-05	1.5E-04
95	1994/95	air polluti	Carbon Dioxide	Total	tonne/$	1.4E-04	9.4E-05	1.4E-04	9.6E-05	1.3E-04	1.2E-04	1.4E-04	1.0E-04	1.6E-04	2.4E-04	2.2E-04
96	1994/95		Methane	Total	tonne/$	6.2E-08	3.4E-08	3.7E-08	2.8E-08	5.2E-08	3.5E-08	7.5E-08	3.4E-08	7.6E-08	9.0E-08	7.9E-08
97	1994/95		Nitrous Oxide	Total	tonne/$	7.1E-09	4.7E-09	6.6E-09	4.5E-09	6.7E-09	5.1E-09	6.6E-09	5.3E-09	7.6E-09	1.2E-08	1.1E-08
98	1994/95	Water in	Ground Water Takes (m3/$)		$m^3/\$$	1.4E-03	3.0E-03	3.5E-02	2.0E-03	1.0E-02	8.8E-04	1.4E-03	2.2E-03	1.1E-01	8.4E-03	8.9E-03
99	1994/95		Surface Water Takes (m3)		$m^3/\$$	3.6E-03	1.3E-02	3.5E-02	3.9E-03	4.0E-02	1.2E-01	1.6E-03	2.5E-03	1.1E-01	4.1E-02	3.1E-02
100	1994/95		Total Water Takes		$m^3/\$$	5.1E-03	1.6E-02	7.0E-02	5.9E-03	5.0E-02	1.2E-01	3.0E-03	4.7E-03	2.3E-01	4.9E-02	4.0E-02
101	1994/95	Land IN	Land total		ha/$	3.3E-03	1.1E-03	2.5E-04	4.1E-05	1.3E-03	2.5E-05	9.7E-04	1.2E-05	9.0E-05	1.3E-03	6.5E-04
102	1994/95	Energy IN	Aviation Fuel		GJ/$	2.4E-05	1.6E-05	3.2E-05	1.7E-04	2.3E-05	1.5E-05	1.3E-05	7.1E-06	1.9E-05	2.5E-05	1.8E-05
103	1994/95		Black Liquor		GJ/$	5.8E-05	4.8E-05	3.3E-04	1.6E-04	5.9E-05	4.0E-05	3.5E-05	2.6E-05	6.9E-05	1.9E-04	1.7E-04
104	1994/95		Coal		GJ/$	1.2E-04	1.0E-04	1.2E-04	1.1E-04	9.7E-05	5.7E-05	5.3E-05	8.0E-04	5.0E-04	7.1E-04	1.9E-03
105	1994/95		Diesel		GJ/$	2.0E-03	1.3E-03	7.1E-04	3.7E-04	2.8E-03	7.4E-03	1.3E-03	1.9E-03	1.6E-03	1.3E-03	1.3E-03
106	1994/95		Electricity		GJ/$	4.6E-04	8.6E-04	6.0E-04	8.8E-04	7.9E-04	2.1E-04	1.5E-04	1.2E-03	8.0E-04	8.1E-04	1.1E-03
107	1994/95		Fuel Oil		GJ/$	2.8E-05	2.5E-05	4.0E-05	3.4E-05	4.2E-05	2.0E-03	1.4E-05	4.3E-04	2.3E-04	4.8E-05	8.4E-05
108	1994/95		Geothermal		GJ/$	1.9E-05	1.6E-05	1.0E-04	5.1E-05	1.9E-05	1.3E-05	1.1E-05	8.3E-06	2.2E-05	6.2E-05	5.3E-05
109	1994/95		LPG		GJ/$	5.2E-05	2.3E-05	2.8E-05	2.4E-05	3.0E-05	2.4E-05	7.9E-05	2.9E-05	8.5E-05	7.9E-05	5.2E-05
110	1994/95		Natural Gas		GJ/$	1.6E-04	1.4E-04	2.3E-04	5.4E-04	1.5E-04	6.9E-05	8.6E-05	6.2E-05	1.4E-04	3.9E-04	1.6E-03
111	1994/95		Petrol		GJ/$	1.3E-03	8.9E-04	5.1E-04	3.4E-04	1.8E-03	2.3E-04	8.9E-04	4.6E-04	8.2E-04	9.9E-04	8.1E-04
112	1994/95		Wood		GJ/$	2.1E-05	1.6E-05	7.6E-05	3.3E-05	1.7E-05	1.1E-05	1.1E-05	7.3E-06	2.5E-05	4.3E-05	3.7E-05
113	1994/95		Total		GJ/$	4.3E-03	3.5E-03	2.8E-03	2.7E-03	5.8E-03	1.0E-02	2.7E-03	4.9E-03	4.3E-03	4.6E-03	7.2E-03

	A	B	C	D	E	G	H	I	J	K	L	M	N	O	P	Q
114	1994/95	Minerals I	Gold		g/$	6.2E-05	5.5E-05	5.7E-05	6.2E-05	4.7E-05	1.6E-05	6.7E-05	2.8E-04	1.5E-02	7.2E-05	9.7E-05
115	1994/95		Silver		g/$	1.6E-04	1.4E-04	1.5E-04	1.6E-04	1.2E-04	4.1E-05	1.7E-04	7.2E-04	4.0E-02	1.9E-04	2.5E-04
116	1994/95		Coal		tonne/$	1.8E-05	1.6E-05	1.7E-05	1.8E-05	1.4E-05	4.7E-06	2.0E-05	8.2E-05	4.5E-03	2.1E-05	2.9E-05
117	1994/95		Ironsand		tonne/$	1.3E-05	1.1E-05	1.2E-05	1.3E-05	9.4E-06	3.2E-06	1.4E-05	5.6E-05	3.1E-03	1.5E-05	2.0E-05
118	1994/95	Water dis(	Discharges Into Water		$m^3/\$$	1.4E-02	2.3E-02	1.6E-02	9.2E-03	1.7E-02	1.2E-01	7.7E-03	1.4E-02	6.5E-01	3.6E-02	3.2E-02
119	1994/95		Discharges Onto Land		$m^3/\$$	4.4E-04	2.6E-03	3.1E-04	2.7E-04	5.4E-03	4.5E-04	1.7E-04	2.5E-04	1.1E-02	3.5E-03	6.6E-03
120	1994/95		Total Discharges		$m^3/\$$	1.4E-02	2.5E-02	1.7E-02	9.5E-03	2.2E-02	1.3E-01	7.8E-03	1.4E-02	6.6E-01	4.0E-02	3.9E-02
121	1994/95	Water Pol	Into Water	Ammonia (NH4 - kg)	kg/$	3.9E-05	4.6E-04	2.9E-05	1.7E-05	3.5E-05	6.6E-06	1.3E-05	4.4E-06	1.2E-05	3.9E-04	2.6E-04
122	1994/95		Into Water	Biochemical Oxygen Demand ·	kg/$	2.4E-04	7.5E-04	2.1E-04	9.3E-05	4.7E-04	4.3E-05	9.8E-05	3.3E-05	8.9E-05	4.6E-04	4.8E-04
123	1994/95		Into Water	Dissolved Reactive Phosphoro	kg/$	3.4E-05	9.9E-05	2.9E-05	1.3E-05	2.7E-05	6.1E-06	1.4E-05	4.8E-06	1.3E-05	2.8E-05	6.4E-05
124	1994/95		Into Water	Nitrate (NO3 - kg)	kg/$	1.3E-06	2.5E-06	9.8E-07	8.3E-07	3.2E-06	7.6E-07	6.4E-07	2.3E-07	7.0E-07	2.5E-04	2.3E-06
125	1994/95		Into Water	Total Kjeldahl Nitrogen (TKN	kg/$	3.2E-04	4.2E-04	2.8E-04	1.2E-04	3.5E-04	6.0E-05	1.4E-04	4.7E-05	1.2E-04	7.0E-04	3.3E-04
126	1994/95		Into Water	Total Phosphorus (TP - kg)	kg/$	4.8E-05	1.9E-04	3.7E-05	1.7E-05	3.4E-04	7.8E-06	1.7E-05	5.8E-06	1.5E-05	1.0E-04	1.2E-04
127	1994/95		Onto Land	Ammonia (NH4 - kg)	kg/$	5.3E-06	1.7E-04	2.1E-06	2.6E-06	5.7E-06	7.4E-07	7.2E-07	2.3E-07	6.9E-07	1.7E-04	9.5E-05
128	1994/95		Onto Land	Biochemical Oxygen Demand ·	kg/$	1.6E-05	2.0E-04	7.3E-06	4.9E-06	3.2E-04	1.7E-06	2.9E-06	8.6E-07	2.4E-06	1.4E-04	1.1E-04
129	1994/95		Onto Land	Dissolved Reactive Phosphoro	kg/$	1.2E-06	2.4E-05	7.6E-07	5.2E-07	1.0E-06	1.5E-07	3.2E-07	1.1E-07	3.1E-07	1.7E-06	1.3E-05
130	1994/95		Onto Land	Nitrate (NO3 - kg)	kg/$	3.0E-07	7.3E-07	2.0E-07	2.7E-07	1.2E-06	2.9E-07	1.7E-07	6.4E-08	2.1E-07	1.1E-04	7.2E-07
131	1994/95		Onto Land	Total Kjeldahl Nitrogen (TKN	kg/$	8.9E-06	1.0E-05	6.5E-06	3.1E-06	1.1E-04	1.8E-06	3.2E-06	1.1E-06	3.1E-06	2.1E-04	9.1E-06
132	1994/95		Onto Land	Total Phosphorus (TP - kg)	kg/$	9.5E-06	6.1E-05	3.0E-06	1.8E-06	3.5E-04	5.8E-07	1.0E-06	2.1E-07	6.0E-07	4.5E-05	3.6E-05
133	1994/95		Total	Ammonia (NH4 - kg)	kg/$	4.4E-05	6.3E-04	3.1E-05	1.9E-05	4.1E-05	7.4E-06	1.4E-05	4.7E-06	1.3E-05	5.6E-04	3.5E-04
134	1994/95		Total	Biochemical Oxygen Demand ·	kg/$	2.6E-04	9.5E-04	2.1E-04	9.8E-05	7.9E-04	4.5E-05	1.0E-04	3.4E-05	9.1E-05	6.0E-04	5.9E-04
135	1994/95		Total	Dissolved Reactive Phosphoro	kg/$	3.5E-05	1.2E-04	3.0E-05	1.4E-05	2.8E-05	6.3E-06	1.4E-05	4.9E-06	1.3E-05	3.0E-05	7.7E-05
136	1994/95		Total	Nitrate (NO3 - kg)	kg/$	1.6E-06	3.3E-06	1.2E-06	1.1E-06	4.5E-06	1.1E-06	8.1E-07	3.0E-07	9.1E-07	3.6E-04	3.0E-06
137	1994/95		Total	Total Kjeldahl Nitrogen (TKN	kg/$	3.3E-04	4.3E-04	2.9E-04	1.3E-04	4.5E-04	6.2E-05	1.4E-04	4.8E-05	1.3E-04	9.1E-04	3.4E-04
138	1994/95		Total	Total Phosphorus (TP - kg)	kg/$	5.8E-05	2.5E-04	4.0E-05	1.9E-05	7.0E-04	8.4E-06	1.9E-05	6.0E-06	1.6E-05	1.5E-04	1.5E-04
139	1994/95	air polluti	Carbon Dioxide	Total	tonne/$	2.8E-04	2.1E-04	1.9E-04	1.6E-04	3.7E-04	6.9E-04	1.8E-04	3.1E-04	2.8E-04	3.1E-04	4.8E-04
140	1994/95		Methane	Total	tonne/$	1.2E-07	7.9E-08	5.4E-08	3.5E-08	1.5E-07	1.4E-07	8.9E-08	7.0E-08	9.7E-08	9.8E-08	9.6E-08
141	1994/95		Nitrous Oxide	Total	tonne/$	1.3E-08	1.2E-08	9.1E-09	8.2E-09	1.9E-08	2.8E-08	8.2E-09	1.8E-08	1.5E-08	1.5E-08	2.2E-08
142	1997/98	Water in	Ground Water Takes		$m^3/\$$	1.5E-06	2.7E-03	2.4E-02	5.1E-04	6.5E-03	3.3E-04	1.8E-04	0.0E+00	1.0E-01	1.9E-03	4.5E-03
143	1997/98		Surface Water Takes		$m^3/\$$	2.0E-04	2.4E-02	3.8E-02	5.1E-05	3.9E-02	3.5E-03	1.7E-05	0.0E+00	1.5E-01	1.4E-02	1.9E-02
144	1997/98		Total Water Takes		$m^3/\$$	2.0E-04	2.7E-02	6.1E-02	5.6E-04	4.6E-02	3.8E-03	2.0E-04	0.0E+00	2.5E-01	1.6E-02	2.3E-02
145	1997/98	Land IN	Total land		ha/$	2.9E-03	7.1E-04	1.8E-04	3.6E-07	8.7E-04	8.1E-06	6.4E-04	5.5E-06	7.5E-05	5.4E-07	2.0E-07
146	1997/98	Energy IN	Aviation Fuel		GJ/$	0.0E+00	0.0E+00	0.0E+00	1.4E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
147	1997/98		Black Liquor		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
148	1997/98		Coal		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E-04	3.7E-04	5.9E-04	2.2E-03
149	1997/98		Diesel		GJ/$	1.0E-03	9.6E-04	4.7E-04	5.3E-05	2.2E-03	6.0E-03	3.5E-04	4.6E-04	7.6E-04	1.2E-05	2.0E-04
150	1997/98		Electricity		GJ/$	9.6E-05	6.1E-04	2.3E-04	5.6E-04	4.8E-04	6.5E-05	0.0E+00	3.3E-04	5.3E-04	3.2E-04	5.7E-04
151	1997/98		Fuel Oil		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.5E-03	0.0E+00	1.2E-04	2.0E-04	1.0E-05	4.8E-05
152	1997/98		Geothermal		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
153	1997/98		LPG		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.4E-05	3.9E-06
154	1997/98		Natural Gas		GJ/$	1.7E-06	4.7E-06	1.9E-06	3.7E-04	5.5E-06	0.0E+00	0.0E+00	7.1E-06	1.2E-05	2.1E-04	1.7E-03
155	1997/98		Petrol		GJ/$	6.3E-04	5.9E-04	2.9E-04	8.7E-05	1.4E-03	1.1E-05	1.6E-04	6.5E-05	1.1E-04	6.4E-05	2.8E-07
156	1997/98		Wood		GJ/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
157	1997/98		Total		GJ/$	1.7E-03	2.2E-03	9.9E-04	1.2E-03	4.1E-03	7.6E-03	5.1E-04	1.2E-03	2.0E-03	1.2E-03	4.7E-03
158	1997/98	Minerals I	Gold		g/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-02	0.0E+00	0.0E+00
159	1997/98		Silver		g/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.0E-02	0.0E+00	0.0E+00
160	1997/98		Coal		tonne/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.9E-03	0.0E+00	0.0E+00
161	1997/98		Ironsand		tonne/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E-03	0.0E+00	0.0E+00

	A	B	C	D	E	G	H	I	J	K	L	M	N	O	P	Q
162	1997/98	Water dis	Discharges Into Water		m³/$	0.0E+00	1.3E-02	4.5E-04	2.4E-04	2.9E-03	1.4E-03	7.1E-05	0.0E+00	7.4E-01	1.5E-02	1.6E-02
163	1997/98		Discharges Onto Land		m³/$	0.0E+00	2.2E-03	0.0E+00	1.5E-04	1.4E-02	2.6E-04	1.5E-06	0.0E+00	9.0E-02	1.6E-03	7.8E-03
164	1997/98		Total Discharges		m³/$	0.0E+00	1.5E-02	4.5E-04	4.0E-04	1.7E-02	1.6E-03	7.2E-05	0.0E+00	8.3E-01	1.7E-02	2.4E-02
165	1997/98	Water Pol	Into Water	Ammonia (NH4 - kg)	kg/$	0.0E+00	4.3E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.9E-04	0.0E+00
166	1997/98		Into Water	Biochemical Oxygen Demand ·	kg/$	0.0E+00	4.6E-04	0.0E+00	0.0E+00	2.1E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-04	0.0E+00
167	1997/98		Into Water	Dissolved Reactive Phosphoro	kg/$	0.0E+00	5.7E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
168	1997/98		Into Water	Nitrate (NO3 - kg)	kg/$	0.0E+00	1.0E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-04	0.0E+00
169	1997/98		Into Water	Total Kjeldahl Nitrogen (TKN	kg/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.7E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E-04	0.0E+00
170	1997/98		Into Water	Total Phosphorus (TP - kg)	kg/$	0.0E+00	1.4E-04	0.0E+00	0.0E+00	2.4E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.2E-05	0.0E+00
171	1997/98		Onto Land	Ammonia (NH4 - kg)	kg/$	0.0E+00	1.8E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E-07	7.5E-05	1.5E-08
172	1997/98		Onto Land	Biochemical Oxygen Demand ·	kg/$	0.0E+00	1.9E-04	0.0E+00	0.0E+00	9.8E-04	0.0E+00	0.0E+00	0.0E+00	1.5E-06	5.4E-05	1.2E-07
173	1997/98		Onto Land	Dissolved Reactive Phosphoro	kg/$	0.0E+00	2.4E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E-07	8.2E-08	1.9E-08
174	1997/98		Onto Land	Nitrate (NO3 - kg)	kg/$	0.0E+00	4.3E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.4E-05	0.0E+00
175	1997/98		Onto Land	Total Kjeldahl Nitrogen (TKN	kg/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.1E-04	0.0E+00	0.0E+00	0.0E+00	2.0E-06	9.7E-05	1.7E-07
176	1997/98		Onto Land	Total Phosphorus (TP - kg)	kg/$	0.0E+00	5.6E-05	0.0E+00	0.0E+00	1.1E-03	0.0E+00	0.0E+00	0.0E+00	2.5E-07	1.1E-05	1.9E-08
177	1997/98		Total	Ammonia (NH4 - kg)	kg/$	0.0E+00	6.0E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E-07	3.7E-04	1.5E-08
178	1997/98		Total	Biochemical Oxygen Demand ·	kg/$	0.0E+00	6.5E-04	0.0E+00	0.0E+00	1.2E-03	0.0E+00	0.0E+00	0.0E+00	1.5E-06	2.6E-04	1.2E-07
179	1997/98		Total	Dissolved Reactive Phosphoro	kg/$	0.0E+00	8.1E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E-07	8.2E-08	1.9E-08
180	1997/98		Total	Nitrate (NO3 - kg)	kg/$	0.0E+00	1.5E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.6E-04	0.0E+00
181	1997/98		Total	Total Kjeldahl Nitrogen (TKN	kg/$	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E-04	0.0E+00	0.0E+00	0.0E+00	2.0E-06	4.7E-04	1.7E-07
182	1997/98		Total	Total Phosphorus (TP - kg)	kg/$	0.0E+00	1.9E-04	0.0E+00	0.0E+00	1.3E-03	0.0E+00	0.0E+00	0.0E+00	2.5E-07	5.3E-05	1.9E-08
183	1997/98		Carbon Dioxide	Total	tonne/$	1.2E-04	1.3E-04	5.9E-05	5.7E-05	2.6E-04	5.3E-04	3.5E-05	7.7E-05	1.3E-04	8.3E-05	3.3E-04
184	1997/98		Methane	Total	tonne/$	5.1E-08	4.8E-08	2.4E-08	6.6E-09	1.1E-07	1.0E-07	1.4E-08	1.3E-08	2.2E-08	9.5E-09	2.1E-08
185	1997/98		Nitrous Oxide	Total	tonne/$	5.5E-09	7.8E-09	3.5E-09	3.5E-09	1.3E-08	2.1E-08	1.5E-09	4.5E-09	7.4E-09	4.6E-09	1.3E-08
186	1997/98	Water in	Ground Water Takes		m³/$	1.9E-03	1.6E-03	2.3E-03	2.2E-03	2.5E-03	5.3E-04	9.2E-04	5.8E-03	5.1E-03	6.7E-03	4.2E-03
187	1997/98		Surface Water Takes		m³/$	5.5E-03	4.5E-03	3.7E-03	4.3E-03	9.8E-03	1.3E-03	1.8E-03	9.1E-03	8.2E-03	2.7E-02	2.2E-02
188	1997/98		Total Water Takes		m³/$	7.4E-03	6.0E-03	6.0E-03	6.5E-03	1.2E-02	1.8E-03	2.7E-03	1.5E-02	1.3E-02	3.4E-02	2.6E-02
189	1997/98	Land IN	Land total		ha/$	5.7E-04	4.0E-04	7.4E-05	6.6E-05	4.6E-04	2.0E-05	4.0E-04	2.0E-05	1.8E-05	1.4E-03	7.2E-04
190	1997/98	Energy IN	Aviation Fuel		GJ/$	2.6E-05	1.8E-05	2.8E-05	2.5E-05	2.4E-05	1.7E-05	1.4E-05	2.4E-05	2.1E-05	2.6E-05	1.8E-05
191	1997/98		Black Liquor		GJ/$	7.7E-05	6.2E-05	2.9E-04	2.2E-04	6.9E-05	4.4E-05	3.7E-05	8.3E-05	7.4E-05	1.9E-04	1.4E-04
192	1997/98		Coal		GJ/$	1.4E-04	1.2E-04	1.1E-04	1.4E-04	1.1E-04	6.2E-05	5.3E-05	1.6E-04	1.5E-04	2.8E-04	2.1E-04
193	1997/98		Diesel		GJ/$	1.0E-03	5.7E-04	4.0E-04	4.8E-04	9.3E-04	1.3E-03	1.1E-03	1.2E-03	1.0E-03	1.3E-03	1.3E-03
194	1997/98		Electricity		GJ/$	4.3E-04	3.6E-04	4.0E-04	3.8E-04	4.1E-04	1.5E-04	1.6E-04	3.7E-04	3.0E-04	6.2E-04	7.6E-04
195	1997/98		Fuel Oil		GJ/$	3.3E-05	2.7E-05	3.7E-05	4.5E-05	4.4E-05	4.4E-04	1.4E-05	6.9E-05	3.9E-05	4.3E-05	4.1E-05
196	1997/98		Geothermal		GJ/$	2.5E-05	2.0E-05	9.2E-05	7.0E-05	2.2E-05	1.4E-05	1.2E-05	2.7E-05	2.4E-05	6.1E-05	4.6E-05
197	1997/98		LPG		GJ/$	6.9E-05	3.2E-05	3.0E-05	3.6E-05	3.6E-05	2.9E-05	8.5E-05	1.0E-04	9.7E-05	6.9E-05	4.8E-05
198	1997/98		Natural Gas		GJ/$	1.9E-04	1.6E-04	2.1E-04	1.8E-04	1.6E-04	7.6E-05	9.0E-05	1.3E-04	1.4E-04	2.5E-04	2.5E-04
199	1997/98		Petrol		GJ/$	8.1E-04	4.6E-04	3.3E-04	3.9E-04	6.5E-04	2.7E-04	8.0E-04	8.6E-04	8.2E-04	1.0E-03	8.9E-04
200	1997/98		Wood		GJ/$	2.7E-05	2.2E-05	7.0E-05	4.6E-05	2.0E-05	1.3E-05	1.1E-05	2.5E-05	2.8E-05	4.5E-05	3.5E-05
201	1997/98		Total		GJ/$	2.9E-03	1.9E-03	2.0E-03	2.0E-03	2.5E-03	2.4E-03	2.3E-03	3.0E-03	2.7E-03	4.0E-03	3.7E-03
202	1997/98	Minerals I	Gold		g/$	6.9E-05	6.2E-05	5.0E-05	7.1E-05	4.6E-05	1.5E-05	5.4E-05	7.2E-04	6.1E-04	6.8E-05	8.2E-05
203	1997/98		Silver		g/$	1.9E-04	1.7E-04	1.4E-04	2.0E-04	1.3E-04	4.2E-05	1.5E-04	2.0E-03	1.7E-03	1.9E-04	2.3E-04
204	1997/98		Coal		tonne/$	2.4E-05	2.1E-05	1.7E-05	2.4E-05	1.6E-05	5.1E-06	1.9E-05	2.5E-04	2.1E-04	2.3E-05	2.8E-05
205	1997/98		Ironsand		tonne/$	1.6E-05	1.4E-05	1.1E-05	1.6E-05	1.1E-05	3.4E-06	1.2E-05	1.6E-04	1.4E-04	1.6E-05	1.9E-05
206	1997/98	Water dis	Discharges Into Water		m³/$	2.0E-02	2.2E-02	1.5E-02	1.4E-02	1.4E-02	4.0E-03	8.8E-03	4.3E-02	3.7E-02	2.1E-02	2.7E-02
207	1997/98		Discharges Onto Land		m³/$	1.5E-03	1.4E-03	9.5E-04	9.7E-04	2.9E-03	2.8E-04	6.0E-04	4.8E-03	4.1E-03	2.6E-03	3.0E-03
208	1997/98		Total Discharges		m³/$	2.1E-02	2.3E-02	1.6E-02	1.5E-02	1.7E-02	4.3E-03	9.4E-03	4.8E-02	4.1E-02	2.3E-02	3.0E-02
209	1997/98	Water Pol	Into Water	Ammonia (NH4 - kg)	kg/$	4.8E-05	5.3E-05	2.4E-05	2.6E-05	3.8E-05	8.1E-06	1.3E-05	1.5E-05	1.3E-05	1.3E-04	2.9E-04

	A	B	C	D	E	G	H	I	J	K	L	M	N	O	P	Q
210	1997/98		Into Water	Biochemical Oxygen Demand ·	kg/$	2.5E-04	3.1E-04	1.6E-04	1.2E-04	2.0E-04	4.7E-05	9.0E-05	1.0E-04	9.1E-05	2.7E-04	5.1E-04
211	1997/98		Into Water	Dissolved Reactive Phosphoro	kg/$	3.4E-05	4.3E-05	2.2E-05	1.7E-05	2.4E-05	6.6E-06	1.3E-05	1.5E-05	1.3E-05	2.8E-05	6.7E-05
212	1997/98		Into Water	Nitrate (NO3 - kg)	kg/$	1.6E-06	1.8E-06	9.9E-07	1.4E-06	4.0E-06	1.0E-06	7.7E-07	9.0E-07	8.7E-07	5.5E-05	2.5E-06
213	1997/98		Into Water	Total Kjeldahl Nitrogen (TKN	kg/$	3.1E-04	4.0E-04	2.1E-04	1.6E-04	2.3E-04	6.4E-05	1.2E-04	1.4E-04	1.3E-04	3.4E-04	3.1E-04
214	1997/98		Into Water	Total Phosphorus (TP - kg)	kg/$	5.1E-05	5.9E-05	2.9E-05	2.3E-05	6.7E-05	8.5E-06	1.6E-05	1.8E-05	1.6E-05	6.7E-05	1.3E-04
215	1997/98		Onto Land	Ammonia (NH4 - kg)	kg/$	9.3E-06	8.3E-06	3.0E-06	5.2E-06	7.7E-06	1.1E-06	1.1E-06	1.2E-06	1.2E-06	3.4E-05	1.1E-04
216	1997/98		Onto Land	Biochemical Oxygen Demand ·	kg/$	4.8E-05	3.9E-05	1.5E-05	1.4E-05	1.6E-04	3.9E-06	6.5E-06	5.6E-06	5.1E-06	1.1E-04	1.4E-04
217	1997/98		Onto Land	Dissolved Reactive Phosphoro	kg/$	2.3E-06	2.5E-06	1.1E-06	1.2E-06	1.7E-06	3.5E-07	5.7E-07	6.6E-07	5.9E-07	2.8E-06	1.6E-05
218	1997/98		Onto Land	Nitrate (NO3 - kg)	kg/$	3.0E-07	2.9E-07	1.6E-07	2.9E-07	9.4E-07	2.4E-07	1.4E-07	1.7E-07	1.7E-07	1.4E-05	6.1E-07
219	1997/98		Onto Land	Total Kjeldahl Nitrogen (TKN	kg/$	2.3E-05	2.3E-05	1.1E-05	8.1E-06	5.8E-05	3.5E-06	5.9E-06	6.4E-06	5.6E-06	5.7E-05	1.9E-05
220	1997/98		OntoLand	Total Phosphorus (TP - kg)	kg/$	3.9E-05	2.7E-05	8.8E-06	7.1E-06	1.7E-04	1.9E-06	3.3E-06	1.8E-06	1.7E-06	8.9E-05	5.7E-05
221	1997/98		Total	Ammonia (NH4 - kg)	kg/$	5.7E-05	6.1E-05	2.7E-05	3.1E-05	4.6E-05	9.3E-06	1.4E-05	1.6E-05	1.4E-05	1.6E-04	4.0E-04
222	1997/98		Total	Biochemical Oxygen Demand ·	kg/$	2.9E-04	3.5E-04	1.7E-04	1.4E-04	3.7E-04	5.1E-05	9.6E-05	1.1E-04	9.6E-05	3.8E-04	6.5E-04
223	1997/98		Total	Dissolved Reactive Phosphoro	kg/$	3.6E-05	4.6E-05	2.3E-05	1.8E-05	2.6E-05	6.9E-06	1.3E-05	1.6E-05	1.4E-05	3.1E-05	8.2E-05
224	1997/98		Total	Nitrate (NO3 - kg)	kg/$	1.9E-06	2.1E-06	1.1E-06	1.7E-06	5.0E-06	1.3E-06	9.1E-07	1.1E-06	1.0E-06	6.9E-05	3.1E-06
225	1997/98		Total	Total Kjeldahl Nitrogen (TKN	kg/$	3.3E-04	4.2E-04	2.2E-04	1.6E-04	2.9E-04	6.7E-05	1.3E-04	1.5E-04	1.3E-04	3.9E-04	3.3E-04
226	1997/98		Total	Total Phosphorus (TP - kg)	kg/$	9.0E-05	8.6E-05	3.8E-05	3.1E-05	2.4E-04	1.0E-05	1.9E-05	2.0E-05	1.8E-05	1.6E-04	1.8E-04
227	1997/98		Carbon Dioxide	Total	tonne/$	1.8E-04	1.2E-04	1.4E-04	1.4E-04	1.6E-04	1.7E-04	1.5E-04	2.0E-04	1.8E-04	2.6E-04	2.3E-04
228	1997/98		Methane	Total	tonne/$	8.1E-08	4.5E-08	3.9E-08	4.3E-08	6.2E-08	4.8E-08	8.2E-08	9.4E-08	8.7E-08	1.0E-07	8.5E-08
229	1997/98		Nitrous Oxide	Total	tonne/$	9.0E-09	5.9E-09	6.4E-09	6.5E-09	7.9E-09	7.0E-09	7.2E-09	9.7E-09	8.5E-09	1.3E-08	1.2E-08
230	1997/98	Water IN	Ground Water Takes		m^3/$	1.9E-03	4.3E-03	2.6E-02	2.7E-03	8.9E-03	8.6E-04	1.1E-03	5.8E-03	1.1E-01	8.6E-03	8.7E-03
231	1997/98		Surface Water Takes		m^3/$	5.7E-03	2.8E-02	4.2E-02	4.3E-03	4.9E-02	4.8E-03	1.8E-03	9.1E-03	1.6E-01	4.2E-02	4.0E-02
232	1997/98		Total Water Takes		m^3/$	7.6E-03	3.3E-02	6.7E-02	7.0E-03	5.8E-02	5.6E-03	2.9E-03	1.5E-02	2.7E-01	5.0E-02	4.9E-02
233	1997/98	Land IN	Total Land		ha/$	3.4E-03	1.1E-03	2.6E-04	6.6E-05	1.3E-03	2.8E-05	1.0E-03	2.5E-05	9.4E-05	1.4E-03	7.2E-04
234	1997/98	Energy IN	Aviation Fuel		GJ/$	2.6E-05	1.8E-05	2.8E-05	1.7E-04	2.4E-05	1.7E-05	1.4E-05	2.4E-05	2.1E-05	2.6E-05	1.8E-05
235	1997/98		Black Liquor		GJ/$	7.7E-05	6.2E-05	2.9E-04	2.2E-04	6.9E-05	4.4E-05	3.7E-05	8.3E-05	7.4E-05	1.9E-04	1.4E-04
236	1997/98		Coal		GJ/$	1.4E-04	1.2E-04	1.1E-04	1.4E-04	1.1E-04	6.2E-05	5.3E-05	3.9E-04	5.2E-04	8.7E-04	2.4E-03
237	1997/98		Diesel		GJ/$	2.1E-03	1.5E-03	8.7E-04	5.3E-04	3.2E-03	7.3E-03	1.4E-03	1.6E-03	1.8E-03	1.4E-03	1.5E-03
238	1997/98		Electricity		GJ/$	5.2E-04	9.7E-04	6.3E-04	9.4E-04	8.9E-04	2.2E-04	1.6E-04	6.9E-04	8.3E-04	9.4E-04	1.3E-03
239	1997/98		Fuel Oil		GJ/$	3.3E-05	2.7E-05	3.7E-05	4.5E-05	4.4E-05	2.0E-03	1.4E-05	1.9E-04	2.4E-04	5.3E-05	8.9E-05
240	1997/98		Geothermal		GJ/$	2.5E-05	2.0E-05	9.2E-05	7.0E-05	2.2E-05	1.4E-05	1.2E-05	2.7E-05	2.4E-05	6.1E-05	4.6E-05
241	1997/98		LPG		GJ/$	6.9E-05	3.2E-05	3.0E-05	3.6E-05	3.6E-05	2.9E-05	8.5E-05	1.0E-04	9.7E-05	9.4E-05	5.1E-05
242	1997/98		Natural Gas		GJ/$	2.0E-04	1.6E-04	2.1E-04	5.6E-04	1.7E-04	7.6E-05	9.0E-05	1.4E-04	1.5E-04	4.6E-04	2.0E-03
243	1997/98		Petrol		GJ/$	1.4E-03	1.0E-03	6.2E-04	4.8E-04	2.0E-03	2.9E-04	9.5E-04	9.3E-04	9.3E-04	1.1E-03	8.9E-04
244	1997/98		Wood		GJ/$	2.7E-05	2.2E-05	7.0E-05	4.6E-05	2.0E-05	1.3E-05	1.1E-05	2.5E-05	2.8E-05	4.5E-05	3.5E-05
245	1997/98		Total		GJ/$	4.6E-03	4.0E-03	3.0E-03	3.2E-03	6.6E-03	1.0E-02	2.8E-03	4.2E-03	4.7E-03	5.2E-03	8.4E-03
246	1997/98	Minerals I	Gold		g/$	6.9E-05	6.2E-05	5.0E-05	7.1E-05	4.6E-05	1.5E-05	5.4E-05	7.2E-04	1.5E-02	6.8E-05	8.2E-05
247	1997/98		Silver		g/$	1.9E-04	1.7E-04	1.4E-04	2.0E-04	1.3E-04	4.2E-05	1.5E-04	2.0E-03	4.2E-02	1.9E-04	2.3E-04
248	1997/98		Coal		tonne/$	2.4E-05	2.1E-05	1.7E-05	2.4E-05	1.6E-05	5.1E-06	1.9E-05	2.5E-04	5.1E-03	2.3E-05	2.8E-05
249	1997/98		Ironsand		tonne/$	1.6E-05	1.4E-05	1.1E-05	1.6E-05	1.1E-05	3.4E-06	1.2E-05	1.6E-04	3.4E-03	1.6E-05	1.9E-05
250	1997/98	Water dis	Discharges Into Water		m^3/$	2.0E-02	3.4E-02	1.6E-02	1.5E-02	1.7E-02	5.4E-03	8.9E-03	4.3E-02	7.8E-01	3.6E-02	4.3E-02
251	1997/98		Discharges Onto Land		m^3/$	1.5E-03	3.6E-03	9.5E-04	1.1E-03	1.7E-02	5.5E-04	6.0E-04	4.8E-03	9.5E-02	4.2E-03	1.1E-02
252	1997/98		Total Discharges		m^3/$	2.1E-02	3.8E-02	1.7E-02	1.6E-02	3.4E-02	5.9E-03	9.5E-03	4.8E-02	8.7E-01	4.0E-02	5.3E-02
253	1997/98	Water Pol	Into Water	Ammonia (NH4 - kg)	kg/$	4.8E-05	4.8E-04	2.4E-05	2.6E-05	3.8E-05	8.1E-06	1.3E-05	1.5E-05	1.3E-05	4.2E-04	2.9E-04
254	1997/98		Into Water	Biochemical Oxygen Demand ·	kg/$	2.5E-04	7.7E-04	1.6E-04	1.2E-04	4.1E-04	4.7E-05	9.0E-05	1.0E-04	9.1E-05	4.8E-04	5.1E-04
255	1997/98		Into Water	Dissolved Reactive Phosphoro	kg/$	3.4E-05	1.0E-04	2.2E-05	1.7E-05	2.4E-05	6.6E-06	1.3E-05	1.5E-05	1.3E-05	2.8E-05	6.7E-05
256	1997/98		Into Water	Nitrate (NO3 - kg)	kg/$	1.6E-06	2.8E-06	9.9E-07	1.4E-06	4.0E-06	1.0E-06	7.7E-07	9.0E-07	8.7E-07	2.6E-04	2.5E-06
257	1997/98		Into Water	Total Kjeldahl Nitrogen (TKN	kg/$	3.1E-04	4.0E-04	2.1E-04	1.6E-04	3.0E-04	6.4E-05	1.2E-04	1.4E-04	1.3E-04	7.1E-04	3.1E-04

	A	B	C	D	E	G	H	I	J	K	L	M	N	O	P	Q
258	1997/98		Into Water	Total Phosphorus (TP - kg)	kg/$	5.1E-05	1.9E-04	2.9E-05	2.3E-05	3.0E-04	8.5E-06	1.6E-05	1.8E-05	1.6E-05	1.1E-04	1.3E-04
259	1997/98		Onto Land	Ammonia (NH4 - kg)	kg/$	9.3E-06	1.8E-04	3.0E-06	5.2E-06	7.7E-06	1.1E-06	1.1E-06	1.2E-06	1.3E-06	1.1E-04	1.1E-04
260	1997/98		Onto Land	Biochemical Oxygen Demand ·	kg/$	4.8E-05	2.3E-04	1.5E-05	1.4E-05	1.1E-03	3.9E-06	6.5E-06	5.6E-06	6.5E-06	1.6E-04	1.4E-04
261	1997/98		Onto Land	Dissolved Reactive Phosphoro	kg/$	2.3E-06	2.6E-05	1.1E-06	1.2E-06	1.7E-06	3.5E-07	5.7E-07	6.6E-07	8.1E-07	2.8E-06	1.6E-05
262	1997/98		Onto Land	Nitrate (NO3 - kg)	kg/$	3.0E-07	7.2E-07	1.6E-07	2.9E-07	9.4E-07	2.4E-07	1.4E-07	1.7E-07	1.7E-07	6.8E-05	6.1E-07
263	1997/98		Onto Land	Total Kjeldahl Nitrogen (TKN	kg/$	2.3E-05	2.3E-05	1.1E-05	8.1E-06	3.7E-04	3.5E-06	5.9E-06	6.4E-06	7.7E-06	1.5E-04	1.9E-05
264	1997/98		Onto Land	Total Phosphorus (TP - kg)	kg/$	3.9E-05	8.3E-05	8.8E-06	7.1E-06	1.3E-03	1.9E-06	3.3E-06	1.8E-06	1.9E-06	1.0E-04	5.7E-05
265	1997/98		Total	Ammonia (NH4 - kg)	kg/$	5.7E-05	6.6E-04	2.7E-05	3.1E-05	4.6E-05	9.3E-06	1.4E-05	1.6E-05	1.4E-05	5.3E-04	4.0E-04
266	1997/98		Total	Biochemical Oxygen Demand ·	kg/$	2.9E-04	9.9E-04	1.7E-04	1.4E-04	1.6E-03	5.1E-05	9.6E-05	1.1E-04	9.7E-05	6.4E-04	6.5E-04
267	1997/98		Total	Dissolved Reactive Phosphoro	kg/$	3.6E-05	1.3E-04	2.3E-05	1.8E-05	2.6E-05	6.9E-06	1.3E-05	1.6E-05	1.4E-05	3.1E-05	8.3E-05
268	1997/98		Total	Nitrate (NO3 - kg)	kg/$	1.9E-06	3.5E-06	1.1E-06	1.7E-06	5.0E-06	1.3E-06	9.1E-07	1.1E-06	1.0E-06	3.3E-04	3.1E-06
269	1997/98		Total	Total Kjeldahl Nitrogen (TKN	kg/$	3.3E-04	4.2E-04	2.2E-04	1.6E-04	6.7E-04	6.7E-05	1.3E-04	1.5E-04	1.3E-04	8.7E-04	3.3E-04
270	1997/98		Total	Total Phosphorus (TP - kg)	kg/$	9.0E-05	2.8E-04	3.8E-05	3.1E-05	1.6E-03	1.0E-05	1.9E-05	2.0E-05	1.8E-05	2.1E-04	1.8E-04
271	1997/98	air polluti	Carbon Dioxide	Total	tonne/$	3.0E-04	2.4E-04	2.0E-04	2.0E-04	4.2E-04	6.9E-04	1.9E-04	2.8E-04	3.1E-04	3.4E-04	5.6E-04
272	1997/98		Methane	Total	tonne/$	1.3E-07	9.3E-08	6.2E-08	5.0E-08	1.7E-07	1.5E-07	9.6E-08	1.1E-07	1.1E-07	1.1E-07	1.1E-07
273	1997/98		Nitrous Oxide	Total	tonne/$	1.4E-08	1.4E-08	9.8E-09	1.0E-08	2.1E-08	2.8E-08	8.7E-09	1.4E-08	1.6E-08	1.7E-08	2.5E-08

	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
7	12	13	14	15	16	17	18	19	20	21	22	23	24	25	28	29	30
8	Manufacture of other food	Beverage Manufacture	Textile Manufacture	Wood & Wood Products	Paper Manufacturing	Printing & Publishing	Other Chemicals	Basic Chemicals	Non-metallic Minerals	Basic Metal Industries	Fabricated Metals	Equipment Manufacture	Transport Equipment	Other Manufacturing	Water works	Construction	Trade
10	3.7E-04	2.8E-03	9.0E-04	5.9E-04	1.3E-02	2.6E-05	3.9E-04	1.2E-04	3.0E-04	2.9E-04	0.0E+00	8.6E-05	0.0E+00	1.8E-04	3.5E-01	0.0E+00	3.5E-06
11	2.0E-04	2.9E-04	4.4E-04	1.8E-04	3.3E-02	0.0E+00	0.0E+00	1.2E-03	5.3E-03	1.5E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E+00	0.0E+00	0.0E+00
12	5.7E-04	3.1E-03	1.3E-03	7.7E-04	4.6E-02	2.6E-05	3.9E-04	1.4E-03	5.6E-03	1.5E-02	0.0E+00	8.6E-05	0.0E+00	1.8E-04	1.5E+00	0.0E+00	3.5E-06
13	2.6E-06	3.8E-07	2.4E-07	1.2E-06	1.9E-07	4.2E-07	4.7E-07	2.7E-07	1.8E-06	2.8E-07	4.1E-07	4.0E-07	2.3E-07	6.2E-07	2.9E-04	2.2E-07	1.6E-07
14	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-05	0.0E+00
15	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.1E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
16	1.5E-04	1.7E-04	1.7E-04	1.1E-04	5.3E-04	0.0E+00	6.1E-05	4.3E-05	3.6E-03	9.0E-03	1.7E-05	1.6E-05	8.8E-06	0.0E+00	0.0E+00	0.0E+00	5.3E-05
17	1.3E-04	1.2E-04	7.3E-05	2.5E-05	0.0E+00	2.9E-05	2.0E-04	1.4E-04	1.4E-04	5.6E-05	2.3E-04	2.1E-04	1.1E-04	2.5E-05	0.0E+00	3.5E-04	4.9E-05
18	7.2E-04	6.1E-04	1.9E-04	5.3E-04	3.2E-03	2.0E-04	6.1E-04	4.3E-04	6.0E-04	1.1E-02	1.5E-04	1.4E-04	7.4E-05	7.0E-04	1.5E-03	3.2E-05	3.0E-04
19	6.8E-05	2.3E-05	3.3E-05	6.8E-05	3.3E-04	0.0E+00	3.5E-05	2.5E-05	2.3E-05	4.6E-04	1.3E-05	1.2E-05	6.6E-06	1.8E-06	0.0E+00	0.0E+00	1.1E-06
20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
21	4.1E-05	6.5E-06	3.3E-06	3.5E-06	1.1E-05	1.3E-05	9.7E-06	6.8E-06	1.3E-04	6.6E-05	1.9E-05	1.8E-05	9.5E-06	8.5E-06	0.0E+00	1.4E-05	1.0E-05
22	7.4E-04	4.9E-04	4.3E-04	3.6E-04	1.7E-03	0.0E+00	5.0E-04	3.5E-04	1.0E-03	1.7E-03	2.1E-04	1.9E-04	1.0E-04	1.1E-04	0.0E+00	9.2E-06	7.3E-05
23	2.9E-04	1.2E-04	2.3E-05	1.6E-06	1.1E-06	1.3E-06	1.3E-05	9.3E-06	6.2E-08	3.2E-06	3.1E-05	2.9E-05	1.6E-05	2.0E-04	0.0E+00	1.2E-04	8.4E-04
24	0.0E+00	0.0E+00	0.0E+00	8.9E-04	1.2E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-05
25	2.1E-03	1.5E-03	9.2E-04	2.0E-03	1.6E-02	2.4E-04	1.4E-03	1.0E-03	5.5E-03	2.3E-02	6.6E-04	6.2E-04	3.3E-04	1.0E-03	1.5E-03	5.4E-04	1.3E-03
26	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
27	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
28	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
29	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	5.9E-03	2.9E-04	1.6E-04	2.7E-04	4.5E-02	0.0E+00	0.0E+00	7.0E-03	1.6E-04	2.1E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.2E-02	0.0E+00	1.3E-05
31	1.1E-07	0.0E+00	2.9E-05	4.8E-05	0.0E+00	0.0E+00	5.9E-08	1.7E-07	5.3E-07	2.5E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.7E-02	0.0E+00	2.7E-06
32	5.9E-03	2.9E-04	1.9E-04	3.1E-04	4.5E-02	0.0E+00	5.9E-08	7.0E-03	1.6E-04	2.1E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.9E-02	0.0E+00	1.6E-05
33	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.1E-05	0.0E+00	1.0E-09
34	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.8E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.9E-04	0.0E+00	7.1E-09
35	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.1E-05	0.0E+00	1.0E-09
36	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-06	0.0E+00	0.0E+00
37	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.9E-04	0.0E+00	1.0E-08
38	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.5E-05	0.0E+00	1.0E-09
39	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.0E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.1E-09
40	0.0E+00	0.0E+00	0.0E+00	2.4E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.2E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.5E-08
41	0.0E+00	0.0E+00	0.0E+00	5.9E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.1E-09
42	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
43	0.0E+00	0.0E+00	0.0E+00	3.5E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.7E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.0E-08
44	0.0E+00	0.0E+00	0.0E+00	5.9E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-08
45	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-08	0.0E+00	8.0E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.1E-05	0.0E+00	9.1E-09
46	0.0E+00	0.0E+00	0.0E+00	2.4E-08	0.0E+00	0.0E+00	0.0E+00	8.8E-08	0.0E+00	6.2E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.9E-04	0.0E+00	7.2E-08
47	0.0E+00	0.0E+00	0.0E+00	5.9E-09	0.0E+00	0.0E+00	0.0E+00	1.3E-08	0.0E+00	9.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.1E-05	0.0E+00	1.0E-08
48	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-06	0.0E+00	0.0E+00
49	0.0E+00	0.0E+00	0.0E+00	3.5E-08	0.0E+00	0.0E+00	0.0E+00	1.2E-07	0.0E+00	8.7E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.9E-04	0.0E+00	1.0E-07
50	0.0E+00	0.0E+00	0.0E+00	5.9E-09	0.0E+00	0.0E+00	0.0E+00	1.7E-08	0.0E+00	1.0E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.5E-05	0.0E+00	1.2E-08
51	1.1E-04	7.9E-05	5.4E-05	1.7E-04	1.4E-03	9.4E-06	7.0E-05	4.9E-05	4.2E-04	1.3E-03	3.7E-05	3.5E-05	1.9E-05	4.4E-05	5.1E-05	3.5E-05	8.1E-05
52	2.4E-08	1.1E-08	4.7E-09	1.5E-08	1.3E-07	9.7E-10	5.4E-09	3.8E-09	4.5E-08	7.6E-08	6.1E-09	5.7E-09	3.1E-09	1.3E-08	1.1E-10	1.2E-08	5.7E-08
53	5.9E-09	4.7E-09	2.1E-09	7.0E-09	5.3E-08	1.2E-09	4.2E-09	3.0E-09	1.3E-08	1.0E-07	1.7E-09	1.6E-09	8.6E-10	4.3E-09	7.9E-09	1.6E-09	4.6E-09
54	4.5E-03	6.9E-03	2.8E-03	1.5E-03	7.1E-03	3.0E-03	1.6E-03	3.9E-03	1.2E-02	7.8E-03	1.9E-03	1.3E-03	9.3E-04	6.3E-03	1.6E-01	2.3E-03	1.4E-03
55	2.5E-02	1.7E-02	8.3E-03	3.2E-03	2.0E-02	7.7E-03	4.0E-03	5.7E-03	2.0E-02	1.0E-02	5.3E-03	3.3E-03	2.5E-03	8.6E-03	5.2E-01	5.0E-03	3.6E-03
56	2.9E-02	2.4E-02	1.1E-02	4.7E-03	2.7E-02	1.1E-02	5.6E-03	9.5E-03	3.2E-02	1.8E-02	7.2E-03	4.6E-03	3.4E-03	1.5E-02	6.8E-01	7.3E-03	5.0E-03
57	1.6E-04	1.1E-04	8.8E-04	1.8E-04	1.0E-04	2.2E-05	2.8E-05	1.8E-05	2.3E-05	1.5E-05	1.7E-05	1.9E-05	1.4E-05	2.9E-05	1.6E-04	3.2E-05	2.4E-05
58	2.1E-05	2.1E-05	2.2E-05	2.2E-05	2.6E-05	1.7E-05	1.7E-05	9.2E-06	1.8E-05	1.4E-05	1.7E-05	2.2E-05	2.0E-05	2.2E-05	1.6E-05	2.1E-05	2.7E-05

	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
59	2.5E-04	3.1E-04	1.1E-04	1.7E-04	1.5E-03	1.1E-03	1.9E-04	7.5E-05	1.7E-04	6.5E-05	1.0E-04	1.5E-04	7.0E-05	2.2E-04	1.1E-04	1.4E-04	1.9E-04
60	1.7E-04	3.9E-04	1.7E-04	1.8E-04	1.9E-04	1.4E-04	1.1E-04	1.8E-04	7.4E-04	8.5E-04	8.7E-04	3.7E-04	3.0E-04	3.8E-04	2.9E-04	5.8E-04	3.6E-04
61	1.5E-03	7.0E-04	8.1E-04	7.5E-04	7.7E-04	4.1E-04	3.5E-04	4.1E-04	5.6E-04	3.5E-04	3.4E-04	3.2E-04	2.2E-04	4.1E-04	2.3E-04	4.5E-04	4.3E-04
62	5.1E-04	6.0E-04	4.0E-04	4.4E-04	9.1E-04	7.0E-04	3.3E-04	3.7E-04	4.7E-04	1.2E-03	1.2E-03	6.3E-04	4.8E-04	6.7E-04	1.1E-03	5.8E-04	6.2E-04
63	2.7E-04	5.4E-05	3.8E-05	4.6E-05	1.2E-04	7.1E-05	3.4E-05	6.6E-05	5.7E-05	7.7E-05	6.3E-05	4.2E-05	3.1E-05	6.0E-05	2.4E-05	4.4E-05	4.8E-05
64	8.0E-05	9.9E-05	3.5E-05	5.5E-05	4.9E-04	3.6E-04	6.0E-05	2.4E-05	5.4E-05	2.1E-05	3.2E-05	4.7E-05	2.3E-05	7.0E-05	3.5E-05	4.5E-05	6.0E-05
65	6.1E-05	6.4E-05	3.7E-05	6.6E-05	6.8E-05	4.2E-05	3.0E-05	2.3E-05	6.3E-05	3.3E-05	3.8E-05	3.2E-05	2.3E-05	3.5E-05	2.6E-05	4.7E-05	4.1E-05
66	2.9E-04	3.2E-04	2.6E-04	2.3E-04	4.6E-04	3.4E-04	1.6E-04	1.3E-04	2.9E-04	2.3E-04	2.7E-04	1.9E-04	1.6E-04	2.0E-04	1.5E-04	3.1E-04	1.8E-04
67	6.3E-04	6.4E-04	6.1E-04	6.2E-04	5.8E-04	3.5E-04	3.0E-04	2.7E-04	4.2E-04	3.3E-04	3.4E-04	3.1E-04	2.5E-04	3.5E-04	2.0E-04	3.7E-04	3.8E-04
68	5.1E-05	6.6E-05	2.7E-05	2.1E-04	2.9E-04	2.0E-04	4.0E-05	1.9E-05	4.7E-05	2.2E-05	3.7E-05	5.3E-05	4.0E-05	5.2E-05	2.8E-05	1.2E-04	4.0E-05
69	3.8E-03	3.3E-03	2.5E-03	2.8E-03	5.4E-03	3.8E-03	1.6E-03	1.6E-03	2.9E-03	3.2E-03	3.3E-03	2.2E-03	1.6E-03	2.5E-03	2.2E-03	2.7E-03	2.4E-03
70	4.2E-05	9.9E-05	4.1E-05	4.6E-05	2.7E-05	1.6E-05	7.0E-05	4.1E-04	1.2E-03	9.4E-04	1.0E-04	5.0E-05	4.2E-05	7.2E-04	7.4E-05	1.6E-04	4.5E-05
71	1.1E-04	2.6E-04	1.1E-04	1.2E-04	7.0E-05	4.2E-05	1.8E-04	1.1E-03	3.2E-03	2.4E-03	2.7E-04	1.3E-04	1.1E-04	1.9E-03	1.9E-04	4.1E-04	1.2E-04
72	1.2E-05	2.9E-05	1.2E-05	1.3E-05	7.9E-06	4.8E-06	2.1E-05	1.2E-04	3.6E-04	2.8E-04	3.1E-05	1.5E-05	1.2E-05	2.1E-04	2.2E-05	4.6E-05	1.3E-05
73	8.4E-06	2.0E-05	8.3E-06	9.2E-06	5.4E-06	3.3E-06	1.4E-05	8.3E-05	2.5E-04	1.9E-04	2.1E-05	1.0E-05	8.5E-06	1.5E-04	1.5E-05	3.2E-05	9.1E-06
74	2.3E-02	1.4E-02	9.7E-03	7.6E-03	1.5E-02	1.2E-02	8.3E-03	2.1E-02	5.8E-02	4.6E-02	1.0E-02	8.2E-03	6.3E-03	3.8E-02	3.1E-02	1.4E-02	8.9E-03
75	7.3E-04	8.2E-04	6.0E-04	2.1E-04	6.2E-04	1.9E-04	2.3E-04	4.4E-04	1.4E-03	8.4E-04	2.6E-04	1.9E-04	1.6E-04	6.8E-04	2.2E-02	3.4E-04	2.5E-04
76	2.4E-02	1.5E-02	1.0E-02	7.8E-03	1.6E-02	1.2E-02	8.5E-03	2.2E-02	5.9E-02	4.6E-02	1.0E-02	8.4E-03	6.5E-03	3.8E-02	5.2E-02	1.5E-02	9.2E-03
77	2.5E-05	2.2E-05	4.4E-05	1.3E-05	1.2E-05	1.3E-05	9.7E-06	8.5E-06	1.3E-05	1.0E-05	9.5E-06	1.2E-05	1.1E-05	1.3E-05	6.4E-05	1.8E-05	1.6E-05
78	1.2E-04	1.5E-04	1.5E-04	9.1E-05	9.1E-05	9.5E-05	6.7E-05	5.1E-05	9.8E-05	7.3E-05	6.8E-05	9.0E-05	7.8E-05	8.7E-05	5.1E-04	1.4E-04	1.1E-04
79	1.4E-05	2.0E-05	1.9E-05	1.3E-05	1.3E-05	1.4E-05	9.3E-06	7.1E-06	1.4E-05	1.0E-05	9.7E-06	1.3E-05	1.1E-05	1.2E-05	7.3E-05	2.0E-05	1.6E-05
80	6.1E-06	1.8E-06	1.2E-05	9.5E-07	7.5E-07	6.4E-07	8.7E-07	1.5E-06	7.1E-07	5.8E-07	6.5E-07	8.0E-07	5.7E-07	1.7E-06	2.1E-06	9.5E-07	8.7E-07
81	1.5E-04	1.9E-04	1.9E-04	1.3E-04	1.3E-04	1.3E-04	9.1E-05	7.1E-05	1.4E-04	1.0E-04	9.4E-05	1.2E-04	1.1E-04	1.2E-04	7.1E-04	1.9E-04	1.5E-04
82	3.1E-05	3.2E-05	3.2E-05	1.6E-05	1.6E-05	1.7E-05	1.3E-05	9.0E-06	1.7E-05	1.3E-05	1.2E-05	1.6E-05	1.4E-05	1.5E-05	8.8E-05	2.4E-05	2.0E-05
83	6.1E-06	2.7E-06	1.3E-05	1.0E-06	7.5E-07	6.5E-07	9.3E-07	1.2E-06	7.3E-07	6.4E-07	7.2E-07	8.2E-07	6.6E-07	1.5E-06	1.3E-06	9.7E-07	1.6E-06
84	1.8E-05	1.2E-05	1.8E-05	2.9E-06	2.5E-06	2.5E-06	3.4E-06	2.0E-06	2.5E-06	2.1E-06	2.1E-06	2.6E-06	2.2E-06	3.1E-06	6.5E-06	3.6E-06	3.8E-06
85	5.7E-07	5.8E-07	1.1E-06	3.1E-07	2.8E-07	3.0E-07	2.3E-07	1.7E-07	3.1E-07	2.5E-07	2.4E-07	3.0E-07	2.6E-07	3.0E-07	8.6E-07	4.4E-07	4.4E-07
86	2.6E-06	6.2E-07	5.1E-06	3.2E-07	2.3E-07	1.7E-07	3.1E-07	6.0E-07	2.0E-07	1.7E-07	2.1E-07	2.5E-07	1.6E-07	6.7E-07	3.0E-07	2.6E-07	2.6E-07
87	1.1E-05	7.2E-06	1.4E-05	3.2E-06	2.9E-06	3.0E-06	2.8E-06	2.5E-06	3.1E-06	2.5E-06	2.4E-06	3.1E-06	2.6E-06	3.8E-06	8.6E-06	4.5E-06	3.6E-06
88	1.5E-05	9.4E-06	8.7E-06	9.7E-07	7.1E-07	6.4E-07	2.0E-06	5.9E-07	6.4E-07	5.2E-07	6.1E-07	7.1E-07	5.6E-07	9.2E-07	1.3E-06	8.9E-07	1.1E-06
89	3.1E-05	2.5E-05	5.7E-05	1.4E-05	1.3E-05	1.3E-05	1.1E-05	9.7E-06	1.4E-05	1.1E-05	1.0E-05	1.3E-05	1.1E-05	1.5E-05	6.6E-05	1.9E-05	1.8E-05
90	1.3E-04	1.6E-04	1.7E-04	9.4E-05	9.4E-05	9.7E-05	7.0E-05	5.3E-05	1.0E-04	7.5E-05	7.0E-05	9.2E-05	8.0E-05	9.0E-05	5.2E-04	1.4E-04	1.1E-04
91	1.5E-05	2.1E-05	2.0E-05	1.3E-05	1.3E-05	1.4E-05	9.5E-06	7.3E-06	1.4E-05	1.1E-05	9.9E-06	1.3E-05	1.1E-05	1.3E-05	7.4E-05	2.0E-05	1.6E-05
92	8.8E-06	2.4E-06	1.7E-05	1.3E-06	9.8E-07	8.2E-07	1.2E-06	2.1E-06	9.1E-07	7.6E-07	8.6E-07	1.0E-06	7.4E-07	2.4E-06	2.4E-06	1.2E-06	1.1E-06
93	1.6E-04	2.0E-04	2.0E-04	1.3E-04	1.3E-04	1.3E-04	9.4E-05	7.3E-05	1.4E-04	1.0E-04	9.7E-05	1.3E-04	1.1E-04	1.2E-04	7.2E-04	2.0E-04	1.5E-04
94	4.5E-05	4.1E-05	4.1E-05	1.7E-05	1.7E-05	1.7E-05	1.5E-05	9.6E-06	1.8E-05	1.3E-05	1.3E-05	1.6E-05	1.4E-05	1.6E-05	8.9E-05	2.5E-05	2.1E-05
95	2.6E-04	2.2E-04	1.6E-04	2.0E-04	4.3E-04	3.0E-04	1.1E-04	1.0E-04	2.0E-04	2.0E-04	2.1E-04	1.4E-04	1.0E-04	1.6E-04	1.2E-04	1.9E-04	1.6E-04
96	7.9E-08	7.0E-08	5.9E-08	6.9E-08	8.9E-08	5.7E-08	3.4E-08	3.0E-08	5.4E-08	3.9E-08	4.1E-08	3.6E-08	2.7E-08	4.1E-08	2.5E-08	4.5E-08	4.4E-08
97	1.2E-08	1.0E-08	7.8E-09	9.0E-09	1.7E-08	1.2E-08	5.2E-09	5.4E-09	8.7E-09	1.2E-08	1.3E-08	7.8E-09	5.8E-09	8.8E-09	8.6E-09	8.7E-09	8.4E-09
98	4.9E-03	9.7E-03	3.7E-03	2.1E-03	2.0E-02	3.0E-03	2.0E-03	4.0E-03	1.3E-02	8.0E-03	1.9E-03	1.3E-03	9.3E-04	6.5E-03	5.1E-01	2.3E-03	1.4E-03
99	2.5E-02	1.7E-02	8.7E-03	3.4E-03	5.3E-02	7.7E-03	4.0E-03	6.9E-03	2.5E-02	2.5E-02	5.3E-03	3.3E-03	2.5E-03	8.6E-03	1.7E+00	5.0E-03	3.6E-03
100	3.0E-02	2.7E-02	1.2E-02	5.5E-03	7.4E-02	1.1E-02	6.0E-03	1.1E-02	3.7E-02	3.3E-02	7.2E-03	4.7E-03	3.4E-03	1.5E-02	2.2E+00	7.3E-03	5.0E-03
101	1.7E-04	1.1E-04	8.8E-04	1.8E-04	1.0E-04	2.3E-05	2.8E-05	1.8E-05	2.5E-05	1.6E-05	1.8E-05	1.9E-05	1.4E-05	3.0E-05	4.6E-04	3.2E-05	2.4E-05
102	2.1E-05	2.1E-05	2.2E-05	2.2E-05	2.6E-05	1.7E-05	1.7E-05	9.2E-06	1.8E-05	1.4E-05	1.7E-05	2.2E-05	2.0E-05	2.2E-05	1.6E-05	3.4E-05	2.7E-05
103	2.5E-04	3.1E-04	1.1E-04	1.7E-04	8.6E-03	1.1E-03	1.9E-04	7.5E-05	1.7E-04	6.5E-05	1.0E-04	1.5E-04	7.0E-05	2.2E-04	1.1E-04	1.4E-04	1.9E-04
104	3.2E-04	5.6E-04	3.4E-04	2.9E-04	7.2E-04	1.4E-04	1.7E-04	2.2E-04	4.4E-03	9.8E-03	8.9E-04	3.8E-04	3.1E-04	3.8E-04	2.9E-04	5.8E-04	4.2E-04
105	1.6E-03	8.2E-04	8.8E-04	7.8E-04	7.7E-04	4.4E-04	5.5E-04	5.5E-04	6.9E-04	4.1E-04	5.6E-04	5.3E-04	3.4E-04	4.4E-04	2.3E-04	8.0E-04	4.8E-04
106	1.2E-03	1.2E-03	5.9E-04	9.6E-04	4.1E-03	8.9E-04	9.5E-04	8.1E-04	1.1E-03	1.3E-02	1.4E-03	7.6E-04	5.6E-04	1.4E-03	2.6E-03	6.2E-04	9.2E-04
107	3.3E-04	7.7E-05	7.1E-05	1.1E-04	4.5E-04	7.1E-05	6.9E-05	9.0E-05	8.0E-05	5.3E-04	7.7E-05	5.4E-05	3.8E-05	6.2E-05	2.4E-05	4.4E-05	4.9E-05
108	8.0E-05	9.9E-05	3.5E-05	5.5E-05	2.7E-03	3.6E-04	6.0E-05	2.4E-05	5.4E-05	2.1E-05	3.2E-05	4.7E-05	2.3E-05	7.0E-05	3.5E-05	4.5E-05	6.0E-05
109	1.0E-04	7.0E-05	4.0E-05	7.0E-05	7.9E-05	5.5E-05	4.0E-05	3.0E-05	1.9E-04	9.8E-05	5.6E-05	5.0E-05	3.2E-05	4.3E-05	2.6E-05	6.1E-05	5.1E-05
110	1.0E-03	8.1E-04	6.9E-04	5.9E-04	2.2E-03	3.4E-04	6.6E-04	4.8E-04	1.3E-03	1.9E-03	4.8E-04	3.9E-04	2.7E-04	3.1E-04	1.5E-04	3.2E-04	2.5E-04
111	9.2E-04	7.6E-04	6.3E-04	6.2E-04	5.8E-04	3.5E-04	3.1E-04	2.8E-04	4.2E-04	3.3E-04	3.7E-04	3.4E-04	2.7E-04	5.5E-04	2.0E-04	4.9E-04	1.2E-03
112	5.1E-05	6.6E-05	2.7E-05	1.1E-03	1.5E-03	2.0E-04	4.0E-05	1.9E-05	4.7E-05	2.2E-05	3.7E-05	5.3E-05	4.0E-05	5.2E-05	2.8E-05	1.2E-04	5.3E-05
113	6.0E-03	4.8E-03	3.4E-03	4.8E-03	2.2E-02	4.0E-03	3.1E-03	2.6E-03	8.4E-03	2.6E-02	4.0E-03	2.8E-03	2.0E-03	3.5E-03	3.7E-03	3.2E-03	3.7E-03

	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
114	4.2E-05	9.9E-05	4.1E-05	4.6E-05	2.7E-05	1.6E-05	7.0E-05	4.1E-04	1.2E-03	9.4E-04	1.0E-04	5.0E-05	4.2E-05	7.2E-04	7.4E-05	1.6E-04	4.5E-05
115	1.1E-04	2.6E-04	1.1E-04	1.2E-04	7.0E-05	4.2E-05	1.8E-04	1.1E-03	3.2E-03	2.4E-03	2.7E-04	1.3E-04	1.1E-04	1.9E-03	1.9E-04	4.1E-04	1.2E-04
116	1.2E-05	2.9E-05	1.2E-05	1.3E-05	7.9E-06	4.8E-06	2.1E-05	1.2E-04	3.6E-04	2.8E-04	3.1E-05	1.5E-05	1.2E-05	2.1E-04	2.2E-05	4.6E-05	1.3E-05
117	8.4E-06	2.0E-05	8.3E-06	9.2E-06	5.4E-06	3.3E-06	1.4E-05	8.3E-05	2.5E-04	1.9E-04	2.1E-05	1.0E-05	8.5E-06	1.5E-04	1.5E-05	3.2E-05	9.1E-06
118	2.9E-02	1.4E-02	9.9E-03	7.9E-03	6.1E-02	1.2E-02	8.3E-03	2.8E-02	5.8E-02	6.6E-02	1.0E-02	8.2E-03	6.3E-03	3.8E-02	6.2E-02	1.4E-02	9.0E-03
119	7.3E-04	8.2E-04	6.3E-04	2.5E-04	6.2E-04	1.9E-04	2.3E-04	4.5E-04	1.4E-03	8.7E-04	2.6E-04	1.9E-04	1.6E-04	6.8E-04	6.9E-02	3.4E-04	2.5E-04
120	3.0E-02	1.5E-02	1.1E-02	8.1E-03	6.1E-02	1.2E-02	8.5E-03	2.9E-02	6.0E-02	6.7E-02	1.0E-02	8.4E-03	6.5E-03	3.8E-02	1.3E-01	1.5E-02	9.2E-03
121	2.5E-05	2.2E-05	4.4E-05	1.3E-05	1.2E-05	1.3E-05	9.7E-06	8.5E-06	1.3E-05	1.0E-05	9.5E-06	1.2E-05	1.1E-05	1.3E-05	1.3E-04	1.8E-05	1.6E-05
122	1.2E-04	1.5E-04	1.5E-04	9.1E-05	9.1E-05	9.5E-05	6.7E-05	5.1E-05	9.8E-05	7.3E-05	6.8E-05	9.0E-05	7.8E-05	8.7E-05	1.0E-03	1.4E-04	1.1E-04
123	1.4E-05	2.0E-05	1.9E-05	1.3E-05	1.3E-05	1.4E-05	9.3E-06	7.1E-06	1.4E-05	1.0E-05	9.7E-06	1.3E-05	1.1E-05	1.2E-05	1.4E-04	2.0E-05	1.6E-05
124	6.1E-06	1.8E-06	1.2E-05	9.5E-07	7.5E-07	6.4E-07	8.7E-07	1.5E-06	7.1E-07	5.8E-07	6.5E-07	8.0E-07	5.7E-07	1.7E-06	3.5E-06	9.5E-07	8.7E-07
125	1.5E-04	1.9E-04	1.9E-04	1.3E-04	1.3E-04	1.3E-04	9.1E-05	7.1E-05	1.4E-04	1.0E-04	9.4E-05	1.2E-04	1.1E-04	1.2E-04	1.4E-03	1.9E-04	1.5E-04
126	3.1E-05	3.2E-05	3.2E-05	1.6E-05	1.6E-05	1.7E-05	1.3E-05	9.1E-06	1.7E-05	1.3E-05	1.2E-05	1.6E-05	1.4E-05	1.5E-05	1.7E-04	2.4E-05	2.0E-05
127	6.1E-06	2.7E-06	1.3E-05	1.0E-06	7.5E-07	6.5E-07	9.3E-07	1.2E-06	7.3E-07	7.2E-07	7.2E-07	8.2E-07	6.6E-07	1.5E-06	1.3E-06	9.7E-07	1.6E-06
128	1.8E-05	1.2E-05	1.8E-05	3.0E-06	2.5E-06	2.5E-06	3.4E-06	2.0E-06	2.5E-06	2.7E-06	2.1E-06	2.6E-06	2.2E-06	3.1E-06	6.5E-06	3.6E-06	3.9E-06
129	5.7E-07	5.8E-07	1.1E-06	3.2E-07	2.8E-07	3.0E-07	2.3E-07	1.7E-07	3.1E-07	3.4E-07	2.4E-07	3.0E-07	2.6E-07	3.0E-07	8.6E-07	4.4E-07	4.5E-07
130	2.6E-06	6.2E-07	5.1E-06	3.2E-07	2.3E-07	1.7E-07	3.1E-07	6.0E-07	2.0E-07	1.7E-07	2.1E-07	2.5E-07	1.6E-07	6.7E-07	3.0E-07	2.6E-07	2.6E-07
131	1.1E-05	7.2E-06	1.4E-05	3.3E-06	2.9E-06	3.0E-06	2.8E-06	2.5E-06	3.1E-06	3.4E-06	2.4E-06	3.1E-06	2.6E-06	3.8E-06	8.6E-06	4.5E-06	3.7E-06
132	1.5E-05	9.4E-06	8.7E-06	9.8E-07	7.1E-07	6.4E-07	2.0E-06	5.9E-07	6.4E-07	6.2E-07	6.1E-07	7.1E-07	5.6E-07	9.2E-07	1.3E-06	8.9E-07	1.1E-06
133	3.1E-05	2.5E-05	5.7E-05	1.4E-05	1.3E-05	1.3E-05	1.1E-05	9.7E-06	1.4E-05	1.1E-05	1.0E-05	1.3E-05	1.1E-05	1.5E-05	1.3E-04	1.9E-05	1.8E-05
134	1.3E-04	1.6E-04	1.7E-04	9.4E-05	9.4E-05	9.7E-05	7.0E-05	5.3E-05	1.0E-04	7.6E-05	7.0E-05	9.2E-05	8.0E-05	9.0E-05	1.0E-03	1.4E-04	1.1E-04
135	1.5E-05	2.1E-05	2.0E-05	1.3E-05	1.3E-05	1.4E-05	9.5E-06	7.3E-06	1.4E-05	1.1E-05	9.9E-06	1.3E-05	1.1E-05	1.3E-05	1.5E-04	2.0E-05	1.6E-05
136	8.8E-06	2.4E-06	1.7E-05	1.3E-06	9.8E-07	8.2E-07	1.2E-06	2.1E-06	9.1E-07	7.6E-07	8.6E-07	1.0E-06	7.4E-07	2.4E-06	3.8E-06	1.2E-06	1.1E-06
137	1.6E-04	2.0E-04	2.0E-04	1.3E-04	1.3E-04	1.3E-04	9.4E-05	7.4E-05	1.4E-04	1.0E-04	9.7E-05	1.3E-04	1.1E-04	1.2E-04	1.4E-03	2.0E-04	1.5E-04
138	4.5E-05	4.1E-05	4.1E-05	1.7E-05	1.7E-05	1.7E-05	1.5E-05	9.7E-06	1.8E-05	1.3E-05	1.3E-05	1.6E-05	1.4E-05	1.6E-05	1.7E-04	2.5E-05	2.1E-05
139	3.7E-04	3.0E-04	2.2E-04	3.7E-04	1.8E-03	3.1E-04	1.8E-04	1.5E-04	6.3E-04	1.5E-03	2.4E-04	1.8E-04	1.2E-04	2.1E-04	1.7E-04	2.2E-04	2.4E-04
140	1.0E-07	8.1E-08	6.4E-08	8.4E-08	2.2E-07	5.8E-08	3.9E-08	3.4E-08	9.9E-08	1.1E-07	4.7E-08	4.1E-08	3.0E-08	5.4E-08	2.6E-08	5.7E-08	1.0E-07
141	1.8E-08	1.5E-08	1.0E-08	1.6E-08	7.0E-08	1.3E-08	9.5E-09	8.3E-09	2.2E-08	1.1E-07	1.5E-08	9.4E-09	6.6E-09	1.3E-08	1.6E-08	1.0E-08	1.3E-08
142	1.6E-04	2.3E-03	4.6E-04	5.3E-04	1.8E-02	2.4E-05	3.2E-05	1.2E-04	3.9E-04	2.7E-04	0.0E+00	8.9E-05	0.0E+00	1.7E-04	2.7E-01	0.0E+00	3.3E-06
143	2.1E-04	5.6E-04	3.8E-04	1.4E-04	0.0E+00	0.0E+00	0.0E+00	3.0E-04	2.8E-03	1.4E-02	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E+00	0.0E+00	0.0E+00
144	3.7E-04	2.9E-03	8.5E-04	6.7E-04	1.8E-02	2.4E-05	3.2E-05	4.2E-04	3.2E-03	1.4E-02	0.0E+00	8.9E-05	0.0E+00	1.7E-04	1.4E+00	0.0E+00	3.3E-06
145	2.6E-06	3.8E-07	2.4E-07	1.2E-06	1.9E-07	4.2E-07	4.7E-07	2.7E-07	1.8E-06	2.8E-07	4.1E-07	4.0E-07	2.3E-07	6.2E-07	2.9E-04	2.2E-07	1.6E-07
146	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.6E-05	0.0E+00
147	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.8E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
148	1.4E-04	1.8E-04	1.3E-04	1.1E-04	5.1E-04	0.0E+00	6.1E-05	3.9E-05	3.7E-03	7.7E-03	1.8E-05	1.8E-05	8.8E-06	0.0E+00	0.0E+00	0.0E+00	5.7E-05
149	1.2E-04	1.2E-04	5.7E-05	2.5E-05	0.0E+00	2.8E-05	2.0E-04	1.3E-04	1.4E-04	4.8E-05	2.4E-04	2.3E-04	1.1E-04	2.1E-05	0.0E+00	4.2E-04	5.2E-05
150	7.0E-04	6.4E-04	1.5E-04	5.4E-04	3.1E-03	1.9E-04	6.1E-04	3.9E-04	6.1E-04	9.7E-03	1.5E-04	1.5E-04	7.4E-05	5.9E-04	1.7E-03	3.9E-05	3.2E-04
151	6.6E-05	2.4E-05	2.6E-05	7.0E-05	3.2E-04	0.0E+00	3.5E-05	2.2E-05	2.3E-05	3.9E-04	1.4E-05	1.4E-05	6.6E-06	1.5E-06	0.0E+00	0.0E+00	1.1E-06
152	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
153	4.0E-05	6.8E-06	2.6E-06	3.6E-06	1.1E-05	1.2E-05	9.6E-06	6.1E-06	1.3E-04	5.7E-05	2.0E-05	1.9E-05	9.5E-06	7.1E-06	0.0E+00	1.7E-05	1.1E-05
154	7.1E-04	5.1E-04	3.3E-04	3.7E-04	1.6E-03	0.0E+00	4.9E-04	3.1E-04	1.0E-03	1.4E-03	2.2E-04	2.1E-04	1.0E-04	9.1E-05	0.0E+00	1.1E-05	7.8E-05
155	2.8E-04	1.2E-04	1.8E-05	1.7E-06	1.1E-06	1.2E-06	1.3E-05	8.4E-06	6.3E-08	2.8E-06	3.2E-05	3.2E-05	1.5E-05	1.7E-04	0.0E+00	1.5E-04	8.9E-04
156	0.0E+00	0.0E+00	0.0E+00	9.1E-04	1.2E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-05
157	2.1E-03	1.6E-03	7.1E-04	2.0E-03	1.6E-02	2.4E-04	1.4E-03	9.0E-04	5.6E-03	1.9E-02	7.0E-04	6.8E-04	3.3E-04	8.8E-04	1.7E-03	6.6E-04	1.4E-03
158	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
159	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
160	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
161	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
162	8.5E-05	3.2E-05	1.2E-04	9.0E-04	5.0E-02	0.0E+00	0.0E+00	4.4E-02	1.6E-03	2.0E-02	0.0E+00	6.4E-07	1.4E-06	0.0E+00	3.3E-02	0.0E+00	3.4E-06
163	3.7E-07	8.2E-06	0.0E+00	1.1E-04	4.3E-03	0.0E+00	5.9E-08	2.1E-07	4.6E-06	5.4E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.3E-03	0.0E+00	2.6E-06
164	8.5E-05	4.0E-05	1.2E-04	1.0E-03	5.4E-02	0.0E+00	5.9E-08	4.4E-02	1.6E-03	2.0E-02	0.0E+00	6.4E-07	1.4E-06	0.0E+00	3.7E-02	0.0E+00	6.1E-06
165	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.3E-05	0.0E+00	9.7E-10
166	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.0E-04	0.0E+00	6.8E-09
167	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.3E-05	0.0E+00	9.7E-10
168	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-06	0.0E+00	0.0E+00
169	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.1E-04	0.0E+00	9.7E-09
170	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.7E-05	0.0E+00	9.7E-10
171	0.0E+00	0.0E+00	0.0E+00	2.9E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.7E-09
172	0.0E+00	0.0E+00	0.0E+00	2.2E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.2E-08
173	0.0E+00	0.0E+00	0.0E+00	2.9E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.7E-09
174	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
175	0.0E+00	0.0E+00	0.0E+00	3.0E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.6E-08
176	0.0E+00	0.0E+00	0.0E+00	3.5E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-08
177	0.0E+00	0.0E+00	0.0E+00	2.9E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.3E-05	0.0E+00	8.7E-09
178	0.0E+00	0.0E+00	0.0E+00	2.2E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.0E-04	0.0E+00	6.9E-08
179	0.0E+00	0.0E+00	0.0E+00	2.9E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.3E-05	0.0E+00	9.7E-09
180	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-06	0.0E+00	0.0E+00
181	0.0E+00	0.0E+00	0.0E+00	3.0E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.1E-04	0.0E+00	9.6E-08
182	0.0E+00	0.0E+00	0.0E+00	3.5E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.7E-05	0.0E+00	1.2E-08
183	1.1E-04	8.4E-05	4.2E-05	1.8E-04	1.3E-03	9.1E-06	6.9E-05	4.4E-05	4.3E-04	1.1E-03	3.9E-05	3.8E-05	1.9E-05	3.7E-05	5.7E-05	4.3E-05	8.6E-05
184	2.3E-08	1.1E-08	3.6E-09	1.6E-08	1.2E-07	9.4E-10	5.4E-09	3.4E-09	4.6E-08	6.5E-08	6.4E-09	6.3E-09	3.1E-09	1.1E-08	1.2E-10	1.5E-08	6.0E-08
185	5.8E-09	5.0E-09	1.6E-09	7.2E-09	5.1E-08	1.1E-09	4.2E-09	2.7E-09	1.3E-08	8.5E-08	1.8E-09	1.8E-09	8.6E-10	3.6E-09	8.9E-09	2.0E-09	4.8E-09
186	5.1E-03	7.8E-03	3.4E-03	1.6E-03	8.7E-03	4.3E-03	2.0E-03	4.1E-03	1.2E-02	7.7E-03	2.1E-03	1.4E-03	1.3E-03	6.1E-03	1.5E-01	2.4E-03	1.6E-03
187	1.6E-02	2.2E-02	1.2E-02	3.2E-03	1.7E-02	3.6E-03	4.7E-03	8.6E-03	2.5E-02	1.4E-02	6.4E-03	3.5E-03	3.6E-03	9.8E-03	6.5E-01	5.4E-03	4.1E-03
188	2.1E-02	3.0E-02	1.5E-02	4.8E-03	2.6E-02	7.8E-03	6.8E-03	1.3E-02	3.8E-02	2.2E-02	8.4E-03	4.9E-03	4.9E-03	1.6E-02	8.0E-01	7.9E-03	5.7E-03
189	2.0E-04	1.4E-04	1.0E-03	2.3E-04	1.3E-04	3.1E-05	3.9E-05	2.9E-05	3.0E-05	2.2E-05	2.2E-05	2.2E-05	2.3E-05	4.2E-05	2.0E-04	4.2E-05	3.7E-05
190	2.3E-05	2.4E-05	3.0E-05	2.4E-05	3.0E-05	2.0E-05	2.1E-05	1.5E-05	2.2E-05	1.8E-05	2.0E-05	2.3E-05	2.4E-05	3.0E-05	1.8E-05	2.4E-05	2.9E-05
191	2.6E-04	3.3E-04	1.6E-04	1.8E-04	1.8E-03	1.3E-03	2.2E-04	1.1E-04	1.9E-04	8.5E-05	1.1E-04	1.4E-04	9.6E-05	2.7E-04	1.1E-04	1.6E-04	1.9E-04
192	2.2E-04	3.7E-04	2.0E-04	1.7E-04	2.2E-04	1.6E-04	1.3E-04	1.7E-04	7.6E-04	8.1E-04	7.6E-04	3.2E-04	3.0E-04	3.8E-04	2.8E-04	5.7E-04	3.5E-04
193	1.6E-03	8.4E-04	1.0E-03	9.0E-04	9.5E-04	5.5E-04	4.7E-04	4.6E-04	7.1E-04	4.9E-04	4.3E-04	3.8E-04	3.3E-04	5.7E-04	2.9E-04	5.6E-04	5.2E-04
194	5.6E-04	6.5E-04	5.1E-04	4.6E-04	1.0E-03	8.0E-04	4.0E-04	4.3E-04	5.4E-04	1.2E-03	1.1E-03	5.9E-04	5.3E-04	7.3E-04	1.4E-03	6.2E-04	6.0E-04
195	2.5E-04	5.7E-05	4.3E-05	5.0E-05	1.5E-04	8.4E-05	4.0E-05	4.8E-05	6.9E-05	8.6E-05	6.3E-05	4.1E-05	3.9E-05	7.0E-05	2.6E-05	4.8E-05	5.2E-05
196	8.4E-05	1.1E-04	5.1E-05	5.9E-05	5.6E-04	4.0E-04	7.2E-05	3.5E-05	6.2E-05	2.7E-05	3.6E-05	4.6E-05	3.1E-05	8.7E-05	3.6E-05	5.1E-05	6.1E-05
197	7.0E-05	7.1E-05	5.5E-05	7.8E-05	8.2E-05	5.4E-05	4.1E-05	3.7E-05	7.6E-05	4.3E-05	4.4E-05	3.6E-05	3.2E-05	4.9E-05	3.0E-05	5.6E-05	4.7E-05
198	3.2E-04	3.3E-04	2.5E-04	2.4E-04	5.3E-04	3.9E-04	2.0E-04	1.9E-04	3.2E-04	2.5E-04	2.7E-04	2.0E-04	1.9E-04	2.5E-04	1.6E-04	3.3E-04	2.1E-04
199	7.5E-04	7.7E-04	8.2E-04	7.4E-04	7.1E-04	4.7E-04	4.1E-04	4.4E-04	5.5E-04	4.6E-04	4.3E-04	3.6E-04	4.1E-04	5.1E-04	2.6E-04	4.7E-04	4.6E-04
200	5.5E-05	7.2E-05	4.0E-05	2.1E-04	3.3E-04	2.3E-04	4.8E-05	2.9E-05	5.7E-05	2.9E-05	4.2E-05	5.1E-05	5.1E-05	6.6E-05	3.0E-05	1.4E-04	4.2E-05
201	4.2E-03	3.6E-03	3.2E-03	3.1E-03	6.3E-03	4.4E-03	2.0E-03	2.0E-03	3.3E-03	3.5E-03	3.3E-03	2.2E-03	2.0E-03	3.0E-03	2.6E-03	3.0E-03	2.6E-03
202	4.0E-05	8.6E-05	4.9E-05	4.2E-05	2.6E-05	1.6E-05	7.0E-05	3.7E-04	1.2E-03	9.1E-04	9.9E-05	4.6E-05	4.4E-05	6.6E-04	6.4E-05	1.5E-04	4.2E-05
203	1.1E-04	2.4E-04	1.4E-04	1.2E-04	7.3E-05	4.6E-05	2.0E-04	1.0E-03	3.3E-03	2.6E-03	2.8E-04	1.3E-04	1.2E-04	1.9E-03	1.8E-04	4.1E-04	1.2E-04
204	1.4E-05	2.9E-05	1.7E-05	1.4E-05	8.9E-06	5.6E-06	2.4E-05	1.3E-04	4.0E-04	3.1E-04	3.4E-05	1.6E-05	1.5E-05	2.2E-04	2.2E-05	5.0E-05	1.5E-05
205	9.2E-06	2.0E-05	1.1E-05	9.7E-06	5.9E-06	3.7E-06	1.6E-05	8.4E-05	2.7E-04	2.1E-04	2.3E-05	1.0E-05	1.0E-05	1.5E-04	1.5E-05	3.3E-05	9.7E-06
206	1.2E-02	1.5E-02	1.5E-02	9.6E-03	2.0E-02	1.5E-02	1.4E-02	3.3E-02	6.8E-02	5.5E-02	1.2E-02	9.1E-03	8.4E-03	4.3E-02	3.6E-02	1.7E-02	1.0E-02
207	1.7E-03	1.6E-03	1.3E-03	6.7E-04	1.6E-03	1.2E-03	9.1E-04	2.6E-03	7.8E-03	6.0E-03	9.1E-04	6.3E-04	6.2E-04	4.6E-03	3.5E-03	1.4E-03	8.4E-04
208	1.3E-02	1.7E-02	1.6E-02	1.0E-02	2.2E-02	1.6E-02	1.5E-02	3.6E-02	7.6E-02	6.1E-02	1.3E-02	9.8E-03	9.1E-03	4.8E-02	3.9E-02	1.8E-02	1.1E-02
209	3.6E-05	2.6E-05	6.2E-05	1.4E-05	1.5E-05	1.4E-05	1.3E-05	1.4E-05	1.6E-05	1.3E-05	1.2E-05	1.4E-05	1.5E-05	1.8E-05	7.4E-05	2.0E-05	2.0E-05

	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
210	1.3E-04	1.5E-04	1.9E-04	9.2E-05	1.0E-04	1.0E-04	7.8E-05	7.8E-05	1.1E-04	9.0E-05	7.5E-05	9.2E-05	1.0E-04	1.0E-04	5.8E-04	1.4E-04	1.1E-04
211	1.6E-05	2.0E-05	2.3E-05	1.3E-05	1.4E-05	1.5E-05	1.1E-05	1.1E-05	1.6E-05	1.3E-05	1.1E-05	1.3E-05	1.4E-05	1.4E-05	8.3E-05	2.0E-05	1.6E-05
212	9.2E-06	2.2E-06	1.7E-05	1.2E-06	9.9E-07	8.5E-07	1.3E-06	2.6E-06	9.7E-07	8.7E-07	8.7E-07	9.6E-07	8.7E-07	2.9E-06	2.5E-06	1.2E-06	1.1E-06
213	1.6E-04	1.9E-04	2.3E-04	1.3E-04	1.4E-04	1.4E-04	1.1E-04	1.1E-04	1.5E-04	1.2E-04	1.0E-04	1.3E-04	1.4E-04	1.4E-04	8.1E-04	1.9E-04	1.5E-04
214	3.4E-05	3.3E-05	4.0E-05	1.7E-05	1.8E-05	1.8E-05	1.5E-05	1.4E-05	1.9E-05	1.6E-05	1.3E-05	1.6E-05	1.8E-05	1.9E-05	1.0E-04	2.4E-05	2.1E-05
215	8.5E-06	4.2E-06	1.6E-05	1.5E-06	1.3E-06	1.2E-06	1.6E-06	2.0E-06	1.4E-06	1.4E-06	1.3E-06	1.3E-06	1.6E-06	2.4E-06	2.4E-06	1.7E-06	3.5E-06
216	5.9E-05	3.9E-05	4.3E-05	6.7E-06	5.8E-06	5.7E-06	1.1E-05	5.8E-06	6.0E-06	5.3E-06	4.9E-06	5.5E-06	6.1E-06	7.8E-06	1.4E-05	7.7E-06	9.0E-06
217	1.2E-06	1.1E-06	2.0E-06	6.2E-07	6.1E-07	6.4E-07	5.4E-07	5.3E-07	7.0E-07	6.1E-07	5.1E-07	6.0E-07	6.9E-07	7.0E-07	1.8E-06	8.9E-07	9.6E-07
218	2.3E-06	4.9E-07	4.2E-06	2.5E-07	1.9E-07	1.6E-07	3.0E-07	6.1E-07	1.8E-07	1.7E-07	1.8E-07	1.9E-07	1.6E-07	6.8E-07	2.7E-07	2.2E-07	2.1E-07
219	2.5E-05	1.8E-05	2.3E-05	6.1E-06	5.9E-06	6.2E-06	7.0E-06	5.6E-06	6.6E-06	5.6E-06	4.7E-06	5.7E-06	6.1E-06	7.5E-06	1.8E-05	8.4E-06	6.8E-06
220	5.6E-05	3.6E-05	3.1E-05	3.2E-06	2.3E-06	2.0E-06	9.1E-06	2.5E-06	2.0E-06	1.8E-06	2.0E-06	2.1E-06	2.2E-06	3.5E-06	3.4E-06	2.6E-06	3.6E-06
221	4.5E-05	3.0E-05	7.8E-05	1.6E-05	1.6E-05	1.6E-05	1.4E-05	1.6E-05	1.7E-05	1.5E-05	1.3E-05	1.5E-05	1.7E-05	2.0E-05	7.7E-05	2.1E-05	2.4E-05
222	1.9E-04	1.9E-04	2.3E-04	9.9E-05	1.1E-04	1.1E-04	9.0E-05	8.3E-05	1.2E-04	9.5E-05	7.9E-05	9.8E-05	1.1E-04	1.1E-04	5.9E-04	1.5E-04	1.2E-04
223	1.7E-05	2.1E-05	2.5E-05	1.4E-05	1.5E-05	1.5E-05	1.1E-05	1.1E-05	1.6E-05	1.3E-05	1.1E-05	1.4E-05	1.5E-05	1.5E-05	8.5E-05	2.1E-05	1.7E-05
224	1.1E-05	2.7E-06	2.1E-05	1.4E-06	1.2E-06	1.0E-06	1.6E-06	3.2E-06	1.2E-06	1.0E-06	1.0E-06	1.2E-06	1.0E-06	3.6E-06	2.8E-06	1.4E-06	1.3E-06
225	1.8E-04	2.1E-04	2.5E-04	1.3E-04	1.4E-04	1.5E-04	1.1E-04	1.1E-04	1.6E-04	1.3E-04	1.1E-04	1.3E-04	1.4E-04	1.5E-04	8.3E-04	2.0E-04	1.5E-04
226	9.0E-05	6.8E-05	7.1E-05	2.0E-05	2.0E-05	2.0E-05	2.4E-05	1.6E-05	2.1E-05	1.8E-05	1.5E-05	1.8E-05	2.0E-05	2.2E-05	1.0E-04	2.7E-05	2.4E-05
227	2.8E-04	2.5E-04	2.1E-04	2.2E-04	5.0E-04	3.4E-04	1.4E-04	1.3E-04	2.3E-04	2.2E-04	2.1E-04	1.4E-04	1.3E-04	2.0E-04	1.4E-04	2.1E-04	1.7E-04
228	9.0E-08	8.2E-08	7.9E-08	8.1E-08	1.1E-07	7.1E-08	4.5E-08	4.4E-08	6.7E-08	5.2E-08	4.9E-08	4.0E-08	4.1E-08	5.7E-08	3.2E-08	5.5E-08	5.2E-08
229	1.3E-08	1.1E-08	1.0E-08	1.0E-08	2.0E-08	1.4E-08	6.6E-09	6.4E-09	1.0E-08	1.3E-08	1.2E-08	7.7E-09	7.0E-09	1.0E-08	1.0E-08	9.7E-09	8.8E-09
230	5.3E-03	1.0E-02	3.8E-03	2.1E-03	2.6E-02	4.3E-03	2.1E-03	4.2E-03	1.3E-02	7.9E-03	2.1E-03	1.5E-03	1.3E-03	6.3E-03	4.3E-01	2.4E-03	1.6E-03
231	1.6E-02	2.3E-02	1.2E-02	3.4E-03	1.7E-02	3.6E-03	4.7E-03	8.9E-03	2.8E-02	2.8E-02	6.4E-03	3.5E-03	3.6E-03	9.8E-03	1.8E+00	5.4E-03	4.1E-03
232	2.1E-02	3.3E-02	1.6E-02	5.5E-03	4.3E-02	7.8E-03	6.8E-03	1.3E-02	4.1E-02	3.6E-02	8.4E-03	5.0E-03	4.9E-03	1.6E-02	2.2E+00	7.9E-03	5.7E-03
233	2.1E-04	1.4E-04	1.0E-03	2.3E-04	1.3E-04	3.2E-05	3.9E-05	2.9E-05	3.2E-05	2.2E-05	2.3E-05	2.3E-05	2.4E-05	4.2E-05	4.9E-04	4.3E-05	3.7E-05
234	2.3E-05	2.4E-05	3.0E-05	2.4E-05	3.0E-05	2.0E-05	2.1E-05	1.5E-05	2.2E-05	1.8E-05	2.0E-05	2.3E-05	2.4E-05	3.0E-05	1.8E-05	4.0E-05	2.9E-05
235	2.6E-04	3.3E-04	1.6E-04	1.8E-04	8.6E-03	1.3E-03	2.2E-04	1.1E-04	1.9E-04	8.5E-05	1.1E-04	1.4E-04	9.6E-05	2.7E-04	1.1E-04	1.6E-04	1.9E-04
236	3.6E-04	5.5E-04	3.3E-04	2.9E-04	7.2E-04	1.6E-04	1.9E-04	2.1E-04	4.5E-03	8.5E-03	7.8E-04	3.4E-04	3.1E-04	3.8E-04	2.8E-04	5.7E-04	4.1E-04
237	1.7E-03	9.6E-04	1.1E-03	9.3E-04	9.5E-04	5.8E-04	6.7E-04	5.9E-04	8.5E-04	5.3E-04	6.7E-04	6.1E-04	4.5E-04	6.0E-04	2.9E-04	9.9E-04	5.8E-04
238	1.3E-03	1.3E-03	6.6E-04	1.0E-03	4.1E-03	9.9E-04	1.0E-03	8.2E-04	1.1E-03	1.1E-02	1.3E-03	7.4E-04	6.1E-04	1.3E-03	3.1E-03	6.6E-04	9.2E-04
239	3.2E-04	8.2E-05	6.9E-05	1.2E-04	4.7E-04	8.4E-05	7.5E-05	7.0E-05	9.2E-05	4.8E-04	7.6E-05	5.5E-05	4.6E-05	7.1E-05	2.6E-05	4.8E-05	5.3E-05
240	8.4E-05	1.1E-04	5.1E-05	5.9E-05	2.7E-03	4.0E-04	7.2E-05	3.5E-05	6.2E-05	2.7E-05	3.6E-05	4.6E-05	3.1E-05	8.7E-05	3.6E-05	5.1E-05	6.1E-05
241	1.1E-04	7.8E-05	5.7E-05	8.1E-05	9.3E-05	6.7E-05	5.0E-05	4.3E-05	2.0E-04	9.9E-05	6.4E-05	5.6E-05	4.1E-05	5.6E-05	3.0E-05	7.3E-05	5.8E-05
242	1.0E-03	8.4E-04	5.9E-04	6.1E-04	2.2E-03	3.9E-04	6.9E-04	5.1E-04	1.3E-03	1.7E-03	4.8E-04	4.1E-04	3.0E-04	3.4E-04	1.6E-04	3.4E-04	2.9E-04
243	1.0E-03	8.9E-04	8.4E-04	7.4E-04	7.1E-04	4.7E-04	4.3E-04	4.5E-04	5.5E-04	4.6E-04	4.6E-04	3.9E-04	4.3E-04	6.8E-04	2.6E-04	6.1E-04	1.4E-03
244	5.5E-05	7.2E-05	4.0E-05	1.1E-03	1.5E-03	2.3E-04	4.8E-05	2.9E-05	5.7E-05	2.9E-05	4.2E-05	5.1E-05	5.1E-05	6.6E-05	3.0E-05	1.4E-04	5.6E-05
245	6.2E-03	5.2E-03	3.9E-03	5.2E-03	2.2E-02	4.7E-03	3.5E-03	2.9E-03	9.0E-03	2.3E-02	4.0E-03	2.9E-03	2.4E-03	3.9E-03	4.3E-03	3.7E-03	4.0E-03
246	4.0E-05	8.6E-05	4.9E-05	4.2E-05	2.6E-05	1.6E-05	7.0E-05	3.7E-04	1.2E-03	9.1E-04	9.9E-05	4.6E-05	4.4E-05	6.6E-04	6.4E-05	1.5E-04	4.2E-05
247	1.1E-04	2.4E-04	1.4E-04	1.2E-04	7.3E-05	4.6E-05	2.0E-04	1.0E-03	3.3E-03	2.6E-03	2.8E-04	1.3E-04	1.2E-04	1.9E-03	1.8E-04	4.1E-04	1.2E-04
248	1.4E-05	2.9E-05	1.7E-05	1.4E-05	8.9E-06	5.6E-06	2.4E-05	1.3E-04	4.0E-04	3.1E-04	3.4E-05	1.6E-05	1.5E-05	2.2E-04	2.2E-05	5.0E-05	1.5E-05
249	9.2E-06	2.0E-05	1.1E-05	9.7E-06	5.9E-06	3.7E-06	1.6E-05	8.4E-05	2.7E-04	2.1E-04	2.3E-05	1.0E-05	1.0E-05	1.5E-04	1.5E-05	3.3E-05	9.7E-06
250	1.2E-02	1.5E-02	1.5E-02	1.0E-02	7.0E-02	1.5E-02	1.4E-02	7.7E-02	7.0E-02	7.5E-02	1.2E-02	9.1E-03	8.4E-03	4.3E-02	6.8E-02	1.7E-02	1.0E-02
251	1.7E-03	1.6E-03	1.3E-03	7.7E-04	5.9E-03	1.2E-03	9.1E-04	2.6E-03	7.8E-03	6.0E-03	9.1E-04	6.3E-04	6.2E-04	4.6E-03	7.8E-03	1.4E-03	8.4E-04
252	1.3E-02	1.7E-02	1.6E-02	1.1E-02	7.6E-02	1.6E-02	1.5E-02	8.0E-02	7.8E-02	8.1E-02	1.3E-02	9.8E-03	9.1E-03	4.8E-02	7.6E-02	1.8E-02	1.1E-02
253	3.6E-05	2.6E-05	6.2E-05	1.4E-05	1.5E-05	1.4E-05	1.3E-05	1.4E-05	1.6E-05	1.3E-05	1.2E-05	1.4E-05	1.5E-05	1.8E-05	1.4E-04	2.0E-05	2.0E-05
254	1.3E-04	1.5E-04	1.9E-04	9.2E-05	1.0E-04	1.0E-04	7.8E-05	7.8E-05	1.1E-04	9.0E-05	7.5E-05	9.2E-05	1.0E-04	1.0E-04	1.1E-03	1.4E-04	1.1E-04
255	1.6E-05	2.0E-05	2.3E-05	1.3E-05	1.4E-05	1.5E-05	1.1E-05	1.1E-05	1.6E-05	1.3E-05	1.1E-05	1.3E-05	1.4E-05	1.4E-05	1.6E-04	2.0E-05	1.6E-05
256	9.2E-06	2.2E-06	1.7E-05	1.2E-06	9.9E-07	8.5E-07	1.3E-06	2.6E-06	9.7E-07	8.7E-07	8.7E-07	9.6E-07	8.7E-07	2.9E-06	4.0E-06	1.2E-06	1.1E-06
257	1.6E-04	1.9E-04	2.3E-04	1.3E-04	1.4E-04	1.4E-04	1.1E-04	1.1E-04	1.5E-04	1.2E-04	1.0E-04	1.3E-04	1.4E-04	1.4E-04	1.5E-03	1.9E-04	1.5E-04

	R	S	T	U	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH
258	3.4E-05	3.3E-05	4.0E-05	1.7E-05	1.8E-05	1.8E-05	1.5E-05	1.4E-05	1.9E-05	1.6E-05	1.3E-05	1.6E-05	1.8E-05	1.9E-05	1.9E-04	2.4E-05	2.1E-05
259	8.5E-06	4.2E-06	1.6E-05	1.6E-06	1.3E-06	1.2E-06	1.6E-06	2.0E-06	1.4E-06	1.4E-06	1.3E-06	1.3E-06	1.6E-06	2.4E-06	2.4E-06	1.7E-06	3.5E-06
260	5.9E-05	3.9E-05	4.3E-05	6.9E-06	5.8E-06	5.7E-06	1.1E-05	5.8E-06	6.0E-06	5.5E-06	4.9E-06	5.5E-06	6.1E-06	7.8E-06	1.4E-05	7.7E-06	9.1E-06
261	1.2E-06	1.1E-06	2.0E-06	6.5E-07	6.1E-07	6.4E-07	5.4E-07	5.3E-07	7.0E-07	6.4E-07	5.1E-07	6.0E-07	6.9E-07	7.0E-07	1.8E-06	8.9E-07	9.7E-07
262	2.3E-06	4.9E-07	4.2E-06	2.5E-07	1.9E-07	1.6E-07	3.0E-07	6.1E-07	1.8E-07	1.7E-07	1.8E-07	1.9E-07	1.6E-07	6.8E-07	2.7E-07	2.2E-07	2.1E-07
263	2.5E-05	1.8E-05	2.3E-05	6.4E-06	5.9E-06	6.2E-06	7.0E-06	5.6E-06	6.6E-06	5.8E-06	4.7E-06	5.7E-06	6.1E-06	7.5E-06	1.8E-05	8.4E-06	6.9E-06
264	5.6E-05	3.6E-05	3.1E-05	3.2E-06	2.3E-06	2.0E-06	9.1E-06	2.5E-06	2.0E-06	1.8E-06	2.0E-06	2.1E-06	2.2E-06	3.5E-06	3.4E-06	2.6E-06	3.6E-06
265	4.5E-05	3.0E-05	7.8E-05	1.6E-05	1.6E-05	1.6E-05	1.4E-05	1.6E-05	1.7E-05	1.5E-05	1.3E-05	1.5E-05	1.7E-05	2.0E-05	1.4E-04	2.1E-05	2.4E-05
266	1.9E-04	1.9E-04	2.3E-04	9.9E-05	1.1E-04	1.1E-04	9.0E-05	8.3E-05	1.2E-04	9.5E-05	7.9E-05	9.8E-05	1.1E-04	1.1E-04	1.1E-03	1.5E-04	1.2E-04
267	1.7E-05	2.1E-05	2.5E-05	1.4E-05	1.5E-05	1.5E-05	1.1E-05	1.1E-05	1.6E-05	1.3E-05	1.1E-05	1.4E-05	1.5E-05	1.5E-05	1.6E-04	2.1E-05	1.7E-05
268	1.1E-05	2.7E-06	2.1E-05	1.4E-06	1.2E-06	1.0E-06	1.6E-06	3.2E-06	1.2E-06	1.0E-06	1.0E-06	1.2E-06	1.0E-06	3.6E-06	4.2E-06	1.4E-06	1.3E-06
269	1.8E-04	2.1E-04	2.5E-04	1.3E-04	1.4E-04	1.5E-04	1.1E-04	1.1E-04	1.6E-04	1.3E-04	1.1E-04	1.3E-04	1.4E-04	1.5E-04	1.5E-03	2.0E-04	1.5E-04
270	9.0E-05	6.8E-05	7.1E-05	2.0E-05	2.0E-05	2.0E-05	2.4E-05	1.6E-05	2.1E-05	1.8E-05	1.5E-05	1.8E-05	2.0E-05	2.2E-05	1.9E-04	2.7E-05	2.4E-05
271	3.9E-04	3.3E-04	2.5E-04	3.9E-04	1.8E-03	3.5E-04	2.1E-04	1.7E-04	6.7E-04	1.4E-03	2.5E-04	1.8E-04	1.5E-04	2.4E-04	2.0E-04	2.5E-04	2.6E-04
272	1.1E-07	9.3E-08	8.3E-08	9.7E-08	2.3E-07	7.2E-08	5.1E-08	4.8E-08	1.1E-07	1.2E-07	5.5E-08	4.6E-08	4.4E-08	6.8E-08	3.2E-08	7.0E-08	1.1E-07
273	1.9E-08	1.6E-08	1.2E-08	1.7E-08	7.1E-08	1.5E-08	1.1E-08	9.1E-09	2.4E-08	9.9E-08	1.4E-08	9.4E-09	7.9E-09	1.4E-08	1.9E-08	1.2E-08	1.4E-08

	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY
7	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
8	Accommoda tion	Road Transport	Services to Transport	Water Transport	Air Transport	Conununicat ions	Finance	Finance services	Insurance	Real Estate	Business Services	Dwelling ownership	Education	Comnunity Services	Recreation Services	Personal Services	Central Government
10	7.5E-04	0.0E+00	0.0E+00	5.8E-05	1.8E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E-04	6.3E-05	3.0E-03	7.3E-04	6.2E-05
11	2.9E-04	0.0E+00	0.0E+00	1.1E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.0E-05	9.8E-05	4.4E-03	1.8E-04	8.3E-05
12	1.0E-03	0.0E+00	0.0E+00	6.9E-05	1.8E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.8E-04	1.6E-04	7.4E-03	9.1E-04	1.5E-04
13	1.8E-06	5.4E-06	4.9E-07	7.8E-07	2.1E-06	4.4E-07	2.7E-08	4.1E-08	2.3E-08	4.9E-08	1.1E-07	0.0E+00	2.4E-06	7.0E-07	1.0E-04	4.0E-06	1.9E-05
14	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.2E-04
15	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
16	6.6E-06	3.3E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.9E-06	3.0E-06	2.2E-06	3.5E-06	2.7E-06	0.0E+00	2.9E-04	1.9E-04	1.2E-04	1.3E-04	6.2E-05
17	2.5E-05	9.0E-03	0.0E+00	2.4E-03	0.0E+00	8.7E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.6E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E-04
18	6.7E-04	1.4E-04	3.4E-04	0.0E+00	0.0E+00	1.8E-04	1.4E-04	1.4E-04	1.0E-04	1.6E-04	1.6E-04	0.0E+00	2.4E-04	4.9E-04	6.1E-05	6.7E-05	1.2E-04
19	4.1E-05	0.0E+00	0.0E+00	1.0E-03	0.0E+00	0.0E+00	1.0E-05	1.1E-05	7.8E-06	1.2E-05	9.5E-06	0.0E+00	1.1E-05	5.0E-06	0.0E+00	0.0E+00	1.5E-04
20	3.0E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
21	2.1E-05	9.6E-04	0.0E+00	0.0E+00	0.0E+00	1.3E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.7E-09
22	2.4E-04	3.1E-04	0.0E+00	0.0E+00	0.0E+00	1.1E-05	4.0E-05	4.1E-05	3.0E-05	4.7E-05	3.6E-05	0.0E+00	1.5E-04	1.1E-04	6.7E-05	7.4E-05	6.2E-05
23	1.8E-04	7.3E-03	0.0E+00	0.0E+00	0.0E+00	1.6E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.3E-05	0.0E+00	0.0E+00	6.3E-05	4.1E-05	4.5E-05	9.5E-05
24	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
25	1.2E-03	1.8E-02	3.4E-04	3.4E-03	3.3E-03	4.5E-04	1.9E-04	1.9E-04	1.4E-04	2.2E-04	3.3E-04	0.0E+00	6.9E-04	8.7E-04	2.9E-04	3.2E-04	1.0E-03
26	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
27	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
28	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
29	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
30	0.0E+00	1.1E-06	0.0E+00	1.9E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.4E-05	1.6E-04	6.0E-02	3.4E-01	1.1E-07
31	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.4E-07	4.9E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-05	2.1E-05	2.4E-04	6.8E-03	3.0E-04
32	0.0E+00	1.1E-06	0.0E+00	1.9E-05	5.4E-07	4.9E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.7E-05	1.8E-04	6.0E-02	3.5E-01	3.0E-04
33	0.0E+00	0.0E+00	0.0E+00	5.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-07	4.9E-07	2.7E-08	1.0E-03	0.0E+00
34	0.0E+00	0.0E+00	0.0E+00	4.6E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-07	4.0E-06	2.0E-07	8.5E-03	0.0E+00
35	0.0E+00	0.0E+00	0.0E+00	6.8E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-08	5.7E-07	2.7E-08	1.2E-03	0.0E+00
36	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E-08	0.0E+00	2.4E-05	0.0E+00
37	0.0E+00	0.0E+00	0.0E+00	6.4E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.5E-06	2.7E-07	1.2E-02	0.0E+00
38	0.0E+00	0.0E+00	0.0E+00	8.5E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.6E-08	6.8E-07	3.4E-08	1.5E-03	0.0E+00
39	5.2E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.8E-08	2.2E-07	2.1E-05	9.3E-07
40	5.2E-08	0.0E+00	0.0E+00	0.0E+00	1.5E-08	1.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.3E-07	1.8E-06	1.7E-04	7.5E-06
41	5.2E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.2E-08	2.6E-07	2.4E-05	1.1E-06
42	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.7E-07	2.3E-08
43	7.3E-08	0.0E+00	0.0E+00	0.0E+00	2.0E-08	1.6E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.4E-07	2.5E-06	2.4E-04	1.0E-05
44	1.0E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.2E-08	3.1E-07	2.9E-05	1.3E-06
45	5.2E-09	0.0E+00	0.0E+00	5.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-07	5.6E-07	2.5E-07	1.1E-03	9.3E-07
46	5.2E-08	0.0E+00	0.0E+00	4.6E-07	1.5E-08	1.1E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-07	4.5E-06	2.0E-06	8.6E-03	7.5E-06
47	5.2E-09	0.0E+00	0.0E+00	6.8E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-08	6.4E-07	2.9E-07	1.2E-03	1.1E-06
48	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E-08	0.0E+00	2.4E-05	2.3E-08
49	7.3E-08	0.0E+00	0.0E+00	6.4E-07	2.0E-08	1.6E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.3E-06	2.8E-06	1.2E-02	1.0E-05
50	1.0E-08	0.0E+00	0.0E+00	8.5E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.6E-08	7.8E-07	3.4E-07	1.5E-03	1.3E-06
51	5.4E-05	1.2E-03	1.1E-05	2.4E-04	2.3E-04	2.4E-05	7.6E-06	7.9E-06	5.7E-06	9.1E-06	1.6E-05	0.0E+00	4.3E-05	4.4E-05	1.9E-05	2.1E-05	6.7E-05
52	1.3E-08	7.7E-07	2.4E-11	4.6E-08	5.0E-09	1.1E-08	4.8E-10	4.9E-10	3.6E-10	5.7E-10	6.4E-09	0.0E+00	2.7E-08	2.2E-08	1.4E-08	1.5E-08	1.7E-08
53	4.7E-09	5.3E-08	1.8E-09	9.1E-09	3.7E-09	1.7E-09	8.1E-10	8.4E-10	6.0E-10	9.6E-10	1.3E-09	0.0E+00	1.9E-09	3.2E-09	7.3E-10	8.1E-10	2.4E-09
54	3.4E-03	1.7E-03	1.4E-03	6.7E-04	8.5E-04	1.1E-03	5.5E-04	6.7E-04	5.9E-04	5.4E-04	8.8E-04	5.3E-03	1.3E-03	1.4E-03	1.6E-03	2.0E-03	9.4E-04
55	1.1E-02	4.6E-03	3.4E-03	1.7E-03	2.4E-03	3.0E-03	1.3E-03	1.8E-03	1.5E-03	1.3E-03	2.2E-03	1.7E-02	3.9E-03	3.8E-03	3.6E-03	5.7E-03	2.5E-03
56	1.4E-02	6.3E-03	4.8E-03	2.4E-03	3.2E-03	4.1E-03	1.8E-03	2.4E-03	2.1E-03	1.9E-03	3.0E-03	2.2E-02	5.2E-03	5.1E-03	5.2E-03	7.7E-03	3.5E-03
57	1.7E-04	1.5E-05	1.8E-05	1.7E-05	2.7E-05	1.6E-05	1.4E-05	9.8E-06	1.1E-05	8.7E-06	1.5E-05	1.5E-05	1.0E-05	2.1E-05	4.5E-05	1.7E-05	1.5E-05
58	1.4E-05	3.6E-05	1.1E-04	2.7E-05	2.6E-04	2.7E-05	1.6E-05	1.2E-05	1.6E-05	1.2E-05	2.3E-05	3.8E-06	9.3E-06	1.8E-05	3.0E-05	1.6E-05	2.8E-05

	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY
59	1.2E-04	6.8E-05	9.9E-05	4.8E-05	6.8E-05	3.8E-05	8.8E-05	1.3E-04	1.1E-04	6.0E-05	2.0E-04	4.7E-05	1.0E-04	7.8E-05	1.3E-04	1.0E-04	8.1E-05
60	2.2E-04	1.1E-04	1.8E-04	8.0E-05	9.3E-05	4.4E-05	4.0E-05	3.8E-05	4.7E-05	6.4E-05	6.8E-05	7.9E-05	5.6E-05	6.2E-05	1.1E-04	9.5E-05	8.5E-05
61	4.7E-04	1.2E-03	3.6E-04	7.1E-04	2.7E-04	1.9E-04	1.2E-04	1.3E-04	1.4E-04	1.1E-04	2.4E-04	8.5E-05	2.5E-04	1.2E-04	2.7E-04	1.7E-04	1.8E-04
62	4.3E-04	3.0E-04	2.9E-04	1.8E-04	2.6E-04	1.4E-04	1.7E-04	1.8E-04	2.2E-04	1.4E-04	2.6E-04	1.4E-04	1.4E-04	1.7E-04	2.9E-04	2.7E-04	2.0E-04
63	5.7E-05	3.2E-05	2.5E-05	1.3E-04	2.9E-05	1.8E-05	1.5E-05	1.6E-05	1.9E-05	1.2E-05	2.4E-05	8.9E-06	1.3E-05	1.5E-05	2.5E-05	2.1E-05	2.0E-05
64	3.8E-05	2.2E-05	3.2E-05	1.6E-05	2.2E-05	1.2E-05	2.8E-05	4.2E-05	3.6E-05	1.9E-05	6.3E-05	1.5E-05	3.3E-05	2.5E-05	4.2E-05	3.3E-05	2.6E-05
65	3.1E-05	1.2E-04	3.0E-05	4.2E-05	2.3E-05	1.6E-05	1.1E-05	1.2E-05	1.3E-05	1.0E-05	2.3E-05	7.7E-06	2.5E-05	1.0E-05	2.4E-05	1.5E-05	1.5E-05
66	2.6E-04	1.5E-04	1.3E-04	8.7E-05	1.1E-04	5.4E-05	6.6E-05	7.1E-05	8.3E-05	6.0E-05	1.1E-04	5.7E-05	7.0E-05	7.8E-05	1.4E-04	1.2E-04	8.5E-05
67	3.6E-04	1.0E-03	2.8E-04	3.7E-04	2.5E-04	1.7E-04	1.2E-04	1.3E-04	1.3E-04	9.5E-05	2.2E-04	7.5E-05	2.1E-04	1.2E-04	2.5E-04	1.8E-04	1.6E-04
68	2.9E-05	1.9E-05	4.4E-05	1.6E-05	1.8E-05	1.0E-05	1.9E-05	2.6E-05	2.4E-05	1.8E-05	4.0E-05	2.3E-05	2.8E-05	1.8E-05	3.2E-05	3.1E-05	2.3E-05
69	2.0E-03	3.1E-03	1.6E-03	1.7E-03	1.4E-03	7.3E-04	6.9E-04	7.9E-04	8.5E-04	6.1E-04	1.3E-03	5.4E-04	9.4E-04	7.2E-04	1.3E-03	1.0E-03	9.0E-04
70	3.3E-05	4.3E-05	4.8E-05	2.6E-05	2.2E-05	2.2E-05	7.8E-06	8.3E-06	1.0E-05	1.7E-05	1.5E-05	1.8E-05	1.4E-05	2.7E-05	2.8E-05	2.6E-05	2.6E-05
71	8.5E-05	1.1E-04	1.3E-04	6.8E-05	5.8E-05	5.8E-05	2.0E-05	2.1E-05	2.6E-05	4.4E-05	3.8E-05	4.6E-05	3.7E-05	7.0E-05	7.2E-05	6.6E-05	6.7E-05
72	9.7E-06	1.3E-05	1.4E-05	7.8E-06	6.5E-06	6.6E-06	2.3E-06	2.4E-06	3.0E-06	5.0E-06	4.3E-06	5.2E-06	4.2E-06	7.9E-06	8.2E-06	7.5E-06	7.6E-06
73	6.7E-06	8.7E-06	9.8E-06	5.3E-06	4.5E-06	4.5E-06	1.6E-06	1.7E-06	2.0E-06	3.4E-06	3.0E-06	3.6E-06	2.9E-06	5.4E-06	5.6E-06	5.2E-06	5.2E-06
74	1.5E-02	1.3E-02	8.1E-03	4.9E-03	6.7E-03	9.1E-03	5.9E-03	4.5E-03	6.8E-03	5.0E-03	8.2E-03	2.7E-03	6.1E-03	1.1E-02	2.3E-02	1.5E-02	7.2E-03
75	7.6E-04	4.0E-04	2.4E-04	1.4E-04	2.0E-04	2.8E-04	9.9E-05	1.1E-04	1.5E-04	1.2E-04	1.6E-04	7.2E-04	2.4E-04	3.4E-04	3.9E-04	4.7E-04	2.0E-04
76	1.5E-02	1.4E-02	8.4E-03	5.0E-03	6.9E-03	9.4E-03	6.0E-03	4.6E-03	7.0E-03	5.1E-03	8.4E-03	3.4E-03	6.3E-03	1.2E-02	2.3E-02	1.5E-02	7.4E-03
77	6.0E-05	3.2E-05	1.5E-05	1.0E-05	1.7E-05	2.4E-05	8.9E-06	9.0E-06	1.6E-05	1.0E-05	1.6E-05	4.2E-06	1.4E-05	2.9E-05	3.9E-05	3.8E-05	1.6E-05
78	2.1E-04	2.4E-04	1.1E-04	6.6E-05	9.8E-05	1.8E-04	6.5E-05	6.7E-05	1.2E-04	7.9E-05	1.2E-04	3.1E-05	1.1E-04	2.2E-04	3.0E-04	3.0E-04	1.2E-04
79	2.6E-05	3.5E-05	1.6E-05	9.3E-06	1.4E-05	2.6E-05	9.3E-06	9.6E-06	1.7E-05	1.1E-05	1.8E-05	4.4E-06	1.6E-05	3.2E-05	4.3E-05	4.3E-05	1.7E-05
80	2.3E-05	1.3E-06	8.6E-07	1.3E-06	2.8E-06	8.2E-07	5.4E-07	4.9E-07	7.2E-07	4.6E-07	8.3E-07	2.8E-07	6.1E-07	1.7E-06	2.0E-06	1.3E-06	7.0E-07
81	2.9E-04	3.4E-04	1.6E-04	9.1E-05	1.4E-04	2.5E-04	9.1E-05	9.4E-05	1.7E-04	1.1E-04	1.7E-04	4.2E-05	1.5E-04	3.1E-04	4.2E-04	4.2E-04	1.7E-04
82	4.1E-05	4.2E-05	2.0E-05	1.2E-05	1.8E-05	3.2E-05	1.1E-05	1.2E-05	2.1E-05	1.4E-05	2.2E-05	5.4E-06	1.9E-05	3.8E-05	5.2E-05	5.2E-05	2.1E-05
83	1.7E-05	1.2E-06	8.5E-07	1.2E-06	2.4E-06	9.5E-07	5.6E-07	5.0E-07	7.1E-07	4.5E-07	8.2E-07	2.7E-07	5.7E-07	1.5E-06	1.9E-06	1.3E-06	7.5E-07
84	2.1E-05	5.6E-06	3.1E-06	2.6E-06	4.4E-06	4.5E-06	1.9E-06	1.8E-06	3.0E-06	2.0E-06	3.2E-06	7.4E-07	2.7E-06	5.5E-06	8.1E-06	6.7E-06	3.1E-06
85	8.8E-07	7.4E-07	3.7E-07	2.4E-07	3.7E-07	5.7E-07	2.2E-07	2.2E-07	3.7E-07	2.5E-07	3.9E-07	8.1E-08	3.3E-07	6.8E-07	9.5E-07	8.9E-07	3.8E-07
86	1.0E-05	2.7E-07	2.5E-07	5.3E-07	1.1E-06	1.5E-07	1.6E-07	1.4E-07	1.8E-07	1.1E-07	2.2E-07	8.6E-08	1.4E-07	4.8E-07	5.4E-07	2.4E-07	1.7E-07
87	2.4E-05	7.4E-06	3.8E-06	2.9E-06	5.1E-06	5.5E-06	2.3E-06	2.2E-06	3.8E-06	2.5E-06	4.0E-06	8.4E-07	3.4E-06	7.1E-06	9.9E-06	8.9E-06	3.8E-06
88	8.1E-06	1.2E-06	7.9E-07	8.5E-07	1.4E-06	1.2E-06	5.5E-07	4.9E-07	7.3E-07	4.6E-07	8.1E-07	2.2E-07	7.3E-07	1.3E-06	2.3E-06	1.4E-06	8.1E-07
89	7.7E-05	3.3E-05	1.6E-05	1.2E-05	1.9E-05	2.5E-05	9.4E-06	9.5E-06	1.6E-05	1.1E-05	1.7E-05	4.5E-06	1.5E-05	3.1E-05	4.1E-05	4.0E-05	1.6E-05
90	2.3E-04	2.5E-04	1.2E-04	6.9E-05	1.0E-04	1.9E-04	6.7E-05	6.9E-05	1.2E-04	8.1E-05	1.3E-04	3.1E-05	1.1E-04	2.3E-04	3.1E-04	3.1E-04	1.2E-04
91	2.7E-05	3.6E-05	1.6E-05	9.5E-06	1.4E-05	2.7E-05	9.5E-06	9.8E-06	1.8E-05	1.2E-05	1.8E-05	4.4E-06	1.6E-05	3.2E-05	4.4E-05	4.4E-05	1.7E-05
92	3.3E-05	1.5E-06	1.1E-06	1.9E-06	3.9E-06	9.6E-07	7.1E-07	6.3E-07	9.0E-07	5.7E-07	1.0E-06	3.6E-07	7.5E-07	2.1E-06	2.5E-06	1.6E-06	8.8E-07
93	3.1E-04	3.5E-04	1.6E-04	9.4E-05	1.4E-04	2.6E-04	9.3E-05	9.6E-05	1.7E-04	1.1E-04	1.8E-04	4.3E-05	1.6E-04	3.2E-04	4.3E-04	4.3E-04	1.7E-04
94	4.9E-05	4.3E-05	2.0E-05	1.3E-05	1.9E-05	3.3E-05	1.2E-05	1.2E-05	2.2E-05	1.4E-05	2.3E-05	5.6E-06	2.0E-05	4.0E-05	5.5E-05	5.3E-05	2.2E-05
95	1.3E-04	2.1E-04	1.1E-04	1.1E-04	9.1E-05	4.7E-05	4.6E-05	5.5E-05	5.7E-05	4.1E-05	8.8E-05	3.6E-05	6.6E-05	4.8E-05	9.0E-05	6.9E-05	6.0E-05
96	3.8E-08	1.1E-07	3.1E-08	4.4E-08	2.7E-08	1.8E-08	1.3E-08	1.5E-08	1.6E-08	1.1E-08	2.6E-08	8.8E-09	2.4E-08	1.3E-08	2.9E-08	1.9E-08	1.8E-08
97	6.4E-09	9.7E-09	4.9E-09	5.1E-09	4.1E-09	2.3E-09	2.3E-09	2.6E-09	2.8E-09	2.0E-09	4.1E-09	1.8E-09	3.0E-09	2.3E-09	4.3E-09	3.5E-09	2.9E-09
98	4.2E-03	1.7E-03	1.4E-03	7.2E-04	8.5E-04	1.1E-03	5.5E-04	6.7E-04	5.9E-04	5.4E-04	8.8E-04	5.3E-03	1.5E-03	1.4E-03	4.6E-03	2.7E-03	1.0E-03
99	1.1E-02	4.6E-03	3.4E-03	1.7E-03	2.4E-03	3.0E-03	1.3E-03	1.8E-03	1.5E-03	1.3E-03	2.2E-03	1.7E-02	4.0E-03	3.9E-03	8.0E-03	5.9E-03	2.6E-03
100	1.5E-02	6.3E-03	4.8E-03	2.5E-03	3.2E-03	4.1E-03	1.8E-03	2.4E-03	2.1E-03	1.9E-03	3.0E-03	2.2E-02	5.5E-03	5.3E-03	1.3E-02	8.6E-03	3.6E-03
101	1.7E-04	2.0E-05	1.9E-05	1.7E-05	2.9E-05	1.7E-05	1.4E-05	9.8E-06	1.1E-05	8.8E-06	1.5E-05	1.5E-05	1.2E-05	2.1E-05	1.5E-04	2.1E-05	3.4E-05
102	1.4E-05	3.6E-05	1.1E-04	2.7E-05	3.6E-03	2.7E-05	1.6E-05	1.2E-05	1.6E-05	1.2E-05	2.3E-05	3.8E-06	9.3E-06	1.8E-05	3.0E-05	1.6E-05	3.4E-04
103	1.2E-04	6.8E-05	9.9E-05	4.8E-05	6.8E-05	3.8E-05	8.8E-05	1.3E-04	1.1E-04	6.0E-05	2.0E-04	4.7E-05	1.0E-04	7.8E-05	1.3E-04	1.0E-04	8.1E-05
104	2.2E-04	1.4E-04	1.8E-04	8.0E-05	9.3E-05	4.4E-05	4.3E-05	4.1E-05	4.9E-05	6.7E-05	7.1E-05	7.9E-05	3.4E-04	2.5E-04	2.3E-04	2.3E-04	1.5E-04
105	4.9E-04	1.0E-02	3.6E-04	3.1E-03	2.7E-04	2.8E-04	1.2E-04	1.3E-04	1.4E-04	1.1E-04	2.7E-04	8.5E-05	2.5E-04	1.2E-04	2.7E-04	1.7E-04	4.0E-04
106	1.1E-03	4.4E-04	6.3E-04	1.8E-04	2.6E-04	3.2E-04	3.0E-04	3.2E-04	3.2E-04	3.0E-04	4.2E-04	1.4E-04	3.8E-04	6.6E-04	3.5E-04	3.3E-04	3.2E-04
107	9.8E-05	3.2E-05	2.5E-05	1.2E-03	2.9E-05	1.8E-05	2.5E-05	2.7E-05	2.7E-05	2.4E-05	3.3E-05	8.9E-06	2.3E-05	2.0E-05	2.5E-05	2.1E-05	1.7E-04
108	6.8E-05	2.2E-05	3.2E-05	1.6E-05	2.2E-05	1.2E-05	2.8E-05	4.2E-05	3.6E-05	1.9E-05	6.3E-05	1.5E-05	3.3E-05	2.5E-05	4.2E-05	3.3E-05	2.6E-05
109	5.2E-05	1.1E-03	3.0E-05	4.2E-05	2.3E-05	1.8E-05	1.1E-05	1.2E-05	1.3E-05	1.0E-05	2.3E-05	7.7E-06	2.5E-05	1.0E-05	2.4E-05	1.5E-05	1.5E-05
110	5.0E-04	4.6E-04	1.3E-04	8.7E-05	1.1E-04	6.5E-05	1.1E-04	1.1E-04	1.1E-04	1.1E-04	1.4E-04	5.7E-05	2.2E-04	1.9E-04	2.0E-04	1.9E-04	1.5E-04
111	5.4E-04	8.4E-03	2.8E-04	3.7E-04	2.5E-04	3.4E-04	1.2E-04	1.3E-04	1.3E-04	9.5E-05	3.1E-04	7.5E-05	2.1E-04	1.8E-04	2.9E-04	2.2E-04	2.5E-04
112	2.9E-05	1.9E-05	4.4E-05	1.6E-05	1.8E-05	1.0E-05	1.9E-05	2.6E-05	2.4E-05	1.8E-05	4.0E-05	2.3E-05	2.8E-05	1.8E-05	3.2E-05	3.1E-05	2.3E-05
113	3.2E-03	2.1E-02	1.9E-03	5.1E-03	4.7E-03	1.2E-03	8.8E-04	9.9E-04	9.9E-04	8.3E-04	1.6E-03	5.4E-04	1.6E-03	1.6E-03	1.6E-03	1.4E-03	1.9E-03

	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY
114	3.3E-05	4.3E-05	4.8E-05	2.6E-05	2.2E-05	2.2E-05	7.8E-06	8.3E-06	1.0E-05	1.7E-05	1.5E-05	1.8E-05	1.4E-05	2.7E-05	2.8E-05	2.6E-05	2.6E-05
115	8.5E-05	1.1E-04	1.3E-04	6.8E-05	5.8E-05	5.8E-05	2.0E-05	2.1E-05	2.6E-05	4.4E-05	3.8E-05	4.6E-05	3.7E-05	7.0E-05	7.2E-05	6.6E-05	6.7E-05
116	9.7E-06	1.3E-05	1.4E-05	7.8E-06	6.5E-06	6.6E-06	2.3E-06	2.4E-06	3.0E-06	5.0E-06	4.3E-06	5.2E-06	4.2E-06	7.9E-06	8.2E-06	7.5E-06	7.6E-06
117	6.7E-06	8.7E-06	9.8E-06	5.3E-06	4.5E-06	4.5E-06	1.6E-06	1.7E-06	2.0E-06	3.4E-06	3.0E-06	3.6E-06	2.9E-06	5.4E-06	5.6E-06	5.2E-06	5.2E-06
118	1.5E-02	1.3E-02	8.1E-03	4.9E-03	6.7E-03	9.1E-03	5.9E-03	4.5E-03	6.8E-03	5.0E-03	8.2E-03	2.7E-03	6.1E-03	1.1E-02	8.2E-02	3.5E-01	7.2E-03
119	7.6E-04	4.0E-04	2.4E-04	1.4E-04	2.0E-04	2.8E-04	9.9E-05	1.1E-04	1.5E-04	1.2E-04	1.6E-04	7.2E-04	2.5E-04	3.6E-04	6.3E-04	7.2E-03	5.0E-04
120	1.5E-02	1.4E-02	8.4E-03	5.0E-03	6.9E-03	9.4E-03	6.0E-03	4.6E-03	7.0E-03	5.1E-03	8.4E-03	3.4E-03	6.4E-03	1.2E-02	8.3E-02	3.6E-01	7.7E-03
121	6.0E-05	3.2E-05	1.5E-05	1.0E-05	1.7E-05	2.4E-05	8.9E-06	9.0E-06	1.6E-05	1.0E-05	1.6E-05	4.2E-06	1.4E-05	3.0E-05	3.9E-05	1.1E-03	1.6E-05
122	2.1E-04	2.4E-04	1.1E-04	6.6E-05	9.8E-05	1.8E-04	6.5E-05	6.7E-05	1.2E-04	7.9E-05	1.2E-04	3.1E-05	1.1E-04	2.3E-04	3.0E-04	8.8E-03	1.2E-04
123	2.6E-05	3.5E-05	1.6E-05	9.3E-06	1.4E-05	2.6E-05	9.3E-06	9.6E-06	1.7E-05	1.1E-05	1.8E-05	4.4E-06	1.6E-05	3.2E-05	4.3E-05	1.3E-03	1.7E-05
124	2.3E-05	1.3E-06	8.6E-07	1.3E-06	2.8E-06	8.2E-07	5.4E-07	4.9E-07	7.2E-07	4.6E-07	8.3E-07	2.8E-07	6.1E-07	1.7E-06	2.0E-06	2.5E-05	7.0E-07
125	2.9E-04	3.4E-04	1.6E-04	9.2E-05	1.4E-04	2.5E-04	9.1E-05	9.4E-05	1.7E-04	1.1E-04	1.7E-04	4.2E-05	1.5E-04	3.1E-04	4.2E-04	1.2E-02	1.7E-04
126	4.1E-05	4.2E-05	2.0E-05	1.2E-05	1.8E-05	3.2E-05	1.1E-05	1.2E-05	2.1E-05	1.4E-05	2.2E-05	5.4E-06	1.9E-05	3.9E-05	5.2E-05	1.5E-03	2.1E-05
127	1.7E-05	1.2E-06	8.5E-07	1.2E-06	2.4E-06	9.5E-07	5.6E-07	5.0E-07	7.1E-07	4.5E-07	8.2E-07	2.7E-07	5.7E-07	1.6E-06	2.2E-06	2.2E-05	1.7E-06
128	2.1E-05	5.6E-06	3.1E-06	2.6E-06	4.4E-06	4.5E-06	1.9E-06	1.8E-06	3.0E-06	2.0E-06	3.2E-06	7.4E-07	2.7E-06	6.1E-06	9.9E-06	1.8E-04	1.1E-05
129	8.9E-07	7.4E-07	3.7E-07	2.4E-07	3.7E-07	5.7E-07	2.2E-07	2.2E-07	3.7E-07	2.5E-07	3.9E-07	8.1E-08	3.3E-07	7.5E-07	1.2E-06	2.5E-05	1.5E-06
130	1.0E-05	2.7E-07	2.5E-07	5.3E-07	1.1E-06	1.5E-07	1.6E-07	1.4E-07	1.8E-07	1.1E-07	2.2E-07	8.6E-08	1.4E-07	4.8E-07	5.4E-07	7.1E-07	2.0E-07
131	2.4E-05	7.4E-06	3.8E-06	2.9E-06	5.1E-06	5.5E-06	2.3E-06	2.2E-06	3.8E-06	2.5E-06	4.0E-06	8.4E-07	3.4E-06	7.9E-06	1.2E-05	2.5E-04	1.4E-05
132	8.1E-06	1.2E-06	7.9E-07	8.5E-07	1.4E-06	1.2E-06	5.5E-07	4.9E-07	7.3E-07	4.6E-07	8.1E-07	2.2E-07	7.3E-07	1.4E-06	2.6E-06	3.1E-05	2.1E-06
133	7.7E-05	3.3E-05	1.6E-05	1.2E-05	1.9E-05	2.5E-05	9.4E-06	9.5E-06	1.6E-05	1.1E-05	1.7E-05	4.5E-06	1.5E-05	3.1E-05	4.2E-05	1.1E-03	1.7E-05
134	2.3E-04	2.5E-04	1.2E-04	6.9E-05	1.0E-04	1.9E-04	6.7E-05	6.9E-05	1.2E-04	8.1E-05	1.3E-04	3.1E-05	1.1E-04	2.3E-04	3.1E-04	8.9E-03	1.3E-04
135	2.7E-05	3.6E-05	1.6E-05	9.6E-06	1.4E-05	2.7E-05	9.5E-06	9.8E-06	1.8E-05	1.2E-05	1.8E-05	4.4E-06	1.6E-05	3.3E-05	4.4E-05	1.3E-03	1.8E-05
136	3.3E-05	1.5E-06	1.1E-06	1.9E-06	3.9E-06	9.6E-07	7.1E-07	6.3E-07	9.0E-07	5.7E-07	1.0E-06	3.6E-07	7.5E-07	2.2E-06	2.5E-06	2.6E-05	9.0E-07
137	3.1E-04	3.5E-04	1.6E-04	9.5E-05	1.4E-04	2.6E-04	9.3E-05	9.6E-05	1.7E-04	1.1E-04	1.8E-04	4.3E-05	1.6E-04	3.2E-04	4.3E-04	1.3E-02	1.8E-04
138	4.9E-05	4.3E-05	2.0E-05	1.3E-05	1.9E-05	3.3E-05	1.2E-05	1.2E-05	2.2E-05	1.4E-05	2.3E-05	5.6E-06	2.0E-05	4.1E-05	5.5E-05	1.5E-03	2.3E-05
139	1.8E-04	1.4E-03	1.2E-04	3.6E-04	3.2E-04	7.1E-05	5.4E-05	6.3E-05	6.2E-05	5.0E-05	1.0E-04	3.6E-05	1.1E-04	9.2E-05	1.1E-04	9.0E-05	1.3E-04
140	5.2E-08	8.8E-07	3.1E-08	8.9E-08	3.2E-08	2.9E-08	1.4E-08	1.5E-08	1.6E-08	1.2E-08	3.2E-08	8.8E-09	5.1E-08	3.6E-08	4.3E-08	3.5E-08	3.5E-08
141	1.1E-08	6.3E-08	6.6E-09	1.4E-08	7.7E-09	4.1E-09	3.1E-09	3.5E-09	3.4E-09	3.0E-09	5.4E-09	1.8E-09	4.9E-09	5.6E-09	5.1E-09	4.3E-09	5.3E-09
142	8.0E-04	0.0E+00	0.0E+00	4.0E-05	1.8E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E-04	6.3E-05	1.9E-03	1.3E-03	6.0E-05
143	2.6E-04	0.0E+00	0.0E+00	7.8E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.8E-05	8.8E-05	3.2E-03	1.8E-04	8.1E-05
144	1.1E-03	0.0E+00	0.0E+00	4.8E-05	1.8E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.7E-04	1.5E-04	5.0E-03	1.5E-03	1.4E-04
145	1.8E-06	5.4E-06	4.9E-07	7.8E-07	2.1E-06	4.4E-07	2.7E-08	4.1E-08	2.3E-08	4.9E-08	1.1E-07	0.0E+00	2.4E-06	7.0E-07	1.0E-04	4.0E-06	1.9E-05
146	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.4E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E-04
147	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
148	7.1E-06	3.5E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.6E-06	2.7E-06	1.9E-06	3.5E-06	3.1E-06	0.0E+00	3.1E-04	2.3E-04	1.3E-04	1.4E-04	6.0E-05
149	2.7E-05	9.7E-03	0.0E+00	2.8E-03	0.0E+00	1.3E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-04
150	7.2E-04	1.5E-04	4.0E-04	0.0E+00	0.0E+00	2.7E-04	1.7E-04	1.2E-04	8.6E-05	1.6E-04	1.9E-04	0.0E+00	2.5E-04	6.0E-04	6.8E-05	7.3E-05	1.2E-04
151	4.4E-05	0.0E+00	0.0E+00	1.2E-03	0.0E+00	0.0E+00	1.3E-05	9.6E-06	6.6E-06	1.3E-05	1.1E-05	0.0E+00	1.1E-05	6.1E-06	0.0E+00	0.0E+00	1.5E-04
152	3.2E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
153	2.3E-05	1.0E-03	0.0E+00	0.0E+00	0.0E+00	2.0E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.5E-09
154	2.6E-04	3.3E-04	0.0E+00	0.0E+00	0.0E+00	1.6E-05	4.9E-05	3.7E-05	2.5E-05	4.8E-05	4.2E-05	0.0E+00	1.6E-04	1.4E-04	7.5E-05	8.0E-05	6.0E-05
155	1.9E-04	7.8E-03	0.0E+00	0.0E+00	0.0E+00	2.5E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-04	0.0E+00	0.0E+00	7.6E-05	4.5E-05	4.8E-05	9.1E-05
156	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
157	1.3E-03	1.9E-02	4.0E-04	3.9E-03	3.4E-03	6.6E-04	2.3E-04	1.7E-04	1.2E-04	2.3E-04	3.8E-04	0.0E+00	7.3E-04	1.1E-03	3.2E-04	3.4E-04	9.9E-04
158	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
159	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
160	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
161	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY
162	0.0E+00	1.1E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E-05	1.5E-04	1.5E-03	3.1E-01	0.0E+00
163	0.0E+00	0.0E+00	0.0E+00	2.6E-05	4.0E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.3E-05	2.6E-05	1.8E-04	1.5E-02	2.8E-04
164	0.0E+00	1.1E-06	0.0E+00	2.6E-05	4.0E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.4E-05	1.7E-04	1.7E-03	3.2E-01	2.8E-04
165	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.1E-08	4.4E-07	0.0E+00	9.5E-04	0.0E+00
166	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.7E-08	3.6E-06	2.1E-08	7.6E-03	0.0E+00
167	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-08	5.2E-07	5.3E-09	1.1E-03	0.0E+00
168	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-08	0.0E+00	2.1E-05	0.0E+00
169	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.0E-06	3.2E-08	1.1E-02	0.0E+00
170	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.6E-08	6.2E-07	5.3E-09	1.3E-03	0.0E+00
171	1.0E-08	0.0E+00	0.0E+00	3.6E-08	1.2E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.3E-08	3.2E-07	3.8E-05	8.5E-07
172	6.6E-08	0.0E+00	0.0E+00	3.2E-07	1.0E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.6E-07	2.6E-06	3.1E-04	6.9E-06
173	1.0E-08	0.0E+00	0.0E+00	5.3E-08	1.4E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.7E-08	3.7E-07	4.4E-05	9.9E-07
174	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.0E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.3E-09	8.6E-07	1.7E-08
175	9.7E-08	0.0E+00	0.0E+00	4.6E-07	1.4E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.3E-07	3.6E-06	4.3E-04	9.7E-06
176	1.5E-08	0.0E+00	0.0E+00	5.3E-08	1.7E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E-07	4.5E-07	5.3E-05	1.2E-06
177	1.0E-08	0.0E+00	0.0E+00	3.6E-08	1.2E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.1E-08	5.3E-07	3.2E-07	9.8E-04	8.5E-07
178	6.6E-08	0.0E+00	0.0E+00	3.2E-07	1.0E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.7E-08	4.3E-06	2.6E-06	7.9E-03	6.9E-06
179	1.0E-08	0.0E+00	0.0E+00	5.3E-08	1.4E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-08	6.1E-07	3.8E-07	1.1E-03	9.9E-07
180	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.0E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-08	5.3E-09	2.2E-05	1.7E-08
181	9.7E-08	0.0E+00	0.0E+00	4.6E-07	1.4E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.9E-06	3.7E-06	1.1E-02	9.7E-06
182	1.5E-08	0.0E+00	0.0E+00	5.3E-08	1.7E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.6E-08	7.3E-07	4.5E-07	1.4E-03	1.2E-06
183	5.8E-05	1.3E-03	1.3E-05	2.8E-04	2.4E-04	3.5E-05	9.4E-06	7.0E-06	4.8E-06	9.1E-06	1.9E-05	0.0E+00	4.6E-05	5.4E-05	2.1E-05	2.3E-05	6.5E-05
184	1.4E-08	8.3E-07	2.8E-11	5.3E-08	5.2E-09	1.6E-08	5.9E-10	4.4E-10	3.0E-10	5.7E-10	7.3E-09	0.0E+00	2.9E-08	2.7E-08	1.5E-08	1.6E-08	1.6E-08
185	5.1E-09	5.7E-08	2.0E-09	1.0E-08	3.8E-09	2.6E-09	9.9E-10	7.4E-10	5.1E-10	9.7E-10	1.5E-09	0.0E+00	2.1E-09	3.9E-09	8.2E-10	8.8E-10	2.3E-09
186	3.8E-03	1.8E-03	1.4E-03	7.1E-04	9.5E-04	8.6E-04	5.5E-04	9.6E-04	8.3E-04	7.2E-04	1.0E-03	3.7E-03	1.2E-03	9.2E-04	1.6E-03	2.2E-03	1.1E-03
187	1.3E-02	6.0E-03	3.7E-03	1.8E-03	2.6E-03	2.8E-03	1.0E-03	1.9E-03	1.5E-03	1.7E-03	1.6E-03	1.5E-02	3.9E-03	2.9E-03	3.5E-03	7.3E-03	2.9E-03
188	1.7E-02	7.9E-03	5.1E-03	2.5E-03	3.6E-03	3.7E-03	1.6E-03	2.9E-03	2.4E-03	2.4E-03	2.6E-03	1.9E-02	5.2E-03	3.8E-03	5.0E-03	9.6E-03	4.0E-03
189	2.2E-04	2.0E-05	2.2E-05	2.2E-05	3.6E-05	1.5E-05	1.5E-05	1.4E-05	1.7E-05	1.3E-05	1.8E-05	1.4E-05	1.2E-05	1.5E-05	4.7E-05	2.3E-05	1.8E-05
190	1.6E-05	4.2E-05	1.1E-04	2.6E-05	2.7E-04	2.0E-05	1.6E-05	1.4E-05	2.1E-05	1.5E-05	2.4E-05	3.1E-06	8.9E-06	1.2E-05	3.1E-05	1.9E-05	2.9E-05
191	1.2E-04	7.7E-05	9.8E-05	4.7E-05	6.8E-05	3.0E-05	8.1E-05	1.6E-04	1.4E-04	7.3E-05	1.9E-04	3.3E-05	9.0E-05	5.0E-05	1.3E-04	1.2E-04	8.7E-05
192	3.1E-04	1.1E-04	1.8E-04	8.6E-05	1.2E-04	3.6E-05	4.1E-05	4.8E-05	6.2E-05	8.0E-05	7.1E-05	5.3E-05	5.2E-05	5.3E-05	1.3E-04	1.0E-04	1.0E-04
193	5.6E-04	1.5E-03	4.3E-04	8.7E-04	3.2E-04	1.8E-04	1.4E-04	2.0E-04	2.2E-04	1.7E-04	2.8E-04	7.3E-05	2.8E-04	9.6E-05	3.3E-04	2.3E-04	2.4E-04
194	5.0E-04	3.4E-04	3.2E-04	1.8E-04	3.0E-04	1.3E-04	1.9E-04	2.5E-04	2.9E-04	1.9E-04	2.7E-04	1.1E-04	1.4E-04	1.4E-04	3.1E-04	3.1E-04	2.5E-04
195	5.7E-05	3.9E-05	2.4E-05	1.9E-04	2.9E-05	1.6E-05	1.6E-05	2.1E-05	2.4E-05	1.6E-05	2.5E-05	6.6E-06	1.1E-05	9.9E-06	2.4E-05	2.4E-05	2.3E-05
196	4.0E-05	2.5E-05	3.2E-05	1.5E-05	2.2E-05	9.7E-06	2.6E-05	5.2E-05	4.4E-05	2.4E-05	6.1E-05	1.0E-05	2.9E-05	1.6E-05	4.3E-05	3.9E-05	2.8E-05
197	3.6E-05	1.5E-04	3.4E-05	4.3E-05	2.7E-05	1.5E-05	1.2E-05	1.8E-05	1.9E-05	1.5E-05	2.6E-05	6.3E-06	2.7E-05	7.8E-06	2.8E-05	1.9E-05	1.9E-05
198	3.2E-04	1.7E-04	1.4E-04	9.3E-05	1.3E-04	4.6E-05	7.0E-05	9.2E-05	1.1E-04	7.9E-05	1.1E-04	4.1E-05	6.6E-05	5.8E-05	1.5E-04	1.3E-04	1.0E-04
199	4.5E-04	1.3E-03	3.3E-04	3.9E-04	2.9E-04	1.6E-04	1.4E-04	1.9E-04	2.1E-04	1.5E-04	2.6E-04	6.5E-05	2.3E-04	9.4E-05	3.1E-04	2.4E-04	2.1E-04
200	3.2E-05	2.2E-05	4.8E-05	1.7E-05	1.9E-05	8.3E-06	1.8E-05	3.2E-05	3.0E-05	2.3E-05	4.0E-05	1.7E-05	2.5E-05	1.2E-05	3.4E-05	3.6E-05	2.6E-05
201	2.4E-03	3.7E-03	1.7E-03	2.0E-03	1.6E-03	6.5E-04	7.5E-04	1.1E-03	1.2E-03	8.3E-04	1.4E-03	4.1E-04	9.6E-04	5.5E-04	1.5E-03	1.3E-03	1.1E-03
202	3.2E-05	3.7E-05	4.5E-05	2.2E-05	2.0E-05	1.5E-05	6.8E-06	9.0E-06	1.1E-05	1.9E-05	1.3E-05	1.1E-05	1.1E-05	1.6E-05	2.4E-05	2.4E-05	2.5E-05
203	9.1E-05	1.0E-04	1.3E-04	6.2E-05	5.5E-05	4.3E-05	1.9E-05	2.5E-05	3.2E-05	5.4E-05	3.7E-05	3.2E-05	3.2E-05	4.4E-05	6.9E-05	6.7E-05	7.1E-05
204	1.1E-05	1.3E-05	1.5E-05	7.6E-06	6.7E-06	5.2E-06	2.3E-06	3.1E-06	3.8E-06	6.5E-06	4.5E-06	3.9E-06	3.9E-06	5.4E-06	8.4E-06	8.2E-06	8.7E-06
205	7.4E-06	8.5E-06	1.0E-05	5.1E-06	4.5E-06	3.5E-06	1.5E-06	2.1E-06	2.6E-06	4.4E-06	3.0E-06	2.6E-06	2.6E-06	3.6E-06	5.6E-06	5.5E-06	5.8E-06
206	1.5E-02	1.6E-02	8.1E-03	5.4E-03	7.0E-03	6.6E-03	3.6E-03	5.1E-03	7.6E-03	5.8E-03	7.5E-03	2.2E-03	5.9E-03	7.0E-03	1.5E-02	1.6E-02	8.0E-03
207	1.6E-03	8.3E-04	6.0E-04	3.9E-04	5.2E-04	4.0E-04	2.5E-04	3.4E-04	4.7E-04	3.8E-04	4.8E-04	2.0E-04	3.7E-04	4.4E-04	9.2E-04	9.1E-04	5.2E-04
208	1.6E-02	1.6E-02	8.7E-03	5.8E-03	7.5E-03	7.1E-03	3.9E-03	5.4E-03	8.0E-03	6.1E-03	8.0E-03	2.4E-03	6.3E-03	7.4E-03	1.6E-02	1.7E-02	8.5E-03
209	8.0E-05	3.2E-05	1.4E-05	1.2E-05	1.9E-05	1.7E-05	8.5E-06	1.1E-05	1.8E-05	1.3E-05	1.6E-05	3.5E-06	1.3E-05	1.9E-05	3.9E-05	4.1E-05	1.8E-05

	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY
210	2.3E-04	2.4E-04	9.7E-05	6.4E-05	9.8E-05	1.3E-04	5.9E-05	7.5E-05	1.4E-04	9.3E-05	1.2E-04	2.4E-05	1.0E-04	1.3E-04	2.8E-04	3.2E-04	1.3E-04
211	2.8E-05	3.4E-05	1.4E-05	9.0E-06	1.3E-05	1.8E-05	8.3E-06	1.1E-05	1.9E-05	1.3E-05	1.7E-05	3.4E-06	1.4E-05	1.9E-05	4.0E-05	4.5E-05	1.8E-05
212	2.9E-05	1.5E-06	9.7E-07	1.7E-06	3.5E-06	6.5E-07	5.9E-07	6.4E-07	9.6E-07	6.4E-07	9.3E-07	2.6E-07	6.4E-07	1.2E-06	2.1E-06	1.7E-06	8.8E-07
213	3.1E-04	3.3E-04	1.3E-04	8.7E-05	1.3E-04	1.8E-04	8.1E-05	1.0E-04	1.9E-04	1.3E-04	1.6E-04	3.3E-05	1.4E-04	1.8E-04	3.9E-04	4.4E-04	1.8E-04
214	4.7E-05	4.2E-05	1.7E-05	1.2E-05	1.8E-05	2.2E-05	1.0E-05	1.3E-05	2.4E-05	1.6E-05	2.1E-05	4.2E-06	1.8E-05	2.3E-05	5.0E-05	5.5E-05	2.3E-05
215	1.8E-05	2.2E-06	1.2E-06	1.8E-06	3.1E-06	1.2E-06	7.8E-07	8.6E-07	1.3E-06	8.8E-07	1.2E-06	3.1E-07	8.5E-07	1.4E-06	2.8E-06	2.4E-06	1.3E-06
216	4.0E-05	1.2E-05	5.6E-06	5.4E-06	8.6E-06	6.8E-06	3.7E-06	4.3E-06	7.1E-06	4.7E-06	6.4E-06	1.2E-06	5.5E-06	6.8E-06	1.7E-05	1.5E-05	7.0E-06
217	2.0E-06	1.5E-06	6.2E-07	4.8E-07	7.4E-07	7.8E-07	3.9E-07	4.7E-07	8.3E-07	5.7E-07	7.4E-07	1.2E-07	6.0E-07	8.2E-07	1.8E-06	1.9E-06	8.1E-07
218	7.4E-06	2.4E-07	1.9E-07	3.9E-07	8.4E-07	9.2E-08	1.2E-07	1.2E-07	1.7E-07	1.1E-07	1.7E-07	5.1E-08	1.0E-07	2.3E-07	3.8E-07	2.4E-07	1.5E-07
219	2.9E-05	1.4E-05	6.1E-06	4.7E-06	7.5E-06	7.5E-06	3.8E-06	4.6E-06	8.1E-06	5.5E-06	7.2E-06	1.1E-06	6.1E-06	8.0E-06	1.8E-05	1.8E-05	7.8E-06
220	2.6E-05	3.1E-06	2.0E-06	2.5E-06	4.0E-06	2.4E-06	1.5E-06	1.6E-06	2.3E-06	1.5E-06	2.2E-06	4.8E-07	2.1E-06	2.1E-06	6.5E-06	3.9E-06	2.4E-06
221	9.8E-05	3.4E-05	1.5E-05	1.4E-05	2.2E-05	1.8E-05	9.3E-06	1.1E-05	2.0E-05	1.3E-05	1.8E-05	3.8E-06	1.4E-05	2.0E-05	4.1E-05	4.4E-05	1.9E-05
222	2.7E-04	2.5E-04	1.0E-04	7.0E-05	1.1E-04	1.3E-04	6.2E-05	7.9E-05	1.4E-04	9.7E-05	1.3E-04	2.5E-05	1.1E-04	1.4E-04	3.0E-04	3.3E-04	1.4E-04
223	3.0E-05	3.6E-05	1.5E-05	9.5E-06	1.4E-05	1.9E-05	8.7E-06	1.1E-05	2.0E-05	1.4E-05	1.8E-05	3.5E-06	1.5E-05	2.0E-05	4.2E-05	4.7E-05	1.9E-05
224	3.6E-05	1.7E-06	1.2E-06	2.1E-06	4.3E-06	7.5E-07	7.0E-07	7.6E-07	1.1E-06	7.5E-07	1.1E-06	3.1E-07	7.4E-07	1.5E-06	2.5E-06	1.9E-06	1.0E-06
225	3.4E-04	3.5E-04	1.4E-04	9.2E-05	1.4E-04	1.8E-04	8.5E-05	1.1E-04	2.0E-04	1.3E-04	1.7E-04	3.4E-05	1.5E-04	1.9E-04	4.1E-04	4.6E-04	1.9E-04
226	7.2E-05	4.5E-05	1.9E-05	1.4E-05	2.2E-05	2.5E-05	1.2E-05	1.5E-05	2.6E-05	1.8E-05	2.3E-05	4.7E-06	2.0E-05	2.5E-05	5.6E-05	5.9E-05	2.5E-05
227	1.6E-04	2.5E-04	1.2E-04	1.3E-04	1.0E-04	4.2E-05	4.9E-05	7.4E-05	7.7E-05	5.6E-05	9.5E-05	2.8E-05	6.6E-05	3.6E-05	1.0E-04	8.4E-05	7.4E-05
228	4.7E-08	1.3E-07	3.6E-08	4.8E-08	3.2E-08	1.7E-08	1.5E-08	2.2E-08	2.3E-08	1.6E-08	3.0E-08	7.3E-09	2.6E-08	1.1E-08	3.5E-08	2.6E-08	2.4E-08
229	7.8E-09	1.2E-08	5.4E-09	5.9E-09	4.7E-09	2.1E-09	2.5E-09	3.6E-09	3.9E-09	2.7E-09	4.5E-09	1.4E-09	3.0E-09	1.8E-09	4.9E-09	4.2E-09	3.6E-09
230	4.6E-03	1.8E-03	1.4E-03	7.4E-04	9.6E-04	8.6E-04	5.5E-04	9.6E-04	8.3E-04	7.2E-04	1.0E-03	3.7E-03	1.4E-03	9.9E-04	3.4E-03	3.5E-03	1.1E-03
231	1.3E-02	6.0E-03	3.7E-03	1.8E-03	2.6E-03	2.8E-03	1.0E-03	1.9E-03	1.5E-03	1.7E-03	1.6E-03	1.5E-02	4.0E-03	3.0E-03	6.6E-03	7.5E-03	3.0E-03
232	1.8E-02	7.9E-03	5.1E-03	2.6E-03	3.6E-03	3.7E-03	1.6E-03	2.9E-03	2.4E-03	2.4E-03	2.6E-03	1.9E-02	5.4E-03	3.9E-03	1.0E-02	1.1E-02	4.2E-03
233	2.2E-04	2.5E-05	2.3E-05	2.3E-05	3.8E-05	1.5E-05	1.5E-05	1.4E-05	1.7E-05	1.3E-05	1.8E-05	1.4E-05	1.4E-05	1.6E-05	1.5E-04	2.7E-05	3.8E-05
234	1.6E-05	4.2E-05	1.1E-04	2.6E-05	3.7E-03	2.0E-05	1.6E-05	1.4E-05	2.1E-05	1.5E-05	2.4E-05	3.1E-06	8.9E-06	1.2E-05	3.1E-05	1.9E-05	3.3E-04
235	1.2E-04	7.7E-05	9.8E-05	4.7E-05	6.8E-05	3.0E-05	8.1E-05	1.6E-04	1.4E-04	7.3E-05	1.9E-04	3.3E-05	9.0E-05	5.0E-05	1.3E-04	1.2E-04	8.7E-05
236	3.2E-04	1.5E-04	1.8E-04	8.6E-05	1.2E-04	3.6E-05	4.5E-05	5.1E-05	6.4E-05	8.3E-05	7.4E-05	5.3E-05	3.6E-04	2.8E-04	2.6E-04	2.5E-04	1.6E-04
237	5.9E-04	1.1E-02	4.3E-04	3.6E-03	3.2E-04	3.1E-04	1.4E-04	2.0E-04	2.2E-04	1.7E-04	3.1E-04	7.3E-05	2.8E-04	9.6E-05	3.3E-04	2.3E-04	4.5E-04
238	1.2E-03	4.9E-04	7.2E-04	1.8E-04	3.0E-04	4.0E-04	3.5E-04	3.7E-04	3.8E-04	3.5E-04	4.6E-04	1.1E-04	3.9E-04	7.4E-04	3.8E-04	3.8E-04	3.7E-04
239	1.0E-04	3.9E-05	2.4E-05	1.4E-03	2.9E-05	1.6E-05	2.9E-05	3.1E-05	3.1E-05	2.8E-05	3.6E-05	6.6E-06	2.3E-05	1.6E-05	2.4E-05	2.4E-05	1.7E-04
240	7.2E-05	2.5E-05	3.2E-05	1.5E-05	2.2E-05	9.7E-06	2.6E-05	5.2E-05	4.4E-05	2.4E-05	6.1E-05	1.0E-05	2.9E-05	1.6E-05	4.3E-05	3.9E-05	2.8E-05
241	5.9E-05	1.2E-03	3.4E-05	4.3E-05	2.7E-05	1.7E-05	1.2E-05	1.8E-05	1.9E-05	1.5E-05	2.6E-05	6.3E-06	2.7E-05	7.8E-06	2.8E-05	1.9E-05	1.9E-05
242	5.8E-04	5.0E-04	1.4E-04	9.3E-05	1.3E-04	6.2E-05	1.2E-04	1.3E-04	1.3E-04	1.3E-04	1.5E-04	4.1E-05	2.3E-04	2.0E-04	2.2E-04	2.1E-04	1.6E-04
243	6.4E-04	9.1E-03	3.3E-04	3.9E-04	2.9E-04	4.1E-04	1.4E-04	1.9E-04	2.1E-04	1.5E-04	3.7E-04	6.5E-05	2.3E-04	1.7E-04	3.6E-04	2.9E-04	3.0E-04
244	3.2E-05	2.2E-05	4.8E-05	1.7E-05	1.9E-05	8.3E-06	1.8E-05	3.2E-05	3.0E-05	2.3E-05	4.0E-05	1.7E-05	2.5E-05	1.2E-05	3.4E-05	3.6E-05	2.6E-05
245	3.7E-03	2.3E-02	2.1E-03	5.9E-03	5.0E-03	1.3E-03	9.8E-04	1.3E-03	1.3E-03	1.1E-03	1.7E-03	4.1E-04	1.7E-03	1.6E-03	1.8E-03	1.6E-03	2.1E-03
246	3.2E-05	3.7E-05	4.5E-05	2.2E-05	2.0E-05	1.5E-05	6.8E-06	9.0E-06	1.1E-05	1.9E-05	1.3E-05	1.1E-05	1.1E-05	1.6E-05	2.4E-05	2.4E-05	2.5E-05
247	9.1E-05	1.0E-04	1.3E-04	6.2E-05	5.5E-05	4.3E-05	1.9E-05	2.5E-05	3.2E-05	5.4E-05	3.7E-05	3.2E-05	3.2E-05	4.4E-05	6.9E-05	6.7E-05	7.1E-05
248	1.1E-05	1.3E-05	1.5E-05	7.6E-06	6.7E-06	5.2E-06	2.3E-06	3.1E-06	3.8E-06	6.5E-06	4.5E-06	3.9E-06	3.9E-06	5.4E-06	8.4E-06	8.2E-06	8.7E-06
249	7.4E-06	8.5E-06	1.0E-05	5.1E-06	4.5E-06	3.5E-06	1.5E-06	2.1E-06	2.6E-06	4.4E-06	3.0E-06	2.6E-06	2.6E-06	3.6E-06	5.6E-06	5.5E-06	5.8E-06
250	1.5E-02	1.6E-02	8.1E-03	5.4E-03	7.0E-03	6.6E-03	3.6E-03	5.1E-03	7.6E-03	5.8E-03	7.5E-03	2.2E-03	5.9E-03	7.1E-03	1.7E-02	3.2E-01	8.0E-03
251	1.6E-03	8.3E-04	6.0E-04	4.2E-04	5.6E-04	4.0E-04	2.5E-04	3.4E-04	4.7E-04	3.8E-04	4.8E-04	2.0E-04	3.9E-04	4.7E-04	1.1E-03	1.6E-02	8.0E-04
252	1.6E-02	1.6E-02	8.7E-03	5.8E-03	7.5E-03	7.1E-03	3.9E-03	5.4E-03	8.0E-03	6.1E-03	8.0E-03	2.4E-03	6.3E-03	7.6E-03	1.8E-02	3.4E-01	8.8E-03
253	8.0E-05	3.2E-05	1.4E-05	1.2E-05	1.9E-05	1.7E-05	8.5E-06	1.1E-05	1.8E-05	1.3E-05	1.6E-05	3.5E-06	1.3E-05	1.9E-05	3.9E-05	9.9E-04	1.8E-05
254	2.3E-04	2.4E-04	9.7E-05	6.4E-05	9.8E-05	1.3E-04	5.9E-05	7.5E-05	1.4E-04	9.3E-05	1.2E-04	2.4E-05	1.0E-04	1.4E-04	2.8E-04	7.9E-03	1.3E-04
255	2.8E-05	3.4E-05	1.4E-05	9.0E-06	1.3E-05	1.8E-05	8.3E-06	1.1E-05	1.9E-05	1.3E-05	1.7E-05	3.4E-06	1.4E-05	1.9E-05	4.0E-05	1.1E-03	1.8E-05
256	2.9E-05	1.5E-06	9.7E-07	1.7E-06	3.5E-06	6.5E-07	5.9E-07	6.4E-07	9.6E-07	6.4E-07	9.3E-07	2.6E-07	6.4E-07	1.2E-06	2.1E-06	2.3E-05	8.8E-07
257	3.1E-04	3.3E-04	1.3E-04	8.7E-05	1.3E-04	1.8E-04	8.1E-05	1.0E-04	1.9E-04	1.3E-04	1.6E-04	3.3E-05	1.4E-04	1.9E-04	3.9E-04	1.1E-02	1.8E-04

	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY
258	4.7E-05	4.2E-05	1.7E-05	1.2E-05	1.8E-05	2.2E-05	1.0E-05	1.3E-05	2.4E-05	1.6E-05	2.1E-05	4.2E-06	1.8E-05	2.4E-05	5.0E-05	1.4E-03	2.3E-05
259	1.8E-05	2.2E-06	1.2E-06	1.8E-06	3.2E-06	1.2E-06	7.8E-07	8.6E-07	1.3E-06	8.8E-07	1.2E-06	3.1E-07	8.5E-07	1.5E-06	3.2E-06	4.0E-05	2.2E-06
260	4.0E-05	1.2E-05	5.6E-06	5.7E-06	9.6E-06	6.8E-06	3.7E-06	4.3E-06	7.1E-06	4.7E-06	6.4E-06	1.2E-06	5.5E-06	7.5E-06	1.9E-05	3.2E-04	1.4E-05
261	2.0E-06	1.5E-06	6.2E-07	5.3E-07	8.9E-07	7.8E-07	3.9E-07	4.7E-07	8.3E-07	5.7E-07	7.4E-07	1.2E-07	6.0E-07	9.1E-07	2.2E-06	4.6E-05	1.8E-06
262	7.4E-06	2.4E-07	1.9E-07	3.9E-07	8.4E-07	9.2E-08	1.2E-07	1.2E-07	1.7E-07	1.1E-07	1.7E-07	5.1E-08	1.0E-07	2.3E-07	3.9E-07	1.1E-06	1.7E-07
263	2.9E-05	1.4E-05	6.1E-06	5.1E-06	8.9E-06	7.5E-06	3.8E-06	4.6E-06	8.1E-06	5.5E-06	7.2E-06	1.1E-06	6.1E-06	8.9E-06	2.2E-05	4.5E-04	1.7E-05
264	2.6E-05	3.1E-06	2.0E-06	2.5E-06	4.2E-06	2.4E-06	1.5E-06	1.6E-06	2.3E-06	1.5E-06	2.2E-06	4.8E-07	2.1E-06	2.2E-06	6.9E-06	5.7E-05	3.6E-06
265	9.8E-05	3.4E-05	1.5E-05	1.4E-05	2.3E-05	1.8E-05	9.3E-06	1.1E-05	2.0E-05	1.3E-05	1.8E-05	3.8E-06	1.4E-05	2.0E-05	4.2E-05	1.0E-03	2.0E-05
266	2.7E-04	2.5E-04	1.0E-04	7.0E-05	1.1E-04	1.3E-04	6.2E-05	7.9E-05	1.4E-04	9.7E-05	1.3E-04	2.5E-05	1.1E-04	1.4E-04	3.0E-04	8.3E-03	1.4E-04
267	3.0E-05	3.6E-05	1.5E-05	9.5E-06	1.4E-05	1.9E-05	8.7E-06	1.1E-05	2.0E-05	1.4E-05	1.8E-05	3.5E-06	1.5E-05	2.0E-05	4.2E-05	1.2E-03	2.0E-05
268	3.6E-05	1.7E-06	1.2E-06	2.1E-06	4.3E-06	7.5E-07	7.0E-07	7.6E-07	1.1E-06	7.5E-07	1.1E-06	3.1E-07	7.4E-07	1.5E-06	2.5E-06	2.4E-05	1.0E-06
269	3.4E-04	3.5E-04	1.4E-04	9.2E-05	1.4E-04	1.8E-04	8.5E-05	1.1E-04	2.0E-04	1.3E-04	1.7E-04	3.4E-05	1.5E-04	2.0E-04	4.1E-04	1.2E-02	2.0E-04
270	7.2E-05	4.5E-05	1.9E-05	1.4E-05	2.2E-05	2.5E-05	1.2E-05	1.5E-05	2.6E-05	1.8E-05	2.3E-05	4.7E-06	2.0E-05	2.6E-05	5.7E-05	1.4E-03	2.6E-05
271	2.2E-04	1.5E-03	1.3E-04	4.1E-04	3.4E-04	7.7E-05	5.8E-05	8.1E-05	8.2E-05	6.5E-05	1.1E-04	2.8E-05	1.1E-04	9.0E-05	1.2E-04	1.1E-04	1.4E-04
272	6.1E-08	9.6E-07	3.6E-08	1.0E-07	3.7E-08	3.3E-08	1.6E-08	2.2E-08	2.3E-08	1.7E-08	3.7E-08	7.3E-09	5.5E-08	3.8E-08	5.0E-08	4.2E-08	4.0E-08
273	1.3E-08	6.9E-08	7.5E-09	1.6E-08	8.5E-09	4.7E-09	3.5E-09	4.4E-09	4.4E-09	3.7E-09	5.9E-09	1.4E-09	5.1E-09	5.7E-09	5.7E-09	5.1E-09	6.0E-09

	AZ
7	48
8	Local Government
10	1.3E-03
11	0.0E+00
12	1.3E-03
13	7.5E-05
14	0.0E+00
15	0.0E+00
16	2.0E-05
17	0.0E+00
18	4.9E-04
19	5.0E-06
20	0.0E+00
21	0.0E+00
22	1.9E-05
23	0.0E+00
24	0.0E+00
25	5.4E-04
26	0.0E+00
27	0.0E+00
28	0.0E+00
29	0.0E+00
30	2.6E-07
31	2.6E-07
32	5.3E-07
33	0.0E+00
34	0.0E+00
35	0.0E+00
36	0.0E+00
37	0.0E+00
38	0.0E+00
39	0.0E+00
40	0.0E+00
41	0.0E+00
42	0.0E+00
43	0.0E+00
44	0.0E+00
45	0.0E+00
46	0.0E+00
47	0.0E+00
48	0.0E+00
49	0.0E+00
50	0.0E+00
51	1.9E-05
52	2.0E-09
53	2.6E-09
54	2.7E-03
55	7.5E-03
56	1.0E-02
57	2.8E-05
58	1.5E-05

	AZ
59	7.8E-05
60	7.1E-05
61	1.5E-04
62	2.8E-04
63	1.7E-05
64	2.5E-05
65	1.3E-05
66	7.9E-05
67	1.4E-04
68	2.0E-05
69	8.9E-04
70	3.4E-05
71	8.9E-05
72	1.0E-05
73	7.0E-06
74	8.0E-03
75	4.1E-04
76	8.4E-03
77	1.7E-05
78	1.3E-04
79	1.8E-05
80	1.0E-06
81	1.8E-04
82	2.2E-05
83	9.4E-07
84	3.2E-06
85	3.9E-07
86	3.1E-07
87	4.2E-06
88	7.7E-07
89	1.8E-05
90	1.3E-04
91	1.9E-05
92	1.3E-06
93	1.8E-04
94	2.3E-05
95	5.6E-05
96	1.6E-08
97	3.1E-09
98	4.0E-03
99	7.5E-03
100	1.1E-02
101	1.0E-04
102	1.5E-05
103	7.8E-05
104	9.1E-05
105	1.5E-04
106	7.7E-04
107	2.2E-05
108	2.5E-05
109	1.3E-05
110	9.8E-05
111	1.4E-04
112	2.0E-05
113	1.4E-03

	AZ
114	3.4E-05
115	8.9E-05
116	1.0E-05
117	7.0E-06
118	8.0E-03
119	4.1E-04
120	8.4E-03
121	1.7E-05
122	1.3E-04
123	1.8E-05
124	1.0E-06
125	1.8E-04
126	2.2E-05
127	9.4E-07
128	3.2E-06
129	3.9E-07
130	3.1E-07
131	4.2E-06
132	7.7E-07
133	1.8E-05
134	1.3E-04
135	1.9E-05
136	1.3E-06
137	1.8E-04
138	2.3E-05
139	7.5E-05
140	1.8E-08
141	5.7E-09
142	2.9E-05
143	0.0E+00
144	2.9E-05
145	7.5E-05
146	0.0E+00
147	0.0E+00
148	1.9E-05
149	0.0E+00
150	4.8E-04
151	4.9E-06
152	0.0E+00
153	0.0E+00
154	1.9E-05
155	0.0E+00
156	0.0E+00
157	5.3E-04
158	0.0E+00
159	0.0E+00
160	0.0E+00
161	0.0E+00

	AZ
162	2.6E-07
163	0.0E+00
164	2.6E-07
165	0.0E+00
166	0.0E+00
167	0.0E+00
168	0.0E+00
169	0.0E+00
170	0.0E+00
171	0.0E+00
172	0.0E+00
173	0.0E+00
174	0.0E+00
175	0.0E+00
176	0.0E+00
177	0.0E+00
178	0.0E+00
179	0.0E+00
180	0.0E+00
181	0.0E+00
182	0.0E+00
183	1.9E-05
184	1.9E-09
185	2.6E-09
186	2.9E-03
187	1.0E-02
188	1.3E-02
189	3.4E-05
190	1.9E-05
191	8.9E-05
192	9.2E-05
193	2.1E-04
194	3.3E-04
195	1.9E-05
196	2.9E-05
197	1.8E-05
198	1.0E-04
199	2.0E-04
200	2.4E-05
201	1.1E-03
202	3.4E-05
203	9.5E-05
204	1.1E-05
205	7.7E-06
206	9.2E-03
207	6.2E-04
208	9.8E-03
209	1.9E-05

	AZ
210	1.3E-04
211	1.9E-05
212	1.4E-06
213	1.9E-04
214	2.4E-05
215	1.7E-06
216	7.1E-06
217	8.3E-07
218	2.8E-07
219	8.0E-06
220	2.3E-06
221	2.1E-05
222	1.4E-04
223	2.0E-05
224	1.7E-06
225	1.9E-04
226	2.6E-05
227	7.2E-05
228	2.2E-08
229	3.9E-09
230	2.9E-03
231	1.0E-02
232	1.3E-02
233	1.1E-04
234	1.9E-05
235	8.9E-05
236	1.1E-04
237	2.1E-04
238	8.1E-04
239	2.4E-05
240	2.9E-05
241	1.8E-05
242	1.2E-04
243	2.0E-04
244	2.4E-05
245	1.7E-03
246	3.4E-05
247	9.5E-05
248	1.1E-05
249	7.7E-06
250	9.2E-03
251	6.2E-04
252	9.8E-03
253	1.9E-05
254	1.3E-04
255	1.9E-05
256	1.4E-06
257	1.9E-04

	AZ
258	2.4E-05
259	1.7E-06
260	7.1E-06
261	8.3E-07
262	2.8E-07
263	8.0E-06
264	2.3E-06
265	2.1E-05
266	1.4E-04
267	2.0E-05
268	1.7E-06
269	1.9E-04
270	2.6E-05
271	9.1E-05
272	2.4E-08
273	6.5E-09

Appendix 6 – Principal Components Analysis

6.1 The general process for conducting a principal components analysis

There are seven general steps in a principal components analysis:

i) Construct a p times n data matrix where p represents eco-efficiency types ($\mathcal{E}_i$), and n represents samples or sectors. To avoid singularity of the estimated covariance and correlations matrices: $p<n$ (Grossman, Nickerson, & Freeman, 1991, p. 342).

ii) Standardise the variables $\mathcal{E}_1$, $\mathcal{E}_2$, ... $\mathcal{E}_p$ to have zero means[21] and unit variances[22 23].

iii) Calculate the covariance matrix C. This is a correlation matrix if step 2 has been done (Yu et al., 1998). If the values in the correlation matrix are not particularly high, this indicates that several principal components will be required to account for the variation.

iv) Find the eigenvalues λ_1, λ_2, λ_3,...λ_p and the corresponding eigenvectors $\boldsymbol{\gamma}_1$, $\boldsymbol{\gamma}_2$, ... $\boldsymbol{\gamma}_p$. The coefficients of the ith principal component are then given by the $\boldsymbol{\gamma}_i$ while λ_i is its variance.

v) Discard any components that only account for a small proportion of the variation in the data. A PCA of two $p \times n$ data sets, one with sectoral structure and one random, will both produce p components with p component loading vectors, regardless of the type of data set being examined (Grossman et al., 1991, p. 342). Thus, "it is a matter of judgement as to how many components are important" (Manly, 1994, p. 86). If the assumption of multivariate normality holds, statistical eigenvalue tests can be used to reduce the arbitrary nature of selection (Grossman et al., 1991). However, the eco-efficiency indicators are not normally distributed. Therefore, other methods must be used for selecting components, including:

> a) the Kaiser eigenvalue criterion. This criterion involves retaining only those components whose eigenvalues of the correlation matrix are greater than one[24]. Jolliffe (cited in Marcoulides & Hershberger 1997, p. 172) proposed a modification of this

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[21] i.e. subtract the mean from each observation.
[22] i.e. divide all variables by the variance.
[23] This is usual but omitted in some cases. In general the weight assigned to a variable is affected by the relative variance of the variable. The data should be standardised to avoid the relative variance affecting the weights (Sharma, 1996, p. 74).
[24] The rationale for this rule is that for standardised data the amount of variance extracted by each component should, at a minimum, be equal to the variance of at least one variable (Sharma, 1996 p. 76).

criterion. Jollife suggested that Kaiser's rule should be amended to a cut-off point of 0.7.

b) Cattell's scree test (Manly, 1994). This method consists of plotting the eigenvalues of the observed correlation matrix against their ordinal number and noting the point at which the plot becomes 'nearly horizontal.' This is the point where all else is mere "scree."

c) examining the proportion of variance accounted for by the principal components (Manly, 1994; Marcoulides & Hershberger, 1997, p. 172). In general, if the ratio is close to or exceeds 90 percent, the remaining components are considered of no practical value.

According to Marcoulides & Hershberger (1997, p. 173) the best strategy is to examine all criteria. If the results are similar, choosing the criterion becomes a matter of taste. Conversely, if the results are different, the analyst looks for some consensus among the criteria.

vi) Interpret the remaining principal components. Since the principal components are linear combinations of the original variables, it is necessary to interpret the components. The component weights (γ_is) are useful for this purpose. Very small coefficients in the principal component function indicates variables that are redundant in describing the overall variation explained by that component (Crampton, Salmond, & Sutton, 1997). In general, the higher the weights, the more influence it has in the formation of the principal component score and vice versa (Sharma, 1996, p. 79). It is also important to consider the sign of the weight. Those with positive values are considered to be "contrasted between" those with negative values.

vii) Calculate the principal components scores (Yu et al., 1998, p. 114).

6.2 Principal Components Analysis and the eigenstructure of the covariance matrix[25] [26]

Let $\boldsymbol{\varepsilon}$ be a p-component random vector where p is the number of variables. The covariance matrix, C, is given by E($\boldsymbol{\varepsilon\varepsilon}'$). Let $\boldsymbol{\gamma}' = (\gamma_1, \gamma_2, \ldots, \gamma_p)$ be a vector of weights to form the linear combination of the original variables, and $\mathbf{Z} = \boldsymbol{\gamma}' \boldsymbol{\varepsilon}$ be the new variable, which is a linear combination of the original variables. In other words, **Z**, is a weighted linear sum aggregation

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[25] Based on Sharma (1996 p. 84-85)

[26] Alternatively, principal components analysis can be conducted by finding the singular value decomposition (SVD) of the data matrix or a spectral decomposition of the covariates matrix. These methods all give the same results. For a detailed discussion of the algebra behind the SVD and spectral decomposition approaches see Sharma (1996 p. 84 – 87) or Marcoulides & Hershberger (1997)

function. The variance of the new variable is given by E(**ZZ′**) and is equal to E(γ′**ΣΣ**′γ) or γ′Cγ.

The problem is now reduced to finding the weight vector, γ′, such that the variance γ′Cγ, of the new variable is maximum over the class of linear combinations that can be formed subject to the constraint γ′γ=1. The solution to the maximisation problem can be obtained using the following procedure:

Let

$$\xi = \gamma'C\gamma - \lambda(\gamma'\gamma - 1)$$ **Equation A6-1**

Where λ is the Lagrange multiplier. The *p*-component vector of the partial derivative is defined by

$$\frac{\partial \xi}{\partial \gamma} = 2C\gamma - 2\lambda\gamma$$ **Equation A6-2**

Setting the above vector of partial derivatives to zero results in the final solution. That is,

$$(C - \lambda I)\gamma = 0$$ **Equation A6-3**

For the above system of homogenous equations to have a nontrivial solution the determinant of $(C - \lambda I)$ should be 0. That is,

$$|C - \lambda I| = 0$$ **Equation A6-4**

Equation A6-4 is a polynomial in λ of order *p*, and therefore has *p* roots. Let $\lambda_1 \geq \lambda_2 \geq \lambda_3 \geq \ldots \lambda_p$ be the *p* roots. That is, Equation A6-4 results in *p* values for λ, and each value is called the eigenvalue or root of the **C** matrix. Each value of λ results in a set of weights given by the *p*-component vector γ by solving the following equations:

$$(C - \lambda I)\gamma = 0$$ **Equation A6-5**

$$\gamma'\gamma = 1$$ **Equation A6-6**

Therefore, the first eigenvector, γ_1, corresponding to the first eigenvalue, λ_1,is obtained by solving equations

$$(C - \lambda_1 I)\gamma_1 = 0$$ **Equation A6-7**

$$\gamma_1'\gamma_1 = 1$$ **Equation A6-8**

By premultiplying Equation A6-7 by γ_1' it can be shown that

$$\gamma_1'(C - \lambda_1 I)\gamma_1 = 0$$
$$\gamma_1' C \gamma_1 = \lambda_1 \gamma_1' \gamma_1$$

$$\gamma_1' C \gamma_1 = \lambda_1 \qquad \textbf{Equation A6-9}$$

as $\gamma'\gamma = 1$. The left-hand side of Equation A6-9 is the variance of the new variable, Z_1, and is equal to the eigenvalue, λ_1. The first principal component, therefore, is given by the eigenvector, γ_1, corresponding to the largest λ_1.

Let γ_2 be the second p-component vector of weights to form another linear combination. The next linear combination can be found such that the variance of $\gamma_2'\boldsymbol{\varepsilon}$ is the maximum subject to the constraints $\gamma_1'\gamma_2=0$ and $\gamma_2'\gamma_2=1$. It can be shown that γ_2' is the eigenvector of λ_2, the second largest eigenvalue of C. Similarly, it can be shown that the remaining principal components, $\gamma_3'\gamma_4'$, ..., γ'_p, are the eigenvectors corresponding to the eigenvalues, λ_3, λ_4,..., λ_p, of the covariance matrix, C. Thus the problem of finding the weights reduces to finding the eigenstructure of the covariance matrix. The eigenvectors give the vectors of weights and the eigenvalues represent the variances of the new variable, Z, or the principal components.

Appendix 7 – Sector scores from the principal components analysis conducted in this thesis

	sector	Year	Prin1	Prin2	Prin3	Prin4	Prin5	Prin6	Prin7	Prin8	Prin9	Prin10	Prin11	Prin12	Prin13	Prin14
Mixed livestock	1	1995	-0.0655	0.0025	-1.1970	3.1329	0.4834	3.6543	-0.6100	-1.0849	0.9559	0.0546	-0.0474	0.0362	0.0000	0.0000
Dairy farming	2	1995	1.7878	-0.0182	-0.8897	1.1141	-0.1159	0.7380	-0.2681	-1.0182	-1.9273	0.0728	-0.0465	0.0606	0.0000	0.0000
Horticulture	3	1995	-0.2811	-0.7474	-0.1186	-0.1662	0.0900	0.0873	0.0319	-0.0563	0.0822	0.0085	-0.0014	0.0094	0.0000	0.0000
Services to Agriculture	4	1995	-0.4730	-0.9159	-0.0783	-0.3950	-0.1238	-0.1408	-0.0222	0.0153	0.0108	0.0505	-0.0626	0.0341	-0.0001	0.0000
All other farming	5	1995	0.7621	0.7470	-0.8041	0.8573	0.2527	1.8725	-0.0319	1.5068	-0.0750	0.0526	-0.1168	0.0470	0.0001	0.0000
Fishing and Hunting	6	1995	-0.8918	1.6504	0.3576	-0.3590	0.1775	-0.2694	-0.1646	-0.0270	0.1012	-0.2671	-0.6336	-0.3793	0.0000	0.0000
Forestry & Logging	7	1995	-0.4341	-0.6987	-0.4055	0.6129	0.0198	0.9959	0.0588	-0.3141	0.3083	0.0367	0.0109	0.0111	0.0000	0.0000
Oil and Gas Exploration	8	1995	-0.7531	-0.1193	-0.0347	-0.4426	-0.1268	-0.1850	-0.1104	0.0253	0.0298	0.1040	-0.0361	0.0595	0.0000	0.0000
Other mining	9	1995	0.5450	0.8848	7.8009	1.5695	-1.0159	0.3792	0.2239	0.0767	-0.1051	0.0722	0.1919	0.3955	0.0000	0.0000
Meat Products	10	1995	1.8640	0.4367	-1.9400	5.9996	-1.2859	-3.4164	0.3092	0.3768	0.2709	0.0094	-0.0517	0.0201	0.0000	0.0000
Dairy Products	11	1995	0.5912	0.7761	-0.5159	0.4686	-0.0155	0.3331	-0.3907	-0.5604	-0.9888	-0.1046	-0.0795	0.0165	0.0000	0.0000
Manufacture of other food	12	1995	-0.5632	0.2456	-0.1586	-0.1738	-0.0699	-0.0911	0.0129	0.0314	0.0454	0.0188	-0.2032	-0.0093	0.0000	0.0000
Beverage Manufacture	13	1995	-0.5048	-0.1550	-0.1420	-0.3266	-0.0572	-0.0715	0.0037	0.0228	0.0355	0.0362	-0.0698	0.0468	0.0000	0.0000
Textile Manufacture	14	1995	-0.2575	-0.5693	-0.4554	0.7358	-0.0173	0.6279	-0.1335	-0.2340	0.2112	0.0079	-0.0469	0.0419	0.0000	0.0000
Wood & Wood Products	15	1995	-0.6412	-0.1405	-0.2090	-0.2767	-0.0984	0.0159	-0.0410	-0.0430	0.0849	-0.1008	0.1145	0.0161	0.0000	0.0000
Paper Manufacturing	16	1995	-1.7515	5.4251	-0.3527	-0.5750	0.2031	-0.4457	-1.3969	-0.0445	0.1664	-1.0133	-0.0659	0.1098	0.0000	0.0000
Printing & Publishing	17	1995	-0.5912	-0.4070	-0.1113	-0.4481	-0.1053	-0.1771	-0.0751	0.0172	0.0411	-0.0751	0.0146	0.0110	0.0000	0.0000
Other Chemicals	18	1995	-0.5505	-0.8170	-0.0777	-0.4122	-0.1209	-0.1584	-0.0358	0.0320	0.0282	0.0538	-0.0635	0.0392	0.0000	0.0000
Basic Chemicals	19	1995	-0.5105	-0.9297	0.1448	-0.3519	-0.1534	-0.1685	-0.0107	0.0326	0.0259	0.0542	-0.0463	-0.0015	0.0000	0.0000
Non-metallic Minerals	20	1995	-0.7293	0.7547	0.4002	-0.3436	-0.1369	-0.1877	-0.2049	0.0113	0.0425	-0.3861	0.0731	0.1502	0.0000	0.0000
Basic Metal Industries	21	1995	-1.9975	6.4134	-0.0475	-0.6773	0.2513	-0.8049	-2.8518	0.1048	0.1067	1.0426	-0.0465	0.0352	0.0000	0.0000
Fabricated Metals	22	1995	-0.6210	-0.4881	-0.0784	-0.4398	-0.1073	-0.1921	-0.1347	0.0294	0.0309	0.0994	-0.0063	0.0199	0.0000	0.0000
Equipment Manufacture	23	1995	-0.5081	-0.8595	-0.0833	-0.4293	-0.1298	-0.1616	-0.0044	0.0251	0.0292	0.0435	-0.0016	0.0159	0.0000	0.0000
Transport Equipment	24	1995	-0.4740	-1.1370	-0.0661	-0.4273	-0.1365	-0.1545	0.0254	0.0289	0.0249	0.0386	0.0218	0.0067	0.0000	0.0000
Other Manufacturing	25	1995	-0.5120	-0.5212	0.2413	-0.3223	-0.1621	-0.1582	-0.0331	0.0276	0.0250	0.1267	-0.0156	0.0290	0.0000	0.0000
Water works	28	1995	1.4184	0.0013	1.2511	0.7275	6.2367	-0.9486	0.5034	-0.0233	0.0156	-0.0277	-0.0986	-0.1386	0.0000	0.0000
Construction	29	1995	-0.4530	-0.6632	-0.0531	-0.4144	-0.1398	-0.1355	0.0449	0.0124	0.0354	-0.0060	0.0181	0.0245	0.0000	0.0000

Trade	30	1995	-0.5664	-0.3699	-0.1458	-0.4322	-0.1517	-0.1109	0.2514	-0.0029	0.0201	0.0935	0.0178	-0.0028	0.0000	0.0000
Accommodation	31	1995	-0.1554	-0.6071	-0.2738	0.1671	-0.2052	-0.4110	0.0079	0.0478	0.0387	0.1058	-0.0565	0.0160	0.0000	0.0000
Road Transport	32	1995	-1.8693	7.0476	-0.9853	-0.6222	-0.4113	0.3965	3.2225	-0.3100	0.0248	0.3004	-0.2243	0.0931	0.0000	0.0000
Services to Transport	33	1995	-0.4150	-1.1216	-0.0650	-0.4228	-0.1355	-0.1515	0.0328	0.0269	0.0275	0.0538	0.0097	0.0075	0.0000	0.0000
Water Transport	34	1995	-0.7208	-0.0497	-0.1863	-0.4498	-0.1382	-0.1740	0.0468	0.0102	0.0326	-0.0554	-0.1544	0.1170	0.0000	0.0000
Air Transport	35	1995	-0.5641	-0.4862	-0.1441	-0.4076	-0.1293	-0.2252	-0.1723	0.0275	0.0391	-0.2162	-0.3303	0.2085	0.0000	0.0000
Communications	36	1995	-0.2546	-1.3184	-0.0661	-0.4345	-0.1487	-0.1303	0.1148	0.0226	0.0263	0.0485	0.0324	-0.0052	0.0000	0.0000
Finance	37	1995	-0.4211	-1.4940	-0.0442	-0.4142	-0.1442	-0.1447	0.0556	0.0333	0.0235	0.0308	0.0359	-0.0176	0.0000	0.0000
Finance services	38	1995	-0.4294	-1.4564	-0.0535	-0.4230	-0.1412	-0.1502	0.0514	0.0343	0.0224	0.0286	0.0389	-0.0072	0.0000	0.0000
Insurance	39	1995	-0.3397	-1.4369	-0.0549	-0.4287	-0.1463	-0.1486	0.0541	0.0315	0.0252	0.0297	0.0377	-0.0080	0.0000	0.0000
Real Estate	40	1995	-0.3980	-1.5118	-0.0447	-0.4249	-0.1439	-0.1495	0.0482	0.0351	0.0226	0.0336	0.0402	-0.0076	0.0000	0.0000
Business Services	41	1995	-0.3770	-1.2059	-0.0718	-0.4287	-0.1460	-0.1430	0.0815	0.0248	0.0275	0.0291	0.0283	-0.0065	0.0000	0.0000
Dwelling ownership	42	1995	-0.4543	-1.6238	-0.0253	-0.3980	-0.0839	-0.1474	0.0773	0.0357	0.0197	0.0094	0.0580	-0.0118	0.0000	0.0000
Education	43	1995	-0.4114	-1.1706	-0.0859	-0.4299	-0.1514	-0.1178	0.2187	0.0173	0.0238	0.0153	0.0568	-0.0106	0.0000	0.0000
Community Services	44	1995	-0.2042	-1.1729	-0.0801	-0.4259	-0.1492	-0.1430	0.1049	0.0201	0.0306	0.0636	0.0315	-0.0060	0.0000	0.0000
Recreation Services	45	1995	0.0409	-1.0454	0.2271	-0.2295	-0.1641	0.0179	0.1054	-0.0416	0.1043	-0.0580	-0.0960	-0.3746	0.0000	0.0000
Personal Services	46	1995	14.004	1.6735	-0.3164	-1.9536	-0.6451	-0.1071	-0.1065	-0.3329	0.4707	0.0122	-0.0154	0.0269	0.0000	0.0000
Central Government	47	1995	-0.3911	-1.1297	-0.0840	-0.4139	-0.1407	-0.1212	0.0739	0.0169	0.0334	-0.0042	-0.0112	0.0244	0.0000	0.0000
Local Government	48	1995	-0.3447	-1.2810	-0.0786	-0.3250	-0.0951	-0.0677	-0.0242	0.0044	0.0519	0.0916	0.0136	-0.0024	0.0000	0.0000
Mixed livestock	1	1998	0.0318	0.1018	-1.2247	3.2839	0.4997	3.8180	-0.6017	-1.0615	0.9293	0.0231	0.0342	-0.0261	0.0000	0.0000
Dairy farming	2	1998	1.9206	0.1383	-0.8772	1.2204	-0.0812	0.8014	-0.2397	-1.0259	-2.0467	0.0314	0.0465	-0.0375	0.0000	0.0000
Horticulture	3	1998	-0.3446	-0.7288	-0.1194	-0.1478	0.0786	0.1052	0.0707	-0.0474	0.0696	-0.0044	0.0741	-0.0318	0.0000	0.0000
Services to Agriculture	4	1998	-0.4186	-0.7291	-0.0826	-0.3589	-0.1302	-0.1116	0.0066	0.0048	-0.0102	0.0296	-0.0215	-0.0016	0.0000	0.0000
All other farming	5	1998	2.3300	1.2736	-1.1053	0.7898	0.3300	2.7534	-0.0072	4.0855	-0.6748	-0.0569	0.0428	-0.0312	0.0000	0.0000
Fishing and Hunting	6	1998	-1.0911	1.5434	-0.3209	-0.5115	-0.0898	-0.2185	-0.1748	-0.0064	0.0483	-0.1199	-0.4198	0.2636	0.0000	0.0000
Forestry & Logging	7	1998	-0.4378	-0.6614	-0.4254	0.6927	0.0280	1.0802	0.0693	-0.3347	0.3250	0.0214	0.0558	-0.0178	0.0000	0.0000
Oil and Gas Exploration	8	1998	-0.5675	-0.0348	0.2633	-0.3429	-0.1930	-0.0977	0.2048	0.0020	0.0238	0.1118	-0.1802	0.0630	0.0000	0.0000
Other mining	9	1998	0.8642	1.3314	9.3379	1.9142	-1.1528	0.4439	0.2313	0.0512	-0.0568	-0.0489	-0.1410	-0.2818	0.0000	0.0000
Meat Products	10	1998	1.8251	0.5494	-1.8701	5.6225	-1.1513	-2.9085	0.2634	0.4574	0.1864	-0.0243	0.0756	-0.0270	0.0000	0.0000
Dairy Products	11	1998	0.7491	1.0617	-0.5268	0.5856	0.0013	0.3832	-0.4687	-0.6000	-1.1653	-0.1901	0.0396	-0.0934	0.0000	0.0000
Manufacture of other food	12	1998	-0.4677	0.3032	-0.3008	-0.1128	-0.0928	-0.0353	0.0469	0.1323	-0.0113	0.0108	-0.0706	0.0512	0.0000	0.0000
Beverage Manufacture	13	1998	-0.4542	-0.0464	-0.1653	-0.2949	-0.0433	-0.0234	0.0377	0.0797	0.0078	0.0128	0.0199	0.0090	0.0000	0.0000

Textile Manufacture	14	1998	-0.1300	-0.3726	-0.5167	0.9298	-0.0135	0.7438	-0.0935	-0.2279	0.1918	-0.0062	0.0245	-0.0041	0.0000	0.0000
Wood & Wood Products	15	1998	-0.6383	-0.0441	-0.2211	-0.2237	-0.0993	0.0754	-0.0062	-0.0595	0.0936	-0.1297	0.1980	-0.0289	0.0000	0.0000
Paper Manufacturing	16	1998	-1.6630	5.2457	-0.2989	-0.5288	0.0838	-0.3687	-1.2973	-0.0627	0.1797	-1.1420	0.3538	-0.1286	0.0000	0.0000
Printing & Publishing	17	1998	-0.5996	-0.2291	-0.1175	-0.4403	-0.1201	-0.1630	-0.0537	0.0100	0.0433	-0.1147	0.0977	-0.0324	0.0000	0.0000
Other Chemicals	18	1998	-0.5224	-0.6959	-0.0666	-0.3923	-0.1282	-0.1389	-0.0039	0.0416	0.0234	0.0297	-0.0108	-0.0091	0.0000	0.0000
Basic Chemicals	19	1998	-0.3863	-0.7957	0.3834	-0.2790	-0.1953	-0.1474	0.0440	0.0144	0.0465	-0.0174	-0.0778	-0.2958	0.0000	0.0000
Non-metallic Minerals	20	1998	-0.6950	0.8963	0.5023	-0.3110	-0.1542	-0.1703	-0.1638	0.0022	0.0461	-0.4428	0.1746	0.0394	0.0000	0.0000
Basic Metal Industries	21	1998	-1.7094	5.3858	0.1137	-0.5902	0.1734	-0.6883	-2.3758	0.0855	0.0949	0.8220	0.1960	-0.1149	0.0000	0.0000
Fabricated Metals	22	1998	-0.5934	-0.5009	-0.0721	-0.4260	-0.1154	-0.1743	-0.0675	0.0244	0.0265	0.0693	0.0528	-0.0103	0.0000	0.0000
Equipment Manufacture	23	1998	-0.4927	-0.8606	-0.0811	-0.4211	-0.1352	-0.1512	0.0299	0.0228	0.0254	0.0236	0.0499	-0.0087	0.0000	0.0000
Transport Equipment	24	1998	-0.4497	-0.9916	-0.0770	-0.4168	-0.1398	-0.1388	0.0716	0.0202	0.0203	0.0276	0.0565	-0.0111	0.0000	0.0000
Other Manufacturing	25	1998	-0.4737	-0.4029	0.2671	-0.2857	-0.1779	-0.1455	0.0219	0.0213	0.0246	0.0835	0.0339	-0.0322	0.0000	0.0000
Water works	28	1998	1.4619	0.1061	0.9600	0.7157	6.5101	-0.9773	0.5102	-0.0168	-0.0138	0.0522	0.1247	0.1557	0.0000	0.0000
Construction	29	1998	-0.4587	-0.5471	-0.0508	-0.3983	-0.1456	-0.1184	0.0814	0.0054	0.0338	-0.0316	0.0839	-0.0159	0.0000	0.0000
Trade	30	1998	-0.5508	-0.3110	-0.1543	-0.4095	-0.1581	-0.0890	0.3020	-0.0139	0.0008	0.0675	0.0940	-0.0374	0.0000	0.0000
Accommodation	31	1998	-0.0632	-0.4604	-0.3303	0.2742	-0.2076	-0.3850	0.0052	0.0643	-0.0104	0.0894	0.0121	-0.0025	0.0000	0.0000
Road Transport	32	1998	-1.9400	7.4718	-1.0373	-0.6112	-0.4552	0.4688	3.5888	-0.3422	0.0209	0.1701	0.2865	-0.1012	0.0000	0.0000
Services to Transport	33	1998	-0.4403	-1.0763	-0.0675	-0.4144	-0.1362	-0.1457	0.0456	0.0261	0.0243	0.0481	0.0567	-0.0139	0.0000	0.0000
Water Transport	34	1998	-0.7436	0.0985	-0.2030	-0.4451	-0.1421	-0.1703	0.0549	0.0064	0.0286	-0.1147	-0.0356	0.0808	0.0000	0.0000
Air Transport	35	1998	-0.5595	-0.4252	-0.1549	-0.3922	-0.1318	-0.2180	-0.1627	0.0256	0.0289	-0.2403	-0.2834	0.1927	0.0000	0.0000
Communications	36	1998	-0.3447	-1.3185	-0.0700	-0.4278	-0.1483	-0.1275	0.1319	0.0259	0.0208	0.0463	0.0831	-0.0250	0.0000	0.0000
Finance	37	1998	-0.4345	-1.4785	-0.0573	-0.4140	-0.1438	-0.1427	0.0604	0.0345	0.0200	0.0327	0.0625	-0.0157	0.0000	0.0000
Finance services	38	1998	-0.4280	-1.3669	-0.0618	-0.4203	-0.1419	-0.1451	0.0639	0.0320	0.0215	0.0230	0.0574	-0.0143	0.0000	0.0000
Insurance	39	1998	-0.3241	-1.3393	-0.0655	-0.4251	-0.1483	-0.1423	0.0685	0.0288	0.0239	0.0245	0.0589	-0.0151	0.0000	0.0000
Real Estate	40	1998	-0.3828	-1.4372	-0.0511	-0.4219	-0.1444	-0.1452	0.0565	0.0327	0.0222	0.0301	0.0563	-0.0130	0.0000	0.0000
Business Services	41	1998	-0.3872	-1.1701	-0.0794	-0.4248	-0.1489	-0.1371	0.0981	0.0243	0.0241	0.0258	0.0604	-0.0169	0.0000	0.0000
Dwelling ownership	42	1998	-0.4563	-1.6730	-0.0276	-0.3993	-0.0936	-0.1453	0.0840	0.0371	0.0176	0.0093	0.0688	-0.0144	0.0000	0.0000
Education	43	1998	-0.4222	-1.1651	-0.0879	-0.4257	-0.1542	-0.1108	0.2412	0.0181	0.0216	0.0097	0.0848	-0.0234	0.0000	0.0000
Community Services	44	1998	-0.3457	-1.2168	-0.0808	-0.4225	-0.1487	-0.1388	0.1259	0.0243	0.0219	0.0669	0.0676	-0.0211	0.0000	0.0000
Recreation Services	45	1998	-0.0836	-1.0562	-0.1175	-0.2886	-0.1279	0.0176	0.1470	-0.0225	0.0629	0.0019	0.0714	-0.0327	0.0000	0.0000
Personal Services	46	1998	12.8952	1.5248	-0.2882	-1.8207	-0.6043	-0.1014	-0.0663	-0.3081	0.4344	0.0009	0.0129	-0.0061	0.0000	0.0000

Central Government	47	1998	-0.3747	-1.0764	-0.0886	-0.4098	-0.1423	-0.1151	0.0897	0.0156	0.0308	-0.0084	0.0181	0.0117	0.0000	0.0000
Local Government	48	1998	-0.3363	-1.2101	-0.0830	-0.3136	-0.0932	-0.0631	-0.0092	0.0014	0.0480	0.0833	0.0369	-0.0148	0.0000	0.0000