# DEVELOPING A SET OF ENERGY SUSTAINABILITY INDICATORS FOR NEW ZEALAND

By

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## ABSTRACT

Modern New Zealand society relies on the ability to use a number of different resources in order to function effectively. The continued existence of that society therefore requires a continued supply of those resources. Sustainable management, which focuses on enabling present generations to satisfy their needs and wants without adversely affecting the ability of future generations to do the same, is a key concept in ensuring the continued supply of resources. It also reinforces the fact that human society is linked with and has an impact on the functioning of numerous ecosystems. The concept of sustainable management highlights the effects of present decisions on the resource in question and on the linkages that those decisions have with other resources and other aspects of the functioning of the environment and society.

One of the key resources that is affected by the concept of sustainable management is energy. New Zealand society is totally dependent on energy to enable it to continue to function as it does at present. It is therefore important to ensure that there is a sustainable supply of energy that will continue to meet the foreseeable needs of New Zealand energy consumers, without causing significant adverse effects on the other matters that comprise a sustainable society. Some form of monitoring must be undertaken to determine whether energy is being managed sustainability. This thesis seeks to establish a regime of indicators to monitor energy use in New Zealand in terms of the major tenets of sustainability and to apply those indicators to the New Zealand energy system in order to assess the current state of energy use in New Zealand.

There are two stages to achieving the aims of this thesis. The first is to establish the scope of the monitoring programme. This process involved a number of steps. First was a literature review of various formulations of the criteria of effective indicator design and the establishment of a set of criteria that collated this work. A further literature review was undertaken to establish the key tenets of energy sustainability. A survey was then undertaken of the monitoring regimes that are presently in operation or are being developed in New Zealand and around the world. Given the base information that was provided by the reviews and the survey, the next step was the development of the indicators themselves.

The final stage of the thesis was an application of those indicators that could be developed within the constraints of existing data collection regimes. The results of this process clearly demonstrate that New Zealand is on an unsustainable energy path. Most of the indicators demonstrate a movement to an unsustainable state. Specific indicators that show this trend are the level of carbon dioxide emissions, energy intensity, renewable energy use, reliance on imported oil products, total primary energy supply (that is, total energy use) and household expenditure on energy. Although the levels of economic rent being earned by ECNZ are high, it is difficult to form a conclusion about this indicator as it is uncertain how these profits are used once they are paid into the consolidated fund. While real energy prices are decreasing, a number of the benefits of this decrease are being lost as consumption levels increase.

As well as providing an insight into the nature of energy use in New Zealand, this thesis highlights a number of issues concerning the state of information concerning indicator development, energy sustainability and the state of energy data collection in New Zealand. There is an abundance of information available concerning indicator development, so much so, that there is little to be gained from developing the issue further. By contrast, there is

a paucity of detailed information concerning energy sustainability. The majority of that information either focuses on one issue in great detail or takes a very generalised global picture. What is needed is information that fits between these two levels, so that multi-objective sustainable energy management policies can be developed.

The most serious concern is however directed at the state of the energy statistics that are available. There are numerous omissions from the data that is available and numerous inconsistencies. Specific matters to be addressed focus on increasing the subject coverage and the geographic coverage of the data. The time periods that data applies to and the consistency of the collection also need attention.

## ACKNOWLEDGEMENTS

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Thank you to you all.

CONTENTS

CHAPTER ONE

# INTRODUCTION

The aim of this thesis is to analyse the sustainability of New Zealand's energy use over as long a period as data will enable in order to identify how sustainable that energy use is and what, if anything, needs to be done to make it more sustainable. Achieving this aim will require two major stages. The first is the development of energy sustainability indicators. The second is the operationalisation of those indicators in order to be able to obtain a picture of the current state of New Zealand's energy supply and demand system. This chapter will discuss and analyse both of those objectives.

There is an international movement to recognise the impacts of mankind's actions on the environment and to take some steps towards avoiding, or at least reducing, the effects of those actions. In some cases, efforts are also being made to repair the effects of previous activities. This international movement is reflected in such diverse spheres as local interest environmental action groups through to international organisations such as the United Nations. There has also been a major paradigm shift within many disciplines, with traditional disciplines such as economics broadening their focus and recognising that the world in which particular systems operate places restrictions on those systems and often prevents them from behaving exactly according to theory.

The contemporary environmental movement owes its roots to the conservation movements of the late 1960's and the early 1970's, although in many ways it bears little resemblance to those groups. Whereas the initial impetus was mainly for the absolute protection of natural resources, the present movement is more concerned with the sustainable use of resources. The latter incorporates elements of preservation (absolute protection), conservation (using less), efficient resource use, sociology and economics. It has a broader focus than the earlier movements and recognises that, while the continued existence of humans on Earth requires the use of resources, the continued use of resources threatens the existence of humans on Earth.

New Zealand has incorporated the notion of sustainable management in its legislation governing the use of resources by means of s 5 of the Resource Management Act 1991. That section states the core of sustainable management to be:

> *"...managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well being and for their health and safety while -*
>
> *(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and*
>
> *(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and*
>
> *(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment."*

This statement draws heavily on the contemporary thought on sustainability at the time that the Act was being drafted.

Included in those matters that are to be managed sustainably is energy. Energy has been a key component of the functioning of societies since humans discovered fire in prehistoric times. As humans have 'developed', so we have become more dependent on increasingly sophisticated energy conversion processes. Energy is so much a part of modern society that nations are prepared to go to war over it (as evidenced by the Gulf War) and that a minor fault in a transmission system can throw whole cities into chaos.

As the number of users of energy and the means that they have of using energy increase, there is an increasing demand on the primary energy resources that are used to provide the energy forms used by consumers. It is important therefore that energy resources are managed in a way that ensures that those resources continue to provide energy for as long a term as possible. Obviously, given the pervasive nature of energy in society, the old concepts of conservation and preservation are not logical means of managing energy on their own. Adhering to preservation would decrease the range of energy forms that are able to be used and would seriously limit activities in modern societies. While conservation can contribute to the solution, to be effective it would require a major change to the way that modern society functions. As this change is more than most societies could cope with, the answer is therefore to manage energy sustainably. The key components of energy sustainability are the use of renewable energy forms, energy-environment interactions, social factors, security of the supply system, economic factors and efficiency in resource use.

Formulation of a policy objective is only the start of any management process. In order to know whether a particular objective is being achieved or not, it is important for managers to monitor the system that they are managing. One of the most effective monitoring tools is the use of indicators. In order to assess how sustainable the energy system in New Zealand is at present and where the sustainability of the system needs to be improved, a series of indicators will be developed and implemented.

Like any management tool, indicators have their strengths and weaknesses. The strength of indicators lies with their ability to provide detailed information to policy makers in a readily assimilable and concise form. Indicators that reflect the key attributes of the system that is being managed are an important management tool for resource managers, providing managers with information about the state of the system that is being managed and about the efficacy of the management strategies and techniques that are used to manage that system. As such, indicators are a key information tool.

Indicators are not however a method of implementation. They may suggest that a particular course of action or strategy is to be favoured, but they do not bring about the changes that could result from the implementation of that strategy. Rather, they provide the background for those methods.

While indicators are a useful tool, capable of providing significant amounts of detailed information, there can be a tendency to adopt a 'kitchen sink' approach and include as much information about a system as can be collected. Such an approach is not a recommended way of using indicators. Instead, consideration and discernment are required in the selection of the indicators to avoid inefficiencies and 'information overload'.

The final limitation of indicators is that they cannot always represent all matters that are of interest or of use to policy makers. This situation can arise either because of the cost of data collection or because of the nature of the concept in question. The first limitation is ultimately a question of cost, although in the short run available data can be a limitation. The second limitation is a conceptual question about the nature of various phenomenon and can be insurmountable.

As stated above, the purpose of this thesis is to develop a series of indicators that measure the key components of energy sustainability in New Zealand and to analyse those indicators. In doing so, it will be instructive to look firstly at the history of the development of indicators and the use of indicators as a management tool (chapter two). The key criteria for the development of indicators are detailed in chapter three. These are the technical requirements that ensure that the indicators provide managers with true signals about the state of the system. A definition of the concept of energy sustainability is also required to ensure that policy makers are receiving the correct signals about the energy supply and demand system in New Zealand (chapter four).

The efforts of other countries and international organisations in monitoring the sustainable management of energy provide a useful indication of the techniques that can be employed, the difficulties that can be encountered and the methods that can be used to make the task as smooth as possible. Similarly, there are various bodies in New Zealand that are also monitoring some part of the energy supply and demand system, and with it some components of the overall concept of energy sustainability. Studying these monitoring regimes reveals what base information is available in New Zealand and may also indicate areas where it is possible to extend existing monitoring regimes to provide a full system of energy sustainability monitoring. These surveys are the subject of chapters five and six.

Chapters seven and eight develop the series of indicators that will be used in this thesis to monitor the current efficacy of sustainable energy management in New Zealand. These indicators will be developed by applying the criteria of indicator selection from chapter three to the components of energy sustainability that are identified in chapter four. The design of these indicators is also influenced by the requirements of the New Zealand system and by recognition of the fact that energy sustainability is a constantly evolving concept. Those indicators for which there is sufficient base information available at present will be developed and the trends that they illustrate will be analysed in chapter nine. An overall conclusion of the issues that are raised in this thesis is contained in chapter ten.

At all stages in this thesis, it is important to note that the suggested indicators are only one of a range of possible solutions that are appropriate to measure concerns that exist at present. Those concerns will change over time, meaning that the shape of the monitoring regime should change with them. Despite this qualification, the series of indicators that are presented here are appropriate as a measure of the sustainability of New Zealand's energy use, as they draw on an accepted definition of sustainability and comply with accepted criteria of indicator design.

CHAPTER TWO

# HISTORY OF THE USE OF INDICATORS

Indicators can be defined as being closely related to statistics.[1] In fact, indicators can be viewed as being simply statistics put to a specific use or alternatively as statistics measuring intangible phenomena.[2] Any history of indicators will therefore contain a considerable amount of information about the development of the use of statistics. A further factor contributing to this is the fact that the various 'indicator movements' owe their existence to the use (and possibly also the abuse) of statistics in various fields. As a result, the following is a history of the use of statistics at least as much as it is a history of the use of indicators.

The word statistic is derived from Greek and means 'matters of state'. It is therefore not surprising to find that statistics are used in the management and government of national and international affairs. Indicator is derived from the Latin word 'indicare' meaning 'to show'. This root implies that the main function of indicators should be to measure and describe matters so as to draw attention to particular concerns and enable action can be taken to address the issue as required. Setting the course of action that is to be taken is beyond the realm of indicators, despite the fact that any course that is followed will be founded on the information that the indicators may provide.

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[1] *The information about indicators in general and social indicators in particular that is included in this section is an amalgam of a number of books. Since they all have very similar content, it is difficult to assign a particular piece of information to any one author. Instead, the books that were used will be acknowledged in the bibliography.*

[2] *A fuller discussion of this concept is contained in chapter three, dealing with the definition and requirements for developing indicators.*

Quantification has been around in some form or other in human society since the earliest days of the ordering of those societies. The majority of that quantification has focused on social aspects, with less attention paid to economic and environmental factors. This is a reflection on the development of society and of those disciplines more than a reflection on any particular aspect of indicators. The need for quantification in human life gained impetus with the move away from a purely subsistence lifestyle to one involving trade of surplus production. One of the first major uses of quantification was in the calculation of tithes paid to chiefs and other land owning classes.

The earliest records of a census being taken date from 3000 BC in Egypt. There are also references in the bible to David numbering his people and to Herod's census.

One of the most well known collections of data about society and life within that society is William the Conqueror's Domesday Book. This was a systematic record of the resources of all of the people in the newly conquered England. It is however not regarded as a statistical analysis, being viewed instead as a quantification of the population. This is because the main purpose of the survey was the calculation of entitlements and tithes rather than an analysis of any particular aspect of society at that time.

The first statistical enquiries are generally acknowledged as having been conducted in seventeenth century England. They were inspired by two markedly different desires for knowledge. The first was for purposes of international trade and was due to the position of England as the centre of commerce in the western world at that time. The second reason for collecting statistics was to enable monitoring of the effects of the various plagues that were afflicting the seventeenth century world. This led to the development of mortality statistics.

The earliest recorded use of social statistics was by Gaunt in 1662, involving the collection of mortality statistics. This work was updated in 1690 by Halley. Similar work was done by Petty in 1690. Petty had argued for the increased use of statistics in 1662, although it is uncertain how successful he was.

Petty can be viewed as the father of national income accounting, the main area of use of economic indicators. In his book 'Political Arithmetick' published in 1690, Petty tried to establish a statistical basis for economic discussion by using "Terms of Number, Weight, or Measure" instead of "using only comparative and superlative Words".[3]

The next major use of statistics was a calculation of the size of the population of England in 1695 in order to work out the tax yield.

Throughout the eighteenth and early nineteenth century, statistics were used by a number of English rulers, largely for gathering information related to military purposes. Examples of the uses that the data was put to include calculating the size of the army that could be called upon, the amount of food needed to feed the population and the level of benefit relief required by the poor and dependents of servicemen. This exercise can be viewed as the first use of indicators (as distinct from statistics), as there was a degree of interpretation and measurement of intangible phenomena. The question of whether this or the collection programmes of the statistical societies in nineteenth century England (see overleaf) are viewed as being the first use of indicators depends on whether the monitoring can be said to involve application and interpretation or whether it just involved mathematical calculations.

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[3] *Quoted in 'Alternative Economic Indicators', V. Anderson, Routledge, London, 1991, p. 16.*

The French Revolution brought about a great number of changes in French society, not least of which was the creation of a new ruling class. The people who were now charged with the task of ruling France were largely inexperienced and had little of the information that had been available to their predecessors. The demands that they faced from the newly liberated populace were also different to those faced by the autocrats who went before them. To help them in their governing of the people, the French Constituent Assembly therefore ordered that a census be taken and statistical information be collected.

The notion of taking a census focused initially on solely human dimensions. By the early nineteenth century however, the United States of America was including economic information in its censuses, measuring the balance of trade, gold production[4] and acreage devoted to various important crops. The industrial revolution gave the collection and analysis of a wide range of social and economic information further impetus.

In the 1830's, a number of statistical societies appeared in various English cities. They were established with the intention of collecting data to enable the members of those societies to bring about social reform. This movement is viewed by many as the first use of social indicators (as opposed to social statistics), as the aim of the data collection was to enable some intangible phenomenon (the 'state of society') to be measured. Proponents of this theory argue that, by contrast, the earlier data collection efforts were essentially efforts at quantification for use in simple mathematical abstractions about society or its finances. Despite their lofty aims, the statistical societies were short lived, with the movement dying in the 1840's.

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[4] *This could have been measured for its own sake or a measure of relative exchange rates, as this was the period when the world operated on the 'gold standard' to calculate foreign exchange.*

The use of statistics or indicators to measure society and bring about social change came into vogue again in the 1880's. Hyndman, an English socialist, set about measuring poverty in London. His results met with such scepticism when they were published, that, in the best of political traditions, another study was undertaken to attempt to disprove them. The results of this study so shocked its author (Booth) that he ended up agreeing with Hyndman's conclusion. Further studies were carried out at this time by Bowley and Rowntree, leading to the development of the use of the sample survey by Bowley.

Environmental monitoring had its genesis in the eighteenth century as well.[5] There is not however the same certainty about the origins of environmental statistics and indicators as there is regarding social statistics. The first monitoring studies collected information about geological and oceanographic features as well as systematic observations of the health of soil and forests. These studies were mainly conducted in the more scientifically advanced countries of the time. Environmental indicators did not enjoy the more widespread usage that social indicators did at this time and continued to be used for largely academic purposes until after the Stockholm conference on the environment in 1972.[6]

The first of the 'indicator movements' was the social indicator movement. These movements were (and in some cases still are) concerted pushes for increasing the scope of indicator use. The movements have usually accompanied a major development in the boundaries of a particular field. The social indicator movement started in the early twentieth century. Its two main protagonists were an economist, Pigou, and a sociologist, Ogburn. Both were dissatisfied with the efficacy of economics and its inability to explain a number of socio-

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[5] *'The Quest for World Environmental Co-operation:The case of the UN Global Environmental Monitoring System', B. Gosovic, Routledge Press, London, p. 35.*

[6] *Gosovic, above, p. 35.*

economic concepts. They were also inspired by the success that economic statistics had enjoyed, whereby measures such as the Harvard ABC Business Cycle indicators were being used extensively in the United States. Pigou mainly worked 'inside' economics in an attempt to bring it around to his viewpoint, while Ogburn set about finding new ways of measuring the concepts that he considered to be relevant, but which were being overlooked. Ogburn wanted to be able to use statistics for social planning and forecasting and, as a result of his efforts, was given the chair of the Research Committee on Social Trends in 1929. That Committee published a number of reports, most of which were largely ignored.

The work of Ogburn and others in the early social indicators movement received renewed interest in the 1960's from the Kennedy administration. The biggest boost for the use of social indicators came from the National Aeronautical and Space Administration (NASA). NASA wanted to study the second level (or flow-on) effects of the space programme on American society but was unable to do so because of a lack of social data. This led to a raft of reports from other Federal Departments seeking to measure the particular social features that were of interest to them. Studies into flow-on effects occurred in universities and research organisations around the world with the interest in social indicators increasing until the mid-1970's. After 1975, the interest in social indicators waned for all but international development work in the Less Developed Countries.

The development of economic indicators received a boost from two distinct and in many ways distinctly opposite events. The first influence was the Depression. This sparked the development and acceptance of Keynesian macro-economics. Before this time, economics largely focused on micro level concerns, addressing individual consumers rather than the functioning of the economy as a whole. National income accounting was viewed as a more efficient system of data collection than the system that was currently in use, rather than as an end in itself. Keynes' emphasis on aggregate real income and references to national income in his 'General Theory' led to a greater theoretical significance being given to national income. The Second World War saw further developments and refinements of Keynes' theories.[7] The data requirements of Keynes' 'General Theory' shaped the data collection regimes of many governments for a great deal of the post-war period.

The second major impetus in the development of economic indicators was the technological and economic effects of the two world wars. The United States set about developing national accounts at the end of the First World War. By contrast, the other major economic power of the time, the United Kingdom, did not fully embrace national income accounting until the Second World War.[8] The reason for the twenty five year difference in the introduction of national accounting by each of these countries has not been explained. As noted above, Keynesian economics developed greatly under the effects of the Second World War. The two world wars led to a number of changes in world trading patterns and habits. In addition, the Second World War led to the establishment of the United Nations and the International Monetary Fund. These organisations proved to be a catalyst for the development of macro-economic indicators, so much so that today most countries measure their national economic output according to the United Nations' model of Standard National Accounts.

The economic indicators that have been used for the majority of this century are a product of the environments that led to their development and the concerns that dominated at those times. Those concerns were government finance and unemployment.[9] Therefore, economic

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[7] *Anderson, above, pp, 17-18.*

[8] *Anderson, above, p. 16.*

[9] *Anderson, above, p. 18.*

indicators are able to handle the information needs of users who are concerned with these factors very well. The problems that have arisen with the use of economic indicators have arisen not because of some fault in the design of the indicators themselves but in the application of those indicators in areas other than those for which they were designed.

The inappropriate application of economic indicators has led to calls for the development of alternative indicators that take account of the demands that the world faces in the 1990's and beyond. These new indicators take more account of the relationship between economics and the social and environmental sciences.[10]

Environmental indicators came to the notice of the world through the efforts of Maurice Strong and his colleagues at the Stockholm Conference in 1970 and the famous (or infamous, depending on one's outlook) 'Limits to Growth' model developed by Forrester and Meadows.[11] The type of environmental monitoring that was carried out in these two instances needs to be contrasted with the purely scientific type of monitoring that has been carried out by scientists for a long period of time. The former is aimed at policy makers and governments rather than 'technicians'. As a result, it is somewhat simpler than its forerunners and is also more comprehensive in its focus. This means that it focuses more on the totality of a system, rather than just taking a particular spatial or temporal step and taking the rest of the system 'as read'.

The next, some would say logical, step in the development of indicators is the marrying together of these three classes of indicators (that is, economic, environmental and social indicators). These calls for amalgamation came as a result of the Bruntland Report released

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[10] *For example, Anderson, above or the World Bank's Human Development Index.*

[11] *'Limits to Growth', Meadows, et al., Pan Books, 1972.*

in the mid-1980's.[12] There the notion of sustainability was first mooted to a global audience. It dealt with the superficially contradictory issue of pursuing social and economic goals within the constraints imposed by the natural environment. Much has been said about the need to develop indicators of sustainability and workshops have been held by a number of international organisations in an attempt to develop workable sets of indicators. Progress has been hampered by a number of factors, the most fundamental of which is a lack of agreement about the definition of the word 'sustainability'. Another significant stumbling block is the difficulty in measuring some of the concepts that comprise sustainability. Further complications include the lack of available data and the unwillingness of many governments to undertake the work needed to collect the data. This is a reflection of the prevailing political attitude that the role of government in the economy should be minimised. The positions of the Developed and Less Developed Countries also cause problems. These are more closely related to the development of a definition of sustainability, with Less Developed Countries often arguing for less of a role for environmental protection so as not to cut off possible paths to development. Developed Countries meanwhile argue for greater protection, a position that they can easily take now that they have had the advantage of often unrestricted access to resources. In many ways, the crux of the problem is finding the right balance.

From this brief summary of the use of indicators since their inception, it is clear that they are capable of being applied to many different policy management areas. However, to be able to successfully identify policy needs for a particular area, it is crucial that the nature of indicators be well known and that they be developed according to well defined selection criteria. Both of these matters are the subject of the next chapter.

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[12] *'Our Common Future', United Nations Commission for the Environment and Development, Oxford University Press, 1987.*

CHAPTER THREE

# DEFINITION, NATURE AND DEVELOPMENT OF INDICATORS

Although indicators can be a powerful tool for a policy analyst, like any other technique, they have their limitations. While it is trite to say so, the efficacy of indicators is directly related to the quality of their construction. Indicators that comply with the guidelines that have been developed by the authors who are discussed in this chapter generally provide a clearer picture of the phenomenon that is measured than those that do not follow these guidelines. It should be noted however that there are differences between the sets of criteria and that no one set of criteria covers all of the requirements of effective indicator design. The purpose of this chapter is therefore to critically analyse those authors' expressions of the criteria of indicator development before developing a set of criteria that draws on this body of work. Before doing that however, the definition and various aspects of the nature of indicators will be discussed.

## DEFINITION AND NATURE OF INDICATORS

At the most basic level, an indicator is a number that has a meaning beyond mere cardinal value. Indicators have been defined as statistics[13], arbitrary constructs[14], measurements[15] and

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[13] *'Development of Indicators of Environmental Quality', ACIL Australia Pty. Ltd., 1987 and 'Indicators of Sustainable Energy Development', J. Wright, Centre for Resource Management Information Paper No. 28, July 1991.*

[14] *'Economic and Social Measurement Processes Some Questions of Public Policy Indicator Design', A.M. Endes, M.Soc.Sci. Thesis, University of Waikato, 1980.*

quantitative descriptors[16]. Whilst all of these definitions apply to aspects that are a part of the nature of indicators, arguably the last description most completely captures the essential nature of indicators. Their purpose is to measure and describe matters that policy makers and others wish to focus attention on. As such, indicators are not valuable in themselves, rather, they are valuable for what they say about the phenomenon in question. In that regard, they are an "alternative, surrogate or proxy" for a phenomenon that is technically difficult to observe or record[17].

The Ministry for the Environment definition noted above emphasises the fact that the phenomenon in question is unable to be directly measured.[18] This is true for many instances of environmental indicators but is not necessarily true for all indicators. When one uses indicators such as carbon dioxide emissions or numbers of certain species of animals in a particular geographic area, one is using those measures and interpolating that information to make an inference about the state of the environment (that is, global warming or general ecosystem health, respectively). However when one measures price level changes of a basket of commonly purchased goods, as is done in the calculation of the consumer price index, one is measuring the change in price level (or inflation) directly.[19]

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[15] *'Energy Efficiency Monitoring: An Evaluation of Possible Indicators and Implementation Options', M. Patterson, Unpublished Draft, 1993 and 'Reporting State of the Environment Information', Ministry for the Environment and Department of Statistics, November 1991.*

[16] *'Towards Sustainable Development Indicators', H. Opschoor and L. Reijnders in 'In Search of Indicators of Sustainable Development', O. Kuik and H. Verbruggen, Kluwer Academic Publishers, The Netherlands, 1991.*

[17] *Ministry for the Environment and Department of Statistics, p. 22.*

[18] *That definition, at p. 22 of the report, defines indicators as "a variable used to measure the presence or condition of a phenomenon that is not able to be measured directly".*

[19] *Arguably, the consumer price index is different from the change in the price of an individual good, due to the process of aggregation and mathematics required in the calculation of the index, so that it can still be said to be a proxy for an unrecordable event. This argument is however weaker than is the case with the environmental indicators discussed above.*

In so far as indicators are quantitative descriptors of qualitative factors, the Ministry for the Environment definition is appropriate. When however the indicators refer to a more quantitative phenomenon, such as the rate of inflation, the definition over-emphasises the need for a separation between the indicator and the factor being measured. The distinction in the instant example is muddied somewhat by the fact that inflation is used as an indicator of the overall macroeconomic health of a nation as well as having a value in itself (for example, as a comparison value to assist investors in calculating their real income).

This relationship between a concept and the indicator that measures it can be more appropriately described as being one in which the indicator condenses information about the concept.[20] The role of condensing information is also noted in the lengthy definition used by Dialogue Consultants, which refers to indicators as being:

> "established objectively through dialogue and critical hermeneutic analysis".[21]

Similarly, Endes talks of:

> "collecting and interpreting empirical data so as to provide a connection to a contingent variable"[22]

and the requirement that the indicator be distinguished from the indicated.[23] While each of these definitions still acknowledges the potential for division between the indicator and the actual event, they arguably make better allowance for the consumer price index type of situation as there is less emphasis than in the previous definitions.

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[20] *Patterson., p. 13.*

[21] *'Indicators of Sustainable Development', Dialogue Consultants, New Zealand, June 1992, p. 48.*

[22] *Endes, p. 41.*

[23] *Endes, p. 7.*

Patterson[24], Endes[25] and Dialogue Consultants[26] all note the fact that indicators are underlaid by a particular theory or theoretical relationship. Again this point is more applicable to indicators which measure qualitative phenomena. Measuring carbon dioxide emissions in order to gain knowledge of the effects of fossil fuel consumption on the environment is quite clearly based on a theory about the relationship between carbon dioxide and global warming. Measuring the amount of energy required to gain a given physical output so as to be able to judge the efficiency of a use of energy is based not on theory but on a combination of a description of a process and a simple mathematical relationship. The desirability of energy efficiency is based on theory, but the strength of the theory is not what the indicator is setting out to measure. In this regard, Endes especially can be said to overstate the importance of theory. While Endes' statement is appropriate to indicators that are used in an essentially theoretical discipline (in his case, economics), it has less relevance in the more applied disciplines, such as resource management. In these applied disciplines, the role of theory is to ensure that the indicators used have been selected rationally, rather than actually defining the nature of the indicators that have been selected and setting the parameters of the monitoring system.[27]

Wright's definition of indicators, namely that they are thriftily collected and are a compromise between scientific description and the demand for concise information, raises a point that is relevant both in the definition of indicators and in the criteria for selecting indicators.[28] This point has been graphically depicted by Braat, as reproduced in figure one

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[24] *Above, p. 13.*

[25] *Above, p.7.*

[26] *Above, p. 56.*

[27] *Patterson, p. 13.*

[28] *Above, p.4.*

below.[29]

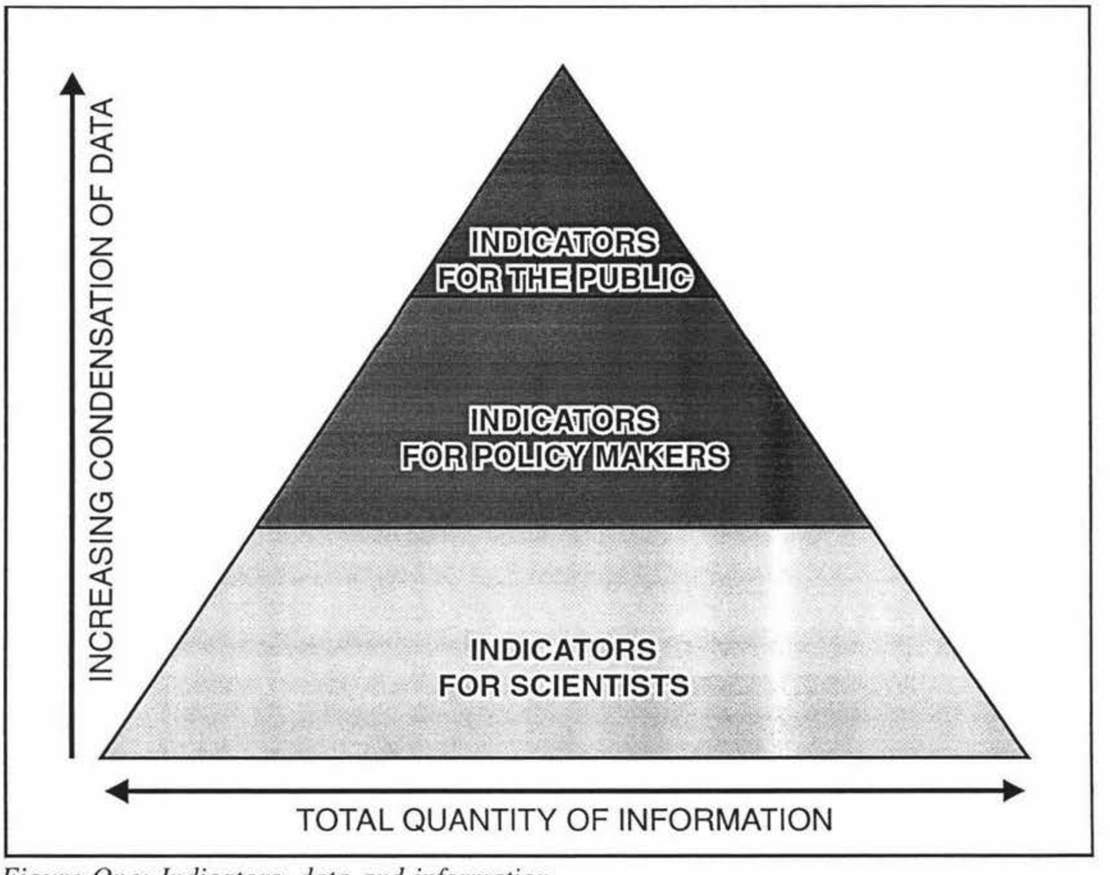


*Figure One: Indicators, data and information*
*(Source: Braat, above)*

Wright and Braat's point is important because indicators are a management tool and a source of information for the individuals and organisations that are affected by that management. In each case, the indicators and their meaning are analysed by people before being acted on as necessary. These people obviously have a limit to their capacity to assimilate information, so that there is no benefit from overloading them with information. Similarly, there is a point where additional information provides less additional guidance - a 'diminishing marginal returns of information' is occurring. In this regard, indicators are unlikely to measure every aspect in a particular area of interest or concern but instead are likely to have

[29] *Braat, p. 59.*

been selected as the most useful of a range of possible measures of the phenomenon. This point is expressed by Dialogue Consultants as being that indicators give specific partial views rather than covering the complete picture.[30]

Whilst indicators are indeed a tool, they are not a complete problem solving process in themselves. Their function is only to illustrate and highlight a particular situation. As such, their greatest use comes in the monitoring process rather than surveys or research[31], a fact that follows naturally from the fact that indicators describe a phenomenon. It also demonstrates a strength in using indicators in policy making, as they draw areas needing attention to the notice of policy makers but do not attempt to prescribe one particular means of solving them. Instead, indicators are designed to monitor conditions at one point in time so that strategies can be developed to address the state of the system which is being monitored. This type of approach is favoured because it enables a number of policy options to be kept open.

Some concepts are unable to be measured by indicators. For example, it is difficult to envisage an indicator that could meaningfully measure the effects of an energy project on Maori cultural values. These effects would be useful to measure in terms of the obligations under the Resource Management Act 1991 but it is difficult to imagine anything more useful than a simple 'yes/no' indication of whether or not these issues have been accounted for.

One final factor that users and creators of indicators should bear in mind is that indicators are not immutable.[32] As the nature of a particular area of interest changes, so the indicators

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[30] *Above, p. 48.*

[31] *ACIL, p. 2.*

[32] *ACIL, p.3.*

that are used to analyse it should change. Failure to do so will lead to decision makers being supplied with incomplete or inappropriate information. This factor is strongly linked with the criteria of good indicator design.

**CLASSIFICATION OF INDICATORS**

There are a number of bases on which indicators can be classified. Holtz talks of simple and composite indicators.[33] The former are direct measures of conditions whilst the latter are ratios or other, often more complicated, mathematical transformations of the raw data. Examples of the former are levels of pollutants or the amount of energy used in New Zealand in a year. The latter includes indicators of energy intensity. Both types of indicators are useful in the area of policy making, although they have different strengths and weaknesses.

It can be argued that all indicators could theoretically be defined as composite indicators, as some authors state that the interpretive value of an indicator is derived from the fact that it describes a condition relative to some desired reference point.[34] In practise the use of reference values is not always possible or desirable. For example, if an indicator refers to a feature that policy makers are attempting to minimise, their perceived minimum value will almost certainly be based on a model of the system in question. This model may involve assumptions and may be limited by the state of contemporary scientific knowledge or knowledge of the system in question. Target figures could therefore be over-stated or under-stated, which will effect policy as a result.

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[33] *The author has been unable to find the reference for this work - the result of moving house four times during the writing of this thesis!*

[34] *Dialogue Consultants, p. 48.*

Another method of classifying indicators is by grouping them on the basis of the time period that they attempt to describe. Braat makes this distinction, referring to predictive and retrospective indicators.[35] Opschoor and Reijnders make the same distinction but refer to the different indicators as factual indicators and potential management indicators.[36] It is submitted that these are not in fact different types of indicators, but that the distinction is actually being made on the basis of the way that the indicators are being used. Braat specifically recognises this distinction when he refers to predictive indicators being limited by the strength of the models underlying them[37], which implies that the indicators are simply ordinary indicators applied to a model of the system under analysis. Indeed it is most likely that, if predictive indicators are so useful to policy makers when applied to a model, they will be the same sort of indicators as are applied to managing the contemporary state of the system that is being modelled. That is, predictive indicators would become retrospective indicators.

It is also difficult to talk of predictive indicators and still remain within the definition of the word indicator. As noted in chapter one, the Latin root of indicator means 'to show'. The ability to forecast in models or to develop scenarios is very different to the ability to show the occurrence of an event with certainty.

A final, largely grammatical, point is raised by Hope and Parker[38], who distinguish between indicators and indices. Drawing on work by Ott[39], Hope and Parker define indicators as

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[35] *'The Predictive Meaning of Sustainability Indicators', L. Braat, p. 57 in Kuik and Verbruggen.*

[36] *Above, p. 21.*

[37] *Above, p. 57.*

[38] *Hope and Parker, p. 314.*

[39] *Ott, W. 'Environmental Indices: Theory and Practise', Ann Arbor, Michigan, 1978.*

being comprised of only one variable and indices as being based on more than one variable or indicator. Whilst this distinction may be of relevance in academic debate, it is of limited utility to decision makers, since indices serve the same purpose as indicators and are developed in the same way. They are subject to the same limitations as indicators and have the same advantages, a fact that necessarily flows from indices being composed of indicators. The one major difference is that since indices are a conglomeration of more than one indicator, they allow more information to be collated and assimilated than would otherwise be the case.[40] As a grammatical point, the use of the word index in this sense can create confusion as to whether the number that is being referred to is a composite indicator or a scaling number used to measure changes in terms of a base.

In this thesis therefore, the term 'indicator' is used to refer to both indicators and indices (using Hope and Parker's naming system). If a distinction is required, the term 'composite indicator' will be used to describe indicators that are comprised of more than one variable.

## CRITERIA FOR INDICATOR SELECTION

Although the question of how to develop an effective indicator is central to any attempt to develop indicators, there appears to be no single set of agreed criteria. Whilst all of the expressions of the essential criteria discussed here have some aspects in common, there are a number of fundamental differences. It is also submitted that none of the formulations cover all of the essential criteria.

As there is a limited amount of literature available dealing solely with indicators of

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[40] *As noted above however, there is a limit to the amount of information that can be presented in any one measure before users become overloaded with information.*

sustainability[41], the following is drawn from data regarding the development of indicators for a wide range of purposes. The general principles are applicable here even though the specifics of each case may be different.

The most frequently cited list of fundamental characteristics of indicators is the one that was developed by Liverman et al.[42] They identify nine criteria, namely:

(1) sensitivity to change in time (that is, the ability to show trends and enable cyclical effects to be isolated);

(2) sensitivity to change across space or within groups (this draws attention to effects that are hidden when one looks only at averages and often means focusing on the most sensitive groups);

(3) indicators are predictive or anticipatory (this can be achieved by extrapolating a time series or focusing on an event that will preface another event);

(4) availability of reference or threshold values;

(5) absence of bias (although they do recognise that value judgements are always present);

(6) reversibility or controllability (that is, the indicators show whether the changes taking place are reversible or controllable);

(7) appropriate data transformation (the raw data is in a form that provides as much useful information as possible);

(8) indicators are integrative (that is, individual indicators can be aggregated. However, this leads to the problem of assigning weights);

(9) relative ease of collection and use.

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[41] *As noted by Dialogue Consultants at p. 9 of their report.*

[42] *'Global Sustainability: Towards Measurement', Liverman, et. al., Environmental Management, 12:2 1988, pp. 133-143, at pp. 135-137.*

These criteria are all important in the creation of indicators and are largely uncontroversial. The first two criteria could however be amalgamated, as their combined effect can be succinctly expressed as ensuring that the indicator shows spatial and temporal trends.

These criteria omit some considerations which are still important. For example, there is no mention of ensuring that there are actual or theoretical links between the indicator and the phenomenon being indicated. This is crucial as, if the factor in question is not affected by the factor measured by the indicator, then the indicator is not suitable for that task. While the matters contained in requirements one and two do incorporate these matters, the requirement of linkages to the phenomenon go beyond this by ensuring that the supposed links that exist do actually exist in a system.

A further advantage of including a requirement that the indicators are linked to the system in question is that requirement three is replaced with a factor that is more correctly a requirement of indicator design than one which is more concerned with the way that indicators are used. As it stands, as noted in the first half of this chapter, the requirement that indicators are predictive is more a reflection on their ability to be used in a model than of their linkages with the system that is being modelled. By replacing criteria three with the requirement that indicators are linked to the system that is monitored, a greater degree of rigour is achieved, while retaining the ability to use indicators for modelling purposes.

The requirement of reversibility or controllability (requirement six) is puzzling. Liverman justifies this requirement by saying that it is critical from a management point of view to identify indicators that reveal if impacts are reversible and changeable.[43] Whilst there are advantages to resource managers or policy makers in knowing whether certain effects are

[43] *Liverman et al., p. 136.*

reversible, it is not a necessary condition for managing all effects. Similarly, the presence or absence of reversibility does not decrease the phenomenon's relevance. Indeed Liverman accepts this in the very next sentence when she says that:

> "Perhaps the most important changes to life support systems are those which involve a permanent and irreversible shift in conditions".[44]

From this it is apparent that reversibility is not an essential characteristic of a good indicator.

The condition of knowing whether or not a change is controllable appears to be similarly redundant. If a factor is not controllable, then it should not be a focus for monitoring and management activities since these will, by definition, be ineffective. By including this criterion, Liverman appears to be confused about the nature of indicators. As noted earlier, they are not a complete management process. Rather they are a monitoring tool; a media.[45] This criterion belongs instead in the early stages of the development of a management program, where the scope of the programme is set.

The requirement of being able to refer to threshold or reference values is less a criterion of indicator design than it is a function of indicators themselves. Liverman describes this requirement as establishing contextual information that the monitoring programme can operate within. These values must however be established either by reference to the theory that underlies the indicator (the additional condition discussed above), or are provided by indicators themselves. After the monitoring programme has been established, the latter situation becomes increasingly prevalent. Given this fact and the additional benefits to the rigour of developing indicators from the additional criteria discussed above, it is submitted that this criterion is unnecessary.

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[44] *Liverman et al., p. 136.*

[45] *Dialogue Consultants, p. 48.*

Another extensive list of criteria is provided by ACIL in its 1987 report for the Ministry of Planning and the Environment in Victoria, Australia.[46] ACIL's criteria (which are directed at environmental indicators) are:

(1) be applicable to the whole of the defined segment of the environment (that is, in general terms, they are applicable to the phenomenon to be measured);

(2) based on the critical attributes of the ecosystem to be measured (that is, they are developed by firstly observing the operation of the system under review);

(3) based, where practical, on existing programs of data collection, data storage and the like (this is similar to Liverman's point nine, with additional emphasis on the cost involved in the collection of data);

(4) relate directly to the stated quality objective and to the ecosystem being monitored. One should therefore ask what parameters adequately describe the system, which best demonstrate changes in conditions and how many lines of evidence are needed to validate the conclusions reached;

(5) enable temporal and spatial trends to be assessed (this is Liverman's points one and two);

(6) optimise information and cost effectiveness in the measurement of environmental quality objectives;

(7) facilitate broad community environmental quality assessment and awareness;

(8) the relationship between environmental quality and the indicator is known and linear over the full range of measurement (the requirement of linearity is stated as being important when it comes to formulating policies in response to the trends illustrated by indicators);

(9) be measurable and relatively unsophisticated, inexpensive, quick, accurate and readily available methods and equipment (this is a requirement of timeliness).

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[46] *Above., p. 33.*

In many ways, these criteria are more practical than Liverman's and place greater emphasis on the link between a system or the theory that underpins a system and the indicator itself. Again however critical criteria are missing. One of the most fundamental criteria that has been omitted is the requirement that the indicator be unbiased. There are also no requirements ensuring that the indicators are in a form that the decision makers find most useful.

ACIL's point three, stating that indicators should, where practical, draw on existing data is somewhat puzzling. Obviously there are advantages in doing so, both in terms of cost and timeliness. However, whether the necessary data is or is not collected should not determine how effective a particular indicator is considered to be. The availability of existing data should be taken more as a reflection on the statistics collectors and the efficacy and scope of existing management programs rather than on the quality of a particular indicator. Further, with new monitoring systems, there is a necessary implication that some matters will not be the subject of data collection.

Care must be taken with ACIL's point one to ensure that the 'defined segment of the environment' is carefully and clearly defined. If this was not the case, the indicators developed could be too broad or too narrow and would therefore be meaningless.

The next most extensive list of characteristics has been developed by Braat.[47] That list requires that indicators:

(1) are in an attractive format (that is, it is designed with a specific target group in mind. Aspects of this are similar to Liverman's point seven);

(2) are representative of the chosen system (this is ACIL's point two);

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[47] *Above, pp. 59-61.*

(3) are developed from a scientific basis (this is similar to ACIL's point eight);

(4) are quantifiable;

(5) include reference or threshold values (Liverman's point four);

(6) provide information without social bias (Liverman's point five);

(7) represent reversible and manageable processes (Liverman's point six);

(8) should have predictive meaning (Liverman's point three).

Braat makes the same point regarding reversibility that Liverman et al do. Again, it can be argued that this is not appropriate to the development of indicators but is rather a part of the process of setting the overall focus for the management system. He makes no reference to the ability of the indicators to demonstrate spatial and temporal trends. Apart from this omission, his list is essentially a conglomeration of many of the most fundamental points from the two previous lists.

The inclusion of criterion four is somewhat unnecessary, given the nature of the definition of indicators (see above). By definition, indicators are a quantification of a phenomenon. If a phenomenon cannot be expressed in numerical terms, then, by definition, it cannot be represented by an indicator, negating any considerations of the quality of indicators.

Patterson's list, prepared for the Energy Efficiency and Conservation Authority, contains seven points.[48] Those points are:

(1) clarity of the message (that is, the potential audience is able to understand what the indicator is supposed to say);

(2) scientific basis (this is to be made explicit and aims to minimise theoretical shortcomings);

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[48] *Above, pp. 15-16.*

(3) free of bias (Liverman's point five);

(4) appropriate data transformation (Liverman's point seven);

(5) timeliness (ACIL's point nine);

(6) data cost and availability (a combination of Liverman's point nine and ACIL's point three and nine);

(7) efficient representation of a concept.

This formulation explicitly considers the requirements of the users in measuring the efficacy of the intended indicators. It does however omit some of the important factors contained in the other formulations. Key amongst those is the notion of the indicators being able to show temporal and spatial trends. Similarly, there is no mention of the ability to aggregate the indicators.

## CRITERIA USED FOR INDICATOR SELECTION IN THIS THESIS

Given the various authors' formulations of the criteria for developing effective indicators and the criticisms made of those lists, the following list has been compiled, containing what are considered to be the key requirements to be adhered to in the development of indicators. This list draws from the work of all of the authors mentioned above. The criteria are in no particular order.

**(1) Indicators are representative of the system being assessed and are based on the critical attributes of that system.**

This criterion ensures that the exact relationship between the indicator and the attribute being measured is known throughout the full range of possible values. If indicators are not representative of the system being measured, they will be of limited use to their target audience. This criterion is similar to saying that policy makers should know what it is that they are trying to measure before they set out to measure it. It also recognises that there are limitations on the scope of indicators and that it is not always possible to measure all aspects of more complex systems. In ensuring that the indicators are representative of the system being measured, both scientific exposition and observation are important. The basic notion is to draw on science for a theoretical understanding of the working of the particular system and to validate that theory as far as possible by observation, so as to compensate for the weaknesses of each method to the fullest extent practicable.

**(2) Enable spatial and temporal trends to be assessed.**

By definition, indicators are concerned with on-going or persistent phenomena. This statement applies equally to indicators that are designed to provide a snap-shot of a particular event (such as unemployment figures) as it does of indicators that are designed to enable forecasts to be made (such as weather information). It does not imply that indicators are required to be used in a forecast. One aspect that is built into this requirement is that the indicators are collected over a period of time or over a defined geographic area (or both). In making this statement, the distinction between establishing baseline values and monitoring phenomenon must be borne in mind. As all indicators are intended to be able to show how the parameter that they measure changes due to the passage of time or variations that exist in the conditions that exist in the system, failing this test will mean that the indicators will be of no use to policy makers.

(3) **Optimise information and cost effectiveness.**

All users of information operate in a system that is constrained to some degree, so that any system of indicators that is intended to be of practical use must be mindful of the availability of resources. As a result, it is often worthwhile initially developing a system that is based as much as is practical on existing data collection. This criterion does not mean that no new data should ever be collected, just that consideration should be given to whether it needs to be collected or whether the same results can be achieved by manipulating existing data.

Optimising information must be distinguished from the concept of including more information. As discussed above, there is a point beyond which adding additional information serves only to complicate matters rather than providing illumination. Optimisation of information means providing sufficient information without exceeding that point.

Another side to optimising information is the issue of timeliness. There is no point in preparing indicators that provide all of the information that a policy maker could possibly want if the information is out of date by the time that the indicators are constructed. There is therefore a trade off between the information content of the indicators and the time limitations under which they must be prepared.

Cost effectiveness and optimisation of information need to be balanced against each other, as very often more information comes as a result of increased cost. It is also important to consider these matters both for individual indicators and for the monitoring system as a whole. A global viewpoint applies especially to the matter of information effectiveness as it may be possible to sacrifice some detail in one aspect of the monitoring system and regain the information (or an adequate proxy) somewhere else.

### (4) Indicators should give an unbiased message.

All policy work will necessarily reflect both the biases of the participants and the climate in which the work is conducted. These influences are an unavoidable consequence of human nature. Further subjectivity can be introduced into systems if there is debate over a theory or over the exact nature of a system. It is therefore often difficult to achieve a completely unbiased set of indicators when the system is viewed from first principles.

The requirement can however be achieved by ensuring that, once the broad parameters of the system are set, the indicator regime operates objectively. This concept has been defined by Babbie as 'intersubjectivity'.[49] This criterion does not however imply that all users of the indicators will then always interpret the indicators in the same way. As noted above, different conclusions are an unavoidable concomitant of indicators being used by people in the policy making environment.

This criterion is also related to the fact that the indicators should be linked to the particular phenomenon that they are designed to measure (although that requirement alone will not ensure intersubjectivity).

### (5) Clarity of message.

It is a recognised concept in communication theory that how well a message is received

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[49] *'The Practise of Social Research', E. R. Babbie, Wadsworth Publishing Company, Belmont, California, 1975, p. 40.*

depends on the nature of the message as well as nature of the sender and receiver of that message. All of the other criteria in this list of criteria are concerned with the nature or quality of the message being sent. This criterion is concerned with ensuring that the receiver of the message receives it in a form that they can readily understand and can use. Consideration must therefore be given to the strengths and weaknesses of the receiver of the message. These include factors such as the amount of time and attention that is able to be given to this particular message, their level of education and experience with the concepts and their disposition towards the concepts (especially relevant with a highly politicised message).

The core of this requirement is that the information is provided in the form that users want.[50] Very often satisfying this requirement is a simple matter of converting data into the form of a ratio or calculating percentages. In some cases, the raw data itself will suffice. Providing information in the form of raw data may not however always be the most appropriate means of communicating a message, as illustrated by the continuing debate over accounting for energy quality. What is appropriate in any given situation will be determined by the factors that are noted earlier in this section.

This criterion can result in a series of information trade-offs, especially if the information is being prepared for a heterogeneous audience. One way of solving the problem of heterogeneity of the audience is to develop a series of indicators that can be aggregated to cater to the needs of those target groups that require less detailed information. If this approach is to be taken, point six (below) will need to be considered.

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[50] *This requirement applies to the nature of the data only, not to the substance of the data. Altering the data to provide the answers that a user of the information wants subverts the requirement of absence of bias.*

**(6) Be integrative.**

As noted earlier, there are two major types of indicators, simple indicators and indicators that are formed by aggregating a number of more detailed indicators to provide an overall picture of a system or part of a system. This ability to aggregate can be a useful means of providing a large amount of information in a concise form. Ensuring that the indicators that are developed can be aggregated enables them to gain an overall view of the system whilst also enabling them to concentrate on the aspects of the system that are of more concern to them. It is also a means of overcoming the problem of the decreasing level of scientific information that is required as the user of the information is further divorced from the management programme.

Despite its inclusion in the list of criteria, this last criterion does not always need to be adhered to. In some instances, it is not always possible to meaningfully integrate or aggregate indicators, due to the nature of the phenomena being measured. If the concepts are relatively homogeneous, it is easier to aggregate a number of different indicators. If however the concepts are diverse, aggregation becomes much more difficult. It can become meaningless to aggregate some of the indicators, so that the condition of optimising information would be contradicted if one attempted to do so. The decision of whether or not to adhere to this criterion is one that should be taken in the early stages of defining the whole monitoring programme.

In summary therefore, the list of criteria for designing indicators is:

(1) indicators are representative of the system being assessed and are based on the critical attributes of that system;

(2) enable spatial and temporal trends to be assessed;

(3) optimise information and cost effectiveness;

(4) give an unbiased message;

(5) clarity of message;

(6) be integrative.

Given this list of criteria, the next major step is to apply those criteria to developing a series of indicators that can be used to measure the sustainability of energy usage in New Zealand. Before doing that however, it will be necessary to define the scope of the issue of energy sustainability for the purposes of this exercise and the components of energy sustainability that should be monitored in New Zealand. The next chapter is devoted to those two tasks.

CHAPTER FOUR

# TOWARDS A DEFINITION OF ENERGY SUSTAINABILITY

Before any attempt can be made to develop a set of indicators that comply with the criteria set down in the previous chapter, the term 'energy sustainability' must itself be defined. Despite the large amount of attention given to the notion of sustainability as a whole, there is surprisingly little detailed material dealing with operationalising the specifics of energy sustainability. Partly, this situation has arisen because each of the components of energy sustainability can quite easily be regarded as a complete subject area in itself. The result is that much of the literature deals with the individual aspects that would be commonly accepted as comprising a part of the definition in depth, without considering energy sustainability as a whole. Another short-coming of the literature on energy sustainability is one that applies to sustainable management as well, namely that the term is used as an empty referent. While the lack of specificity allows the precise nature of the definition to be adapted to suit the needs of each individual situation, it can stifle the development of constructive debate as different interest groups can take definitions as they choose.

In this thesis, it is not intended to become immersed in the debate over which definition of the word 'sustainability' is the best. To do so would add little or nothing to the practical issue of addressing the sustainable management of energy in New Zealand. Instead, the definition of sustainability that is contained in the Resource Management Act 1991 will be used. This definition has been chosen because of the level of debate that surrounded its development and the fact that it is derived from internationally recognised definitions of sustainable management. The fact that the definition is contained in the legislation that governs the management of energy resources (as opposed to the minerals that contain that energy) adds further weight to the use of this definition.[51] It is also related to the definition that the Government included in its report to UNCED.[52] The combined effect of these factors is a robust and substantial definition of sustainable management.[53]

As noted in chapter one, sustainable management is defined in s 5 of the Resource Management Act 1991 as:

> *"...managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic, and cultural well being and for their health and safety while -*
>
> *(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and*
>
> *(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and*
>
> *(c) Avoiding, remedying, or mitigating any adverse effects of activities on the environment."*

This definition can apply to sustainable energy management without any modification if the definition of 'natural and physical resources' that is used in the Act[54] is used in this thesis. The definition also directs attention to both the supply and demand sides of the energy system, which is appropriate given that the achievement of a sustainable energy system will

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[51] *In making this comment, it is noted that a number of local authorities have concluded that the management of energy is not a part of their core business. Notwithstanding that position, the inclusion of energy within the natural and physical resources that the Act applies to means that energy management fits completely within the Resource Management Act 1991 framework.*

[52] *'Forging the Links: New Zealand's National Report to the United Nations Conference on the Environment and Development', Ministry for the Environment, 1991.*

[53] *The debate concerning s 5 (such as the argument over the scope of 'environment' in ss 5(2)(c) and the effect of the word 'while') can be put to one side. Rather, the key function of this section for present purposes is to indicate those matters that come within the scope of the definition of sustainable energy management.*

[54] *That definition includes energy and minerals as part of the natural and physical resources of New Zealand.*

require both supply and demand to be targeted.

Several components of energy sustainability are suggested by the above definition, namely:

(1) use of renewable energy sources;

(2) energy-environment interactions;[55]

(3) social considerations;[56]

(4) security or robustness of the energy delivery system;

(5) energy-economy interactions; and

(6) efficient use of energy.

As stated earlier in this chapter, writers commonly regard each of these aspects of the definition of sustainability as a complete subject area in itself. Whilst this view is plausible, it is contended that this type of outlook will not contribute to furthering sustainable energy use in New Zealand, since it ignores the linkages and trade-offs that exist between the six areas. For example, it would be possible to move to an energy system that relied solely on renewable energy sources if extensive use was made of all available technologies. At present however, some of those technologies are not economically viable, often because they are in the early stages of development, while others have undesirable environmental impacts. It would therefore be more beneficial to address sustainability via the twin routes of increasing energy efficiency and using some form of bridging energy source, even if it is an unsustainable option in the long run, until a more viable, sustainable option is found.

A further advantage of addressing the various issues as a whole is that addressing them

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[55] *When assessing environmental effects in this thesis, 'environment' is defined in the same way as it is in the Resource Management Act 1991, so that health and other social effects can be included in the equation.*

[56] *In this thesis, cultural issues are viewed as being a subset of social considerations in general, rather than being a separate category.*

individually can lead to a piecemeal solution being developed that misses some of the issues or leads to other issues being addressed more than once. It is still possible that some issues may be overlooked, however the chances of this occurring are much decreased with an umbrella concept such as sustainable management.

The next part of this chapter will deal with each of the six considerations in turn to both explain why they are considered to be a part of the definition of energy sustainability and to cast light on the types of factors that the indicators should show in each area.

## EXPANDING THE DEFINITION OF ENERGY SUSTAINABILITY

### (1) Use of renewables

A key component of the definition of sustainability is the focus on the long term. In this regard, fossil fuels (being a stock resource) cannot play a major long term role in a sustainable energy system. These resources exist in a fixed quantity (unless one is using a geological time scale) so that, unless the stock of the resource and use rates are such that the resource can naturally replenish over such a long period, they cannot be considered to be renewable. Therefore, any system which relies solely or predominantly on non-renewable energy sources will not be sustainable. The focus must be on promoting the use of renewable energy, namely hydro and the 'alternative' energy sources (wind, solar, biomass, geothermal, wave energy and the like).[57]

The use of renewables is not a panacea, as they can have negative effects. Such matters

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[57] *Energy efficiency is increasingly coming to be recognised as an 'alternative energy source'. It is not discussed in this section however, as it is not considered to be a renewable energy source and is a significant issue that warrants a full discussion in its own right.*

have been brought to light by events surrounding the proposed Ngakawa hydro dam, where objections were made over the proposed flooding of a large area of native forest. Similarly, there were objections to the increased use of geothermal energy by residents of Rotorua as it was felt that domestic use was detrimentally affecting the Whakarewarewa geothermal area, which has spiritual and economic ramifications.

There may also be physical limits on a country's capacity to exploit a particular form of renewable energy. These physical limits may in turn create economic limits. For example, New Zealand is presently in the situation whereby it would cost more to build another large scale hydro dam than it would to build a thermal power station (ignoring the matter of external costs associated with operating a thermal station).

Physical limits can manifest themselves in other ways as well. It is possible that over-reliance on a particular renewable energy source can exceed its 'carrying capacity level' so that it is unable to renew itself sufficiently and becomes a de facto non-renewable resource. This situation is most relevant when dealing with biomass (exceeding the carrying capacity of the land), geothermal (excess draw off depleting fields) and hydro (build up of silt in rivers). There are technical solutions in some cases (such as geothermal re-injection), however it is better to employ good management so as not to exceed those thresholds in the first place. The interrelationship of the issues that comprise sustainable management means that other matters in the framework that is being developed here focus attention on the limitations that affect renewable energy use. In doing so, they illustrate the principal advantage in using a global concept such as sustainable management, over a single issue focus, namely the provision of checks and balances.

The focus for renewables within the indicator framework is therefore to supply as large a proportion of the energy used from renewable sources as is possible, although this should be subject to limitations imposed by some of the other factors to be discussed below.

### (2) Energy-environment interactions

Human existence will naturally always have an effect on the environment, as will that of every other species. The focus here however is on ensuring that, given the technical and economic constraints that exist, the detrimental effects from energy usage are as small as possible.

Energy-environment interactions have probably had more attention paid to them than has been paid to the rest of the matters that comprise energy sustainability. The main focus has been on the issues of global warming and acid rain due to fossil fuel combustion.

Whilst the definition of sustainability focuses on the ramifications of present generations' actions for future generations, it is generally accepted that the focus on environmental factors goes beyond simply ensuring that those aspects of the environment that humans have found a specific use for are conserved. This focus can be seen as being at least a recognition of the fact that humans value leisure and the ability to relax in 'natural surroundings'. A more charitable view would say that it is a reflection of human concern for fellow species and recognition of intrinsic values. The truth is probably a combination of the two viewpoints.

Energy-environment interactions are an important part of energy sustainability because of the impact of energy usage on the earth's carrying capacity. Some forms of energy usage directly lower carrying capacity by virtue of the levels of pollutants that they emit, for example particulates from chimneys and vehicle exhausts, which show through in such factors as the effects of acid rain in Europe. These factors often have a double effect in that they also impact directly on people's health. Similarly, there are fears that global warming will threaten the survival of many species, including humans.

The issue of the greenhouse effect is one that is currently receiving a great deal of attention. There is a school of thought that says that global warming may not be occurring and that there is no need for concern. However, the majority of scientists accept that there is a problem with global warming, which is the viewpoint that is followed here. The change in global temperatures affect species of flora and fauna if they find the climatic conditions that they have evolved in response to are changing more quickly than previously. The increase in global temperatures is also affecting the polar ice-caps, causing them to melt and sea levels to rise at a rate that is threatening many islands around the world.

Not all of the environmental impacts of energy are due to emissions from energy usage. Some impacts are related to production, transportation and refining of energy, including the effects of mining, oil and gas drilling and hydro dams. These activities use land that would otherwise have a number of uses ranging from being left in a natural state to various commercial uses. In using land for energy supply purposes, habitats of many species are put at risk or destroyed. The vegetation that is removed will in some cases detrimentally affect the carbon balance, as plants that were previously sequestering $CO_2$ are destroyed. A further consequence is that land which could be used for other economically beneficial means is no longer able to be used in that way. The prime example of the effects of energy systems on land use in New Zealand is the use of what would otherwise be prime farmland for energy supply purposes.

There is a further relationship that occurs in New Zealand, namely a link between energy, environment and economy. Whilst this type of linkage is naturally present in any human society, it has a further relevance in New Zealand due to the importance of tourism to our economy. The New Zealand tourist industry is based heavily on New Zealand being a 'clean, green' country with plenty of wide open spaces and untouched landscapes. Too much development of any type threatens this image and therefore also threatens an important sector of the economy.

Noise pollution is often overlooked when discussing the environmental effects of energy use, possibly because it usually has a very localised effect. The most obvious way that it impacts on other areas is in its disturbance of human life, although it can also affect species of animals.

The discussion of the effects of noise illustrates an important factor regarding environmental effects. Many of the effects of energy on the environment are very localised. This does not mean however that they are minor effects, as they can still lead to significant flow-on effects due to the nature of interactions within eco-systems. Similarly, a number of site specific effects at a number of different localities soon add up to being a major effect when viewed on a broader scale. Given the nature of many of the localised effects however, it will often be better to manage them on a case by case basis. Specific matters that favour this approach are the variety that exist in locations, effects (both magnitude and type) and the environmental factors that are affected.

In summary, the areas of the energy-environment interaction that are relevant foci for the development of indicators are the emission of pollutants and the use of resources.

### (3) Social considerations

When social considerations are discussed regarding sustainable development in general, they usually refer to inter-generational and intra-generational equity. The former is at the heart of sustainability as defined earlier and reinforces the need for a long run focus. The latter is usually taken as addressing the issue of how to ensure that developing countries are able to achieve the standard of living that the developed countries enjoy today. This issue is beyond the realm of an operationalised set of indicators designed to measure the sustainable management of New Zealand's domestic energy system. There are however still intra-generational considerations that may be relevant to the issue of the sustainable management of the New Zealand energy supply.

Looking firstly at inter-generational aspects of energy usage, the main focus is on ensuring that there will be sufficient energy supplies for future generations. This is largely taken care of by the first criterion, ensuring that there is a large proportion of renewable sources of energy in the total energy supply. Inter-generational equity can operate as a further safeguard to the renewing capacity of renewable resources, by ensuring that the needs of future generations to be able to use those sources of supply are respected. This factor does not mean that present generations should not use non-renewable sources of energy (although there may be other factors which make their use undesirable). Rather, it means that consideration should be given to the way that those resources are being used and that in many cases they may be better used as a form of bridging energy source to a fully sustainable, renewable based energy system than as an energy type on their own. As it is not possible to define all but the most basic needs of future generations with much certainty, this part of the sustainability equation focuses on leaving as many options open for the future as possible.

Having regard to the range of energy-environment effects also takes account of the needs and wants of future generations. This consideration is achieved in much the same way as it is with considerations of renewable energy use, although the considerations here extend beyond the issue of utility of resources.

Aside from the matters discussed above, inter-generational considerations should operate at the preliminary stages of decision making regarding what to do with a particular energy resource or land area, in recognition of the multiple potential uses of many resources. For example, a river basin could be flooded to create a hydro lake or it could be planted in some form of energy crop. It could also be kept as a reserve. Other aspects of the sustainability definition also play a role in this type of decision making. For example, a perceived need for increased energy may be better served by a program of efficiency or end-use matching.

As noted earlier, discussions of intra-generational equity tend to focus on the sustainable development issue of how to redistribute resources between richer and poorer nations and within those poorer nations themselves, both of which are beyond the scope of the present study. There are still intra-generational equity issues which are relevant to New Zealand.

The first issue is the matter of Maori concerns and Treaty of Waitangi issues. Whilst it would be difficult to make a meaningful case for awarding Maori ownership of energy resources by virtue of the Treaty of Waitangi (other than some types of biomass), Maori concerns still have to be taken into account. These concerns are especially relevant to issues of water usage (for example, water usage in thermal power stations) and respecting sacred sites.

Whilst Maori issues are relevant to the domestic production of consumer energy, they are not completely relevant in all aspects of energy production and use. It is also possible to use and produce energy in a way that is culturally acceptable yet patently unsustainable. For example, there is nothing culturally offensive in driving a large car when a small one would suffice or in burning coal to produce electricity, yet both of these uses of energy are unsustainable.

Whilst the matter of considering Maori concerns is important, it is difficult to envisage a meaningful macro-level indicator being developed to take account of it. In this regard, Maori concerns are better addressed at a micro-level, where the values in a particular area are assessed and the impact of a given project on these specific values in then assessed in detail. The Resource Management Act 1991 ensures the efficacy of such an approach.

The second aspect of inter-generational equity that is relevant to New Zealand is the issue of the affordability of energy. This issue is concerned with ensuring that all New Zealanders are able to afford a basic level of energy services that enables them to live in a manner which is considered to be appropriate to a developed society. In assessing this matter, it is important to remember that these energy services can be provided by energy efficiency as well as use of increased amounts of energy. This issue is very much involved with the issues of incomes policy and pricing of energy. Given the fact that electricity is the major energy type in the domestic sector, it is especially linked with the issue of electricity pricing.

While issues relating to incomes policy are outside of the scope of this thesis, pricing matters are not. The pricing of energy can be broken down into two issues. These were discussed in depth by Melhuish[58] and Bertram[59] in the April Report on Social Policy. The first issue

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[58] *'Energy and Social Policy ', M. Melhuish in: 'The Report of the Royal Commission on Social Policy', Volume IV 'Social Perspectives', April 1988, pp. 252 to 292.*

is the affordability of energy. This looks at the proportion of household incomes that are spent on energy. While there will obviously be differences between the different income bands, with higher income brackets understandably able to spend a lower percentage of their income on basic necessities, the concern is to ensure that lower income groups are still able to afford the basic level of domestic energy use that is deemed desirable (or necessary) in our society. As a policy, this may show itself in terms of cross subsidisation built into prices, stepped tariffs or direct income support.

The second area of concern regarding the social impacts of energy pricing is to analyse what happens with the money that is paid for energy. This money is obviously revenue for the energy supplier, some of which is converted into profit. According to economic theory, that profit is an economic cost to consumers. Costs comprise the payments to the factors of production: land, labour, capital and enterprise. The total revenue of the energy supplier equals the sum of all of these costs.[60]

Each of the factors of production will receive transfer payments. This is the level of payment that is required to keep that factor in this particular form of productive use.[61] Any payments above this level are considered to be economic rent to that factor. From a social impact point of view, economic rent will often lead to a less than ideal situation. This situation arises because the selling price of a particular good or service is comprised of the factor payments to each of the factors of production. If one or more of the factors of production is receiving economic rent, consumers are paying more of their income than they

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[59] *'Rents in the New Zealand Energy Sector', G. Bertram in: 'The Report of the Commission on Social Policy', Volume IV 'Social Perspectives', April 1988, pp. 293 to 325.*

[60] *Profit is the payment for enterprise or entrepreneurial skill.*

[61] *For example, most people have a 'minimum wage' below which they would not do the job that they do. This 'minimum wage' is that person's transfer payment.*

need to for the product.

Economic rent is usually analysed in terms of the profits earned by the firm that supplies the product. This approach therefore focuses on rent that is paid to enterprise. While this is often the single biggest accumulation of rent in the price of a product, it glosses over the fact that other factors of production may also be receiving rent payments.

In each case, the issue of whether rent is a cause for concern turns on who receives it and what is done with it. The clearest example of this would be the implications of the use of the economic rent that Bertram calculated was being received by the Electricity Corporation of New Zealand (ECNZ) being used to fund the health sector as opposed to the use of the same money to beautify Rutherford House. While this is an unrealistic example, it illustrates the different benefits that economic rent can have.

In summary, the aspects to be looked at here are partly already covered by the issue of using renewables in preference to non-renewables. As regards intra-generational issues, the key concerns are the proportion of household income spent on energy and the proportion of economic rent earned by energy suppliers.

### (4) Robustness of the energy supply system

Robustness refers to the ability of the supply system to continue providing energy at the times and rates that consumers require, under both normal and adverse conditions.

A key ingredient in ensuring that supply is secure is ensuring that the supply is from a diverse range of sources. This requirement applies equally to using a range of different primary energy sources and to using a range of providers of consumer energy. The importance of the former criterion is illustrated by the way that New Zealand's electricity supply was affected by the low water levels in one key hydro lake in 1992. The second aspect can apply to indigenous and imported energy. As regards imported energy, it applies mainly to oil products and cautions against over-reliance on one exporting country. With indigenous energy production, the emphasis is on building a certain amount of redundancy into the system to allow for breakdowns and routine servicing requirements. It also guards against sudden losses of primary energy sources, be they permanent or temporary.

This criterion may at first appear to be a tenet of good engineering management rather than an aspect of sustainability. Whilst it is undoubtedly a principle of good management practise, this does not preclude it from also being a key aspect of sustainability. It is especially relevant in ensuring that renewable energy sources are not used to such an extent that the energy source is not able to renew itself and hence becomes non-renewable. If the supply system is organised in such a way that no single primary energy source is providing too great a proportion of the total energy used, then there is much less chance of overloading the renewing capacity of renewable energy systems.

While the same requirement obviously does not apply to non-renewable energy sources, it is still relevant. A system which is able to withstand external shocks is in a much better position to be able to meet the long run requirements of sustainability. Quite simply, if the system is unable to provide for the needs of the present generation, then it is unlikely that it will be able to provide for the needs of future generations.[62]

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[62] *This assumes that present generations are actually using resources and are not attempting to save all of a particular type of resource for future generations.*

Therefore, indicators of robustness need to focus on the percentage of total energy usage that is derived from each primary energy type or from a single source and the amount of redundancy built into the supply system as a security measure.

**(5) Energy-economy interactions**

Some advocates of sustainability believe that there is no place for economic concerns in a sustainable society. This view ignores the fact that, for better or worse, modern society is so immersed in economic systems that it would be almost impossible to extricate ourselves from some form of economy, especially in the short to medium term. It also ignores the fact that even a system like barter - which is perceived as being simple and 'green' - is an economic system. The challenge becomes one of deciding how to be able to take the present systems and interactions and shape them to assist in the achievement of sustainability. As has been noted, a strong economy can help achieve a sustainable state - given sufficient policy guidance.

The New Zealand economy is totally dependent on energy systems for its continued operation. It is in the interests of all economic entities to ensure that there is a continued, sustainable supply of energy to enable society to function as we wish it to. For consumers, the on-going supply of energy is directly related to the maintenance of living standards. For producers of goods and services, the concern is the on-going profitability of their business. Society as a whole benefits if the adverse effects of energy use are decreased, both in terms of decreased effects and also through decreased remedial expenditure that would otherwise be required to repair the damage done by extractive and exploitive energy use.

The difficulty that is faced at the moment is that the major economic paradigm (neo-classical monetarist economics) favours a short term decision making horizon. The effect of this focus is exacerbated by the paradigm's insistence on the minimum of intervention in all goods and services markets. These two factors combine to create a situation that is not sustainable,with an energy supply system that lurches from energy source to energy source, exploiting and often squandering what is the cheapest at a particular point in time, passing on internal costs to consumers and focusing solely on short term profits.[63] Under this paradigm, limited attention is paid to the issue of external costs and even less attention is devoted to internalising those costs to the party that imposed them on the environment or on other economic entities. Tying economic considerations to sustainable management (and making them subject to that concept) will overcome this focus and create a powerful force for sustainability, as well as having numerous economic benefits.

As with most of the components of the overall definition, there is more than one part to the issue of energy-economy interactions. Firstly there is the issue of what sort of orientation the suppliers of energy should have. Secondly, there is the issue of how much each unit of a particular energy form costs users. Thirdly, there is the issue of how much each unit of energy costs society.

The issue of the focus of energy suppliers is how to best provide for supplier profitability without compromising the aims of sustainability. While looking at the issue of ensuring supplier profitability may superficially appear to be at odds with the rest of the definition of sustainable management, it actually fits comfortably within the whole definition. As most energy suppliers are profit driven, ensuring their profitability will mean that they are able to continue supplying energy, which in turn creates a degree of security in the energy supply system. Bounds obviously exist to this contention, so that the issue becomes one of

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[63] *The clearest example of this in New Zealand is the use of Maui gas.*

constrained optimisation.

According to current government policy, the best way to achieve supplier security is to leave things to an unregulated market and allow decisions to be made on the basis of economic criteria. New Zealand is alone in the world in having such an unregulated energy sector, which should imply to decision makers and planners that focusing on short run profits is not the way to achieve sustainability.[64]

Opposing a strong profit orientation is not to be taken as implying that energy suppliers should operate as a charity. Energy use in New Zealand would almost certainly be even less sustainable if suppliers were to take that attitude. The fact is simply that energy is such a complex good that it cannot be treated in the same manner as Weetbix, newspapers or other equally commonly used products. Factors other than solely economic criteria must therefore be considered.

New Zealand energy suppliers are in a strong position, so that the issue of attempting to ensure supplier profitability is largely redundant. Two specific reasons favour this approach. Firstly, as there are no regulated prices for energy, producers simply pass their costs on to consumers (that is, a 'cost plus' pricing policy is followed). Whilst there is a point at which the market is no longer able to sustain the prices being asked and whilst account must be taken of substitution effects, the inelastic nature of the perceived demand curve for energy means that at present in New Zealand suppliers' pricing concerns are largely not an issue.

[64] *The unsustainable nature of the market focus can be shown simply by analysing ECNZ's performance over the 1992-1993 year. The Corporation announced that it had increased its profits and had succeeded in increasing sales of electricity by 6% over that accounting period. A continuation of that growth trend is a plausible scenario given ECNZ's profit making orientation (as required under the State Owned Enterprises Act 1986), the fact that electricity is gaining an increased proportion of total energy use around the world and the fact that New Zealand's population is increasing. The result of these factors would be that in approximately 12 years (assuming the 6% rate did not change) New Zealand would need to have as much electricity generation capacity again as exists currently in order to satisfy consumer demand, which is not a viable option.*

Secondly, New Zealand's small population means that most major supply systems are natural monopolies. This applies to the electricity, gas and coal supply systems, although there are some smaller niche market suppliers of electricity and coal. While it is argued by the Government that deregulation of electricity supply authorities has led to competition, for the vast majority of consumers however (that is, other than major electricity consumers), deregulation has meant little or no change.[65]

The other major energy type in New Zealand is oil products, the supply market for which operates on an oligopolistic basis with all firms using the same fuel products from the same refinery and communicating with each other to check how they are going to respond to changes in international prices.[66]

The issue of providing the constraints on the profit motives of suppliers is provided for by the other matters that comprise the definition of energy sustainability. Given that there are more of those elements and that they cover a broad spectrum of issues, they will operate to ensure that profit seeking is not able to undermine achieving sustainability.

In summary therefore, it is argued that attempting to ensure suppliers' profitability is unnecessary.

The second economic issue is how much each energy type costs its consumers. The ideal situation is to price energy in such a way that it does not damage the competitiveness of New Zealand industries and does not place an undue burden on non-commercial users, whilst

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[65] *There is also the issue of how much competition can be created with the current pricing system and when only the final supply market has been deregulated.*

[66] *Personal communication, B.P. Oil (New Zealand) Limited.*

not encouraging an excessive level of use. As energy costs are generally a small proportion of the total costs of most businesses, the former is not of great concern. The present practice of some suppliers of giving bulk discounts to large users of energy also helps to protect those industries for whom energy is a key input. Concern for domestic users is largely dealt with by the social indicators discussed above, although the issue of cross subsidisation may apply here. Cross-subsidisation goes beyond the issue of price relativities between domestic and commercial customers and takes account of relativities between different sectors of the economy.

If the price of energy is set too low, consumers have no incentive to audit their energy use patterns or to alter their use to become more efficient, as necessary. The question of what is an appropriate price to encourage this type of behaviour is dependent on a number of factors, including the nature of the energy type in question, the elasticity of demand, the type of efficiency measures available for that energy type, the cost of those measures as well as the amount of information that consumers have about energy use options. To fully assess the impacts of these matters would require an extensive survey of the market penetration of energy efficiency measures and the development of an equation to assess the relative weight to be assigned to each factor. A proxy measure can however be gained by assessing the approximate changes in the levels of energy use that result from changes in price.

When assessing the impact of price changes on energy use, inflation adjusted (or 'real') prices are used in preference to unadjusted (or 'nominal') prices. Real prices enable the effect of inflation to be isolated in analysing price effects. Once this effect is removed, the institutional factors that have influenced price changes are revealed. These are the factors that are more properly within the realm of energy policy, compared to the factors that influence inflation, which are within the realm of general economic policy.

The final energy-economy issue is how to account for the external costs that are not presently reflected (or fully reflected) in energy prices. External costs (or 'externalities') include environmental costs, health costs, repairs and maintenance due to the negative effects of energy production and use and allowances for the depreciation of fixed stock resources as they are used.

Considerations here overlap with the issues raised regarding environmental and social interactions with the energy supply system. The focus here brings in a further factor, by looking at the financial implications of an energy use decision. The financial burden of these external costs must be borne by a section, or sections, of the energy using population.[67] The two most common groups that have to bear the costs are the present generation's taxpayers and future generations. The current policy of not accounting for the external effects of energy use therefore reflects an abrogation of the present generation's duties under the sustainability ethic.

Calculation of externalities is designed to draw attention to the fact that energy use has impacts beyond the direct costs of that use. These impacts are costed to enable them to be incorporated into the standard neo-classical economics framework. There is nothing special about the monetarisation of these impacts. In some ways, monetarisation of impacts can actually be detrimental, as many of the resources and impacts that are measured do not have recognised valuations, while others are very difficult to value meaningfully. Further, the tools and techniques for assessing values of non-market, collective goods such as the environment are currently often not very well developed. The resulting values that are given to the resources can therefore very easily misrepresent the value of the resource.

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[67] *It is important to note that this point is limited to the financial implications of resource use, rather than the physical burden. The financial costs of a decision are naturally limited to human society, while the physical costs will be felt more widely.*

As a result of these factors, the measurement of impacts in terms of physical units of the pollutants emitted or resources used (as was suggested in the section above concerning energy-environment impacts) is to be preferred over this approach. The processes for measuring these units are far more developed and simpler than attempting to assign an economic value, especially considering that the aim of either process is simply to draw policy makers' and resource users' attention to the impacts of resource use.

Calculating external costs of energy use does still have a role in measuring the more economic or socio-economic impacts of energy use. The nature of these impacts means that they lend themselves more to being measured in economic terms. The principal reason for this difference between environmental and socio-economic external costs is that the latter have a direct impact on economic matters, either through the remedial expenditure that is required or through decreases in productivity or economic efficiency due to the impacts on economic entities. This head of externalities can be viewed as being akin to revenue expenditure (in that it creates an expense), while the former head is more akin to a depreciation in the capital value of the environment.[68]

In summary, the focus for energy-economy indicators is the issue of the effect of the price of energy and the impact of remedial expenditure on the economy.

### (6) Energy efficiency

Energy efficiency would rival energy-environment interactions as the area that has had the most attention focused on it in the literature. It is sometimes considered that addressing

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[68] *This comment should not however necessarily imply that concepts of depreciation of natural capital are strictly applicable.*

energy efficiency will by itself ensure sustainable energy use. Whilst this may be overly optimistic in some situations (for example it is possible to burn coal in an efficient manner to provide space heat yet coal is a non-renewable resource), it is definitely true that the 'fifth fuel' (as energy efficiency is sometimes called) has a key role in the sustainable management of energy.

It does not take much investigation to conclude that efficiency should be included in the definition of sustainability. All major works dealing with sustainability in any sense either explicitly state (or imply very strongly) that humans need to take care in their use of resources and not fritter them away frivolously. The second law of thermodynamics means that with any energy usage there will always be some portion of the input that is not able to be converted into the desired output.[69] However, the second law does not justify using energy in a way that leads to an unnecessary proportion of the energy that is input into the system being converted into waste heat.

There are two branches to the concept of energy efficiency. The first is the concept of gaining the greatest possible useful output per unit of given input. This is the definition that most people would intuitively focus on if asked to define efficiency in any sense. There are issues of how to measure those inputs and outputs, however they will be discussed in the section dealing with the actual development of the indicators.[70]

The second branch deals with the notion of end-use matching, or how to avoid "using a

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[69] *This law states that every energy conversion policy leads to the creation of a useful output and a proportion of energy that is lost as waste energy. The amounts of useful energy and waste energy vary from energy process to energy process.*

[70] *See chapter eight, below.*

chainsaw to cut butter".[71] As the metaphor implies, the aim here is to ensure that the energy source is appropriate to the task that it is intended to be used for. This comment applies equally to ensuring that the energy source is neither too powerful nor not powerful enough for the intended task. Using an energy source that is too low quality for the desired outcome is also wasteful in that it requires more energy than is necessary if the optimal path was followed.

The reason for the former requirement is related to the fact that high quality energy sources need to be produced from lower quality energy sources. Aside from the fact that this process requires equipment which in itself requires energy for its production and operation, every conversion in the chain obeys the second law of thermodynamics. For example, gas is burned at the Huntly and New Plymouth power stations in order to generate electricity that is (inter alia) used to provide heat for cooking. The process of converting gas to electricity is only 40% efficient, so that 60% of the energy in the gas is lost at this stage. Further losses occur in transmission to the household and in the operation of the oven, so that only approximately 30% to 35% of the energy in the gas is actually being converted into the desired end-use (heat for cooking). If the gas was used directly for cooking, a much higher proportion of its energy would be used for the desired purpose. There would still be some losses due to the operation of the stove and delivery, but the proportion of energy converted to desired end-use would be closer to 90%. Less energy would be used overall and more would be preserved for future generations, without detrimentally affecting present generations. Higher quality energy sources can also be reserved for those end uses which cannot use lower quality energy sources. As lower quality energy sources include fossil fuels, this type of end use matching also has environmental benefits and can encourage increased use of renewables.

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[71] *A. B. Lovins, 'Soft Energy Paths', Penguin Books, London, 1977, p. 40.*

The argument for this type of end use matching in New Zealand is often attacked on the grounds that it overlooks the economic advantage that New Zealand has as a result of its large resource of cheap hydro electricity. While it is correct that New Zealand has a large amount of cheap hydro energy, the question is, to what extent it is correct that this will continue to be the case. It is widely acknowledged that the Clyde dam is the cheapest new hydro electric dam that will be built, meaning that for new generation capacity it is now cheaper to focus on either alternative energy sources or thermal power stations. If the latter are going to be used, then it makes more sense to use end-use matching rather than wasting up to 70% of the energy contained in the various fossil fuels. Even if thermal stations are not going to be used, it is cheaper in many instances to focus on reducing the energy used rather than trying to increase consumption. End use matching is one way of achieving this aim. The major limit to furthering the use of end-use matching is the cost of conversion of energy using capital equipment, where this is necessary. It should also be remembered that end-use matching applies to energy forms other than electricity and that there can be benefits beyond the strict sphere of energy use (for example, timber mills avoiding waste disposal costs by burning waste wood for energy). Overall therefore, end-use matching can have a considerable benefit and it is therefore appropriate to include it in the definition of energy sustainability.

In summary, in measuring efficiency the focus is on getting the greatest desired output from the least units of input and ensuring that the energy form used is appropriate to the desired end-use.

## SUMMARY

The six components of the energy sustainability definition give rise to a number of specific concerns about the way that New Zealanders use energy. Not all of these matters are however of primary concern in the sustainable management of energy in New Zealand, as some of them are second tier effects that are implicitly taken care of when fundamental factors are managed. In other cases the people and organisations affected by a particular energy use factor are best able to control their own destiny so that sustainable management is only concerned with setting the bounds within which their discretion can be maximised. Other areas do not lend themselves to being measured by indicators, as the management decisions concerning them are addressed by simply answering a 'yes/no' question. As a result, the following are the areas that are considered to be areas for inclusion in a sustainable energy monitoring program:[72]

(1) proportion of total energy supply provided by renewables (renewables);
(2) minimising environmental impacts of energy supply and consumption (energy-environment interactions);
(3) proportion of household income spent on energy (social factors);
(4) economic rent accruing to energy suppliers (social factors);
(5) diversity of sources of supply (robustness);
(6) safety margin/redundancy in the system (robustness);
(7) the impact of energy pricing on economic activity (economic factors);
(8) remedial expenditure required (economic factors);
(9) output per unit input (efficiency);
(10) end-use matching (efficiency).

The above list of potential indicators is an ideal list. It is feasible that some of the indicators in this list will not be able to be developed either because they do not meet one or more of

[72] *The phrase in brackets is the 'parent' principle in each case.*

the indicator criteria in chapter three, because the concept will not allow a meaningful indicator to be developed, or because there is insufficient base data available to develop the indicators. These issues will be discussed in chapter eight, which focuses on developing the indicator series.

Having identified the key criteria of both effective indicator design and energy sustainability, the foundations for developing a set of indicators of energy sustainability for New Zealand have been laid. Before developing indicators, it will be instructive (as well as being appropriate) to assess the steps that other countries and organisations have taken in the development of sets of indicators of energy sustainability and other aspects of the issue of energy use. An analysis of the monitoring programmes that are conducted by the major players in New Zealand's domestic energy market will be similarly instructive.

These two surveys are the subject of the next two chapters.

CHAPTER FIVE

# INTERNATIONAL MONITORING PROGRAMMES

This chapter and the following chapter discuss the various energy monitoring regimes that are presently being undertaken by a number of countries, international organisations and New Zealand organisations. The regimes that are discussed cover more than what could be considered to be purely energy sustainability matters, essentially because there are no regimes that focus on the totality of energy sustainability as it is defined in this thesis. While it is not necessarily relevant to the development of the proposed set of indicators to analyse regimes that are not devoted to energy sustainability, doing so highlights the types of concerns that some groups have and the type of information that is available at present. Despite this comment, in both this section and the section on monitoring and statistics in New Zealand, it is not intended to conduct an in depth analysis of programmes that solely measure energy data, since most of these programmes were established to meet the respective country's obligations to the Organisation for Economic Cooperation and Development (OECD) and International Energy Agency (IEA)[73] or the United Nations, meaning that they all follow a very similar format. An example of such a programme is the energy matrix contained in the Ministry of Commerce's 'Energy Data File'.

The standard OECD/IEA programme includes energy balance tables which record the different energy types and the quantities of energy of each type that are produced and consumed within the economy, recorded in either some form of equivalenced measure (such

[73] *This organisation is an integral part of the OECD, with the same membership as the OECD, that focuses solely on energy issues.*

as tonnes of oil equivalent), petajoules or energy specific physical units (such as terrawatt hours of electricity). The tables also detail which sectors of the economy the energy is consumed in.

The main differences between the countries show themselves in the sectors that are recorded (although there is a great deal of similarity here) and in the energy types measured. For example, some countries record nuclear energy, while co-generation and district heating schemes are particularly relevant in the Scandinavian countries, reflecting the energy types that are important in each country. Statistics on Less Developed Countries include information on biomass or (vegetal fuels as the IEA call biomass), recognising that this is the major source of energy for the majority of the population in many Less Developed Countries. The weighting given to each of the energy types also commonly manifests itself in the amount of data collected on a particular energy type.

Other commonly included information is more economic in nature, referring to energy prices and the net energy exports of a given country. The latter usually focuses on the issue of fossil fuels, although in the European Community countries electricity is also traded internationally. As well as being an economic measure, net energy exports measures one aspect of the overall security and robustness of the energy supply system of a particular country. It is not however the sole comprehensive measure of this aspect, as it is possible to export too great a proportion of the energy that is produced by a country and therefore affect the energy supply of that country, a fact that is demonstrated in the tables.

The remainder of this chapter will discuss the monitoring programmes of Denmark, Norway, Canada, the World Bank and the OECD/IEA.

**Denmark**

Denmark has not developed a clear definition of energy sustainability and as a result has also not developed a series of indicators that can measure sustainability.[74] The Danish Government measures sustainability in terms of the recommendations of the Bruntland Report, making use of a variety of short run policy instruments to realise this rather vague formulation of sustainability. An energy plan entitled 'Energy 2000' was developed following the broad recommendations of the Bruntland Report. The main target of this plan is the reduction of $CO_2$ emissions and other pollutants. As a part of this strategy, the Danes are focusing on four specific target areas, namely:

- making savings in energy consumption;
- making the supply system more efficient;
- increasing the usage of 'cleaner sources of energy'; and
- undertaking research and development.

It is assumed that the reference to cleaner sources of energy is mainly looking at increasing usage of renewables, although switching to natural gas in preference to other fossil fuels could be included within this policy aim. 'Energy 2000' is labelled a 'short run' plan, being concerned with the period 1988 to 2005 only. As yet no plans have been developed for the period beyond 2005. Other than specific state indicators such as levels of $CO_2$, the only indicator to be developed specifically to measure sustainability is total energy intensity.

Denmark has an energy monitoring programme that covers a range of statistics. These

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[74] *All information in this section is, unless otherwise indicated, from personal communication with Maj Dang Trong of the Danish Energy Agency, Ministry of Energy, Copenhagen.*

statistics are recorded in a volume called, naturally enough, 'Energy Statistics'.[75] The factors measured include standard measures such as gross energy consumption and sector-by-sector consumption figures. Similar tables break gross consumption and production down into the various types of energy source and end use. Other measures include energy self-sufficiency and dependence on oil. Denmark is both an importer and exporter of energy so that a measure of significance to the Danes is the net currency expenditure on energy. There is also a comparison with Denmark's near neighbours and the United States and United Kingdom. Environmental impact is only studied to the extent of measuring $CO_2$ emissions. The statistics are summarised in a table of key indicators that includes energy production, self-sufficiency, dependence on oil, economic activity, a consumption index, standard economic data, average imported energy and consumer energy prices and energy taxes.

**Norway**

Norway has long been recognised as a leader in the field of natural resource accounting. The Norwegians have had a programme of environmental reporting in place since 1973. It is therefore not surprising to know that Norway has one of the more detailed set of statistics on environmental pollution, including the effects of using energy. This document, entitled 'Pollution in Norway'[76], presents information in terms of each type of polluting effect. For example, the chapter on climate change contains graphs on the levels of emissions of greenhouse gases ($CO_2$, $CH_4$ and $N_2O$) and on changes in both the global and Norwegian mean temperature. The total effect of each of the greenhouse gases is in turn broken down to show the contribution of the different sources of $CO_2$ to the total levels. The information is accompanied by a brief exposition on the government's policy goals and the current trends

[75] *'Energy Statistics 1992', Danish Energy Agency, Ministry of Energy, Copenhagen.*

[76] *State Pollution Control Authority, Oslo, October 1993.*

regarding global warming.

This approach provides a clear picture of the situation relating to each area that is of concern to both the public in general and policy makers in particular. It is aimed at a level that is accessible to all people, although the data is such that it may be of limited use to more technically oriented users. The base data which was used to generate these graphs would however presumably be able to provide more detailed information, if required.

In this report, energy-environment interactions are reported in the sections on climate change, ozone in the lower atmosphere (the release of non-volatile organic compounds), acidification (the release of $SO_2$ and $NO_x$), local air pollution and noise (the effects of transport policies on $NO_x$ and CO), the environmental effects of the offshore petroleum industry and acute pollution (oil spills and accidents associated with the production and transport of oil).

This report is, as the title states, designed to monitor various polluting effects in the Norwegian environment, which it does exceedingly well. From the point of view of energy sustainability however, there are more energy-environment concerns that are of interest than the few that are noted here. These additional areas of relevance are the resource use aspects (that is, extractions from the environment as opposed to emissions into it), especially land use. This is especially relevant to extraction and production of fossil fuels and in hydro electricity.

Further environmental information is provided by the Norwegian Oil Industry Association in its 'OLF Environmental Programme: Report Phase 1, Part A: Emissions to Air'.[77] This

[77] *Norwegian Oil Industry Association, December 1991. OLF is the Norwegian abbreviation for the Association.*

report is prepared as part of an ongoing programme that is run by the Association, the Ministry of Petroleum and Energy[78]and the Ministry of Environment. The programme is "directed towards emissions to air and discharges to sea from the upstream petroleum activity" and attempts to provide information on the costs of reducing those emissions.[79] Much of the report is concerned with technical information on the means available to reduce the various emissions and the economic costs of those methods. There is however a section on the emissions that notes the levels of the pollutants and the sources of those pollutants. This section also includes information on the percentage of the total pollutant level that comes from each of the different energy sources.

The background information to the 'Statement on Environmental Policy in the Stortinget, 4 May 1993' includes information on trends in energy consumption.[80] Information is provided on energy consumption by energy type (in petajoules), real energy price level changes, energy intensity changes for Norway and the OECD average, the uses of North Sea gas and the levels of hydro power that are both operational and planned. There is no analysis of the information in the graphs, although the information that they represent is described in words.

This last set of statistics bears strong resemblance to the type of statistics that one would expect from an energy ministry or statistics department. This is no doubt due in part to the fact that the graphs are all drawn from information generated by Norway's statistics department. The graphs appear to have been extracted from the annual energy publication

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[78] *This ministry has since changed its name to the Ministry of Industry and Energy.*

[79] *Above, p. 5.*

[80] *Ministry of Environment, Oslo, included at p. 15 and following.*

'Energistatistikk'.[81] This document contains the standard formulation of energy information that is commonly recorded, with information on energy balances and break downs of consumption on the basis of consumer groups and energy types.

**Canada**

After Norway, Canada would be the country with the most advanced environmental monitoring policy. This monitoring programme has resulted from the environmental policy developed under 'Canada's Green Plan'.[82] A preliminary set of indicators was developed[83] as a part of Canada's commitment to "environmentally responsible decision making".[84]

Energy is measured directly in three indicators. The report acknowledges that the first of these, total primary energy use, does not in fact measure environmental stress, rather it is used as a "proxy for the level of impact that energy use can have on the environment".[85] This statement is true if the changes in the level of environmental damage that can be attributed to the various stages of energy production and consumption are matched with changes in the level and the composition of energy use. While this matching is not made explicit in the report, the inclusion of total primary energy supply in the series of indicators enables users of the data to assess these trends. Matching of energy use and the effects of that use can be achieved by analysing the total energy graph in conjunction with the other graphs that are included in the report.

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[81] *'Energistatistikk 1991', Norvegs Offisielle Statistikk, NOS C50, Oslo 1992.*

[82] *Environment Canada, Ottawa, 1990.*

[83] *'A Report on Canada's Progress Towards a National Set of Environmental Indicators', SOE Report No. 91-1, Indicators Task Force and State of the Environment Reporting, Environment Canada, January 1991.*

[84] *Above, p. iii.*

[85] *Above, p. 87.*

The second indicator is emissions of $CO_2$ per unit of energy consumed, which is measured in terms of tonnes of emissions per tonnes of oil equivalent, emissions per dollar of Gross Domestic Product (GDP) and emissions per capita.[86]

The emissions per capita graph has the disadvantage of potentially disguising sources of increases in the levels of emissions, as the graph assumes a degree of homogeneity in emissions across users that will not in fact be present. A further potential disadvantage of the graph is that it appears to measure total energy related emissions against the number of human consumers of energy.[87] This will necessarily overstate the level of emissions per capita, as it excludes businesses and other users of energy who are not 'natural people'.

The utility of the graph measuring the level of emissions per unit of GDP is questionable. As it stands, the graph is at least as much a measure of changes in the economy as it is of changes in $CO_2$. As the Canadian economy follows the same pattern of change from an industrially based economy to a service based economy that all other OECD countries have undergone over the last thirty years, this ratio must necessarily improve. Improvements in the ratio can however occur without the need for any assessment or alteration of the levels of use of the fuels that emit the $CO_2$. As such this ratio may overstate the efficacy of the policies implemented and hide many potential areas for improvement.

This change to a service based economy is reflected in a further graph that is included in another section of the report. The graph of Canadian energy related emissions of $CO_2$ shows a rapidly increasing overall level of carbon emissions.[88] If the decrease in the level of

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[86] *Above, p. 88.*

[87] *The y-axis scale is measured in terms of tonnes per person.*

[88] *Environment Canada, 1991, above, p. 17.*

emissions per unit of GDP noted above was due to a decrease in emissions, this graph would have to reflect a decrease in emissions. As this change is not reflected in this graph, the implication is therefore that the changes recorded in the emissions per unit of GDP graph are actually changes in GDP.[89] This example highlights the danger of placing too great an emphasis on ratios when developing statistics and neglecting absolute values of the parameter being measured. It also illustrates the utility of including the total energy supply graph.

The major graph under this section of the report is emissions per TOE.[90] Like the other two graphs, this one shows an aggregate situation, rather than breaking down the energy usage dimension into the different energy types. Again the result is a demonstrated improvement in the situation that is potentially equally as much the result of the shift to using electricity as it is a reduction in emissions. Given that a portion of the electricity used in Canada is from thermal generation, this change in the energy mix will not necessarily be as beneficial as it may seem.

It is unclear whether the graph of energy related $CO_2$ emissions includes all forms of energy used in Canada or just those that actually produce net emissions of $CO_2$. The implication from the text is that all forms of energy are included, which creates a somewhat spurious situation. As the proportion of energy derived from hydro, nuclear and biomass sources has more than doubled since 1960[91], this graph gives the impression of an improvement in the level of emissions that is not borne out by the facts. A better solution would have been to

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[89] *This conclusion follows from the fact that the ratio is calculated by dividing the level of emissions by the level of GDP. As the level of GDP increases, the number of times that it will divide into the level of emissions decreases, causing the ratio to decrease.*

[90] *A 'toe' is a unit of measure of energy that converts the units of each of the different energy types to a common base by expressing the amount of work that can be done with each energy type in terms of the 'Tonnes of Oil Equivalent' (hence 'toe') that would be required to do the same amount of work.*

[91] *Above, p. 89.*

break down the ratio into the different energy types and just record emitters of $CO_2$, enabling the sources of the carbon emissions to be more precisely identified and addressed by policy makers.

The third major indicator is fossil fuel intensity of primary energy demand.[92] Again the focus is on the contribution to the greenhouse effect. The main graph merely shows the percentage of total primary energy that is derived from fossil fuels without breaking down that percentage into the various fuel types. This oversight is important, as the energy input mix does not remain constant over time, as the subsidiary graph included in the report illustrates. This variation in the energy mix has implications for emission levels, since the level of emissions from each of the fossil fuels varies. The net result is that the percentage of energy from fossil fuels indicator does not contribute greatly to the management of the environmental effects of energy usage. It would have been better to have included a breakdown of the various energy types in the graph on emissions per capita or in the graph on emissions per unit of energy consumed, as noted earlier.

The end result is that the series of indicators that the Canadians have developed is somewhat limited in its utility, at least from a New Zealand perspective. There is too great a focus on carbon emissions. No mention is made of factors such as acid rain, $NO_x$ or other emission related problems. Similarly, there is no mention of the effects of energy decisions on resource use issues, although this is possibly understandable given the size of Canada. It is uncertain whether these indicators have been altered at all from this preliminary set, as subsequent summary publications appear to follow the same overall line, although there is

[92] *Above, p. 89.*

no explicit mention of particular indicators.[93]

**The World Development Bank**

The World Bank focuses mainly on developing countries as this is the nature of its brief. It does however collect and publish statistics on the OECD countries and those of the former communist block. In doing so it makes use of energy statistics that are collected for the United Nations. It does not appear to publish environmental statistics, although it has produced documents on the environment and development.

The World Bank publishes three energy indicators in its 'World Development Report'.[94] The first of these indicators is average annual percentage growth in energy production and energy consumption (measured in heat units). This indicator shows both security of supply and a very basic measure of efficiency. Security is indicated by comparing the rates of increase for supply and consumption, with the aim being to ensure that the rate of change in supply more than matches the rate of change in consumption. A degree of efficiency can be shown by looking at the change in the rate of consumption. An increasing rate of energy consumption in Less Developed Countries does not by itself indicate decreasing energy efficiency, as most of them still have a strong linkage between energy and GDP, so that an increase in consumption can demonstrate an increase in economic activity.

An equity measure of sorts is provided by the second indicator which measures energy consumption (in kilograms of oil equivalent) per capita. This measure is useful for

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[93] *'Canada's Environment Today: The State of Canada's Environment: Selected Highlights', Government of Canada, undated.*

[94] *Refer to Table 8 of any year of this report.*

international equity comparisons but is of limited use in measuring the equity of access to energy within a country as there is no Lorenz curve type breakdown of consumption. This indicator can also be used as a measure of efficiency to a degree, although to be successful it would require information about the level of output that is achieved from the energy used.

Another aspect of the security of the energy supply is measured by the ratio of the cost of imported energy consumed to the value of the mercantile exports of the individual countries. The more dependent a country is on overseas energy, the less secure is its energy supply system. For many of the developing countries, this ratio is a very appropriate measure of commercial energy security, as their modest states of development mean that there are often few commercial energy developments in these countries. Such a focus however omits locally produced energy types, including non-commercial energy sources which are often the only sources of energy that are available to the majority of the population. As a result, the fuel wood crises that are striking some developing countries (for example, Nepal) are not brought to light. Whilst such concerns are not applicable to New Zealand, they do emphasise the fact that energy security measures need to look beyond total energy to the individual types of energy in order to avoid hiding major concerns in particular supply sectors.

The measures described here only cover rudimentary aspects of the energy situation of the countries described. Given the focus of the World Bank and the importance of energy to developing countries, one would have expected more in depth coverage. These statistics are however useful in highlighting the need for disaggregated information.

**Organisation for Economic Co-operation and Development**

The OECD consists of and represents the 23 'first world' or 'developed' nations. These are the Western European countries, Canada, the United States, Japan, Australia and New Zealand. The OECD has a role in the collection of energy statistics in two ways. Firstly, it monitors aspects of energy use through the working of the IEA. The second way that the OECD has a role in energy management issues is via the information collected and used by its various directorates.

The IEA is mainly concerned with collecting the basic energy data that was referred to at the start of this chapter. To do this, every member country files an annual return specifying energy use in terms of physical units of specified energy forms and fuels. These are published as volumes recording that usage in the same physical units and in terms of TOEs. A similar volume focusing on the energy balances of non-OECD countries provides a more abbreviated form of the information contained in the OECD country reports. There are further volumes published that focus solely on oil and gas.

Most of the data in these volumes is in a very basic form, consisting of matrices that break down the energy types and fuels into the different sectoral end uses that they are put to. There is however some additional information provided in the 'Energy Balances of OECD Countries'. This information includes basic energy intensity and energy productivity ratios as well as energy usage per capita. While the information contained here is very rudimentary, the advantage of these volumes is that they provide a broadly consistent database of these particular ratios for all OECD/IEA countries.[95] Overall the IEA data is

[95] *The data is not perfectly compatible. There are a number of differences regarding the time periods covered by each reporting country and the classification of some fuels (especially coal types). Discussions with some former New Zealand government employees suggest that the annual returns may not always stand up to*

more useful as a basis from which to generate the secondary data needed to construct a more detailed monitoring regime. The comparability of the basic data across the 23 OECD/IEA countries is also an advantage.

The majority of the specific energy monitoring reports from the OECD appear to be sourced from its environmental directorate. In April 1990, the Environment Directorate's Group on the State of the Environment held a workshop on the integration of environmental concerns in sectoral policies. The workshop reviewed the general approach to sectoral indicators and developed a set of twenty three indicators of energy-environment interactions grouped into three major areas.[96] Those areas were sectoral trends of environmental significance, environmental efficiency and impacts and economic considerations.[97] The indicators chosen from this process are shown in Table 1 below which is taken from the OECD report. The indicators listed under the heading of environmental efficiency and impacts imply that the OECD favours a broad definition of the word 'environment' much the same as that used in the Resource Management Act 1991.

Two follow-up reports have assessed the efficacy and suitability of these proposed indicators.[98] A summary of the state of development of the various indicators is provided in each of these by the table on priorities for indicator development. The table from the latest report is reproduced in Table 2.

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*rigorous scrutiny.*

[96] *'Summary of the OECD Workshop on Indicators for the Integration of Environmental Concerns in Sectoral Policies (Paris, April 2-4 1990)', Paper ENV/SE/90.15, Organisation for Economic Co-operation and Development, Paris, p. 5.*

[97] *Above.*

[98] *'Indicators for the Integration of Environmental Concerns into Energy Policies', OECD Group on the State of the Environment, ENV/EPOC/SE(92)4, 20 May 1992 and 'Indicators for the Integration of Environmental Concerns into Energy Policies', OECD Group on the State of the Environment, ENV/EPOC/SE(92)4/REV1, 8 January 1993.*

Table 1.: Indicators identified by the OECD.

<table>
<tr><th>Sectoral Trends of Environmental Significance</th><th>Environmental Efficiency and Impacts</th><th>Economic Considerations</th></tr>
<tr><td>1. Overall Energy Use<br>• Total primary energy requirements<br>• Total fuel consumption by fuel type<br>• Total fuel consumption by sector<br><br>2. Energy Use by Fuel Type<br>• Percent of total primary energy requirement by fuel type<br>• Percent of electricity generation by fuel type<br><br>3. Indigenous Energy Production<br>• Primary energy produced nationally as a percent of total primary energy requirements<br><br>4. Energy Intensity<br>• Total primary energy requirements per unit of GDP<br>• Sectoral end uses:<br>  • Residential - TOE per capita<br>  • Commercial and public sector - TOE per square metre<br>  • Industry - TOE per unit of value added<br>  • Transport - TOE per vehicle/kilometre<br>  • Fossil fuel efficiency for electricity generation</td><td>1. Proven oil/coal/gas reserves in tons of oil equivalent<br><br>2. Air Pollution<br>• Annual volume of air pollution emissions ($SO_X$, $NO_X$, $CO_2$, CO, HC and $CH_4$)<br>• Ratio of emissions per unit of GDP<br>• Ratio of emissions by end use<br><br>3. Water Pollution<br>• Tons of oil released<br>  • through accidents<br>  • continuous basis (refineries, platforms, tankers)<br><br>4. Wastes<br>• Volume of solid waste from energy production<br>• Volume of radioactive wastes (spent fuel)<br><br>5. Land Use<br>• Hectares of land taken up by energy production, transport and transformation (reservoirs, pipelines, open cast mines, harbours, etc.)<br><br>6. Safety<br>• Numbers killed and injured</td><td>A. Environmental Pollution Damages<br>• Environmental pollution damages relating to energy production and consumption, for certain types of pollutants (e.g. $SO_X$)<br><br>B. Energy Policy Responses<br>1. Environmental Expenditures<br>• Total expenditure on pollution prevention and clean up:<br>  • abatement vs. clean technology<br>  • public vs. private<br>• 'Environmentally related' R and D expenditures:<br>  • public vs. private<br>• R and D expenditures on energy<br>  • public vs. private<br>2. Taxation and Subsidies<br>• Direct subsidies by fuel type:<br>  • calculate ratio by TOE<br>  • calculate as a percentage of sectoral activity<br>  • distinguish subsidies for environmental purposes<br>• Total economic subsidies: direct and indirect subsidies, plus externalities<br>• Relative taxation in per cent by different fuel types<br><br>C. Structure and Performance of the Energy Sector<br>• Real energy prices by fuel type</td></tr>
</table>

Table 2. Priorities for indicator development

| Indicator | Policy Relevance | Conceptual Base | Statistical base | | Summary and notes for future work | |
|---|---|---|---|---|---|---|
| | | | Data quality/ comparability | Data Availability | | |
| **1. SECTORAL TRENDS OF ENVIRONMENTAL SIGNIFICANCE** | | | | | | |
| Total primary energy supply (TPES) | 1 | 1 | 1 | 1 (IEA) | A | |
| Energy intensity (TPES per unit of GDP) | 1 | 1 | 1 | 1 (IEA) | A | |
| Total final consumption by fuel type | 1 | 1 | 1 | 1 (IEA) | A | |
| Total final consumption by sector | 1 | 1 | 1 | 1 (IEA) | A | |
| Per cent of total primary energy supply by fuel type | 1 | 1 | 1 | 1 (IEA) | A | |
| Per cent of electricity generation by fuel type | 1 | 1 | 1 | 1 (IEA) | A | |
| Primary energy produced nationally as per cent of TPES | 1 | 1 | 1 | 1 (IEA) | A | |
| Sectoral end uses: Industry (TOE per unit of value added) | 1 | 1 | 2 | 2 (IEA) | B | (d) |
| Sectoral end uses: Residential (TOE per capita) | 1 | 1 | 2 | 2 (IEA) | B | (b),(d) |
| Sectoral end uses: Commercial and public sector (TOE per square metre) | 1 | 2 | 2 | 2 (IEA) | B | (a),(b),(e) |
| Sectoral end uses: Transport[99] | | | | | | |
| Fossil fuel efficiency for electricity generation | 1 | 1 | 1 | 1 (IEA) | A | |
| **2. ENVIRONMENTAL EFFICIENCY AND IMPACTS** | | | | | | |
| Proven oil/coal/gas reserves in TOE | 1 | 2 | 2 | 2 (IEA) | B | (c) |
| Annual volume of air pollutant emissions | 1 | 1 | 2 | 2 (OECD) | B | (a),(b) |
| Ratio of emissions per unit of GDP and per capita | 1 | 1 | 2 | 2 (OECD) | B | (a),(b) |
| Ratio of emissions by end uses | 1 | 1 | 2 | 2 (OECD) | B | (a),(b) |
| Tons of oil released<br>•through accidents<br>•continuous basis | 1 | 2 | 2 | 2 (OECD) | C | (a),(b),(e) |
| Volume of solid waste from energy production | 2 | 1 | 1 | 2 | B | (a),(b),(c) |
| Volume of solid waste per unit of GDP | 2 | 1 | 1 | 2 (OECD) | B | (a),(b),(c) |
| Volume of radioactive waste (spent fuel) | 1 | 1 | 1 | 2 (OECD) | B | (a),(b) |
| Radioactive waste per unit of GDP and per capita | 1 | 1 | 1 | 2 (OECD) | B | (a),(b) |

[99] *This line in the table is not present in the report. It refers to OECD paper ENV/EC/SE(91) 17 (REV), which, to the best of the author's knowledge, is not available in New Zealand.*

| Indicator | Policy Relevance | Conceptual Base | Statistical base | | Summary and notes for future work | |
|---|---|---|---|---|---|---|
| | | | Data quality/ comparability | Data Availability | | |
| Land taken up by energy production, transport and transformation | 2 | 1 | 2 | 2 (OECD) | C | (a),(b),(e) |
| Numbers killed and injured | 1 | 2 | 2 | 2 (OECD) | B | (b) |
| **3. ECONOMIC CONSIDERATIONS** | | | | | | |
| Environmental pollution damages relating to energy production and consumption | 1 | 2 | 2 | (n.a) | C | (e),(f) |
| Total expenditures on pollution prevention and clean-up | 1 | 2 | 2 | 2 (OECD) | C | (a),(e),(f) |
| 'Environmentally related' R and D expenditures in the energy sector | 1 | 2 | 2 | 2 (OECD) | C | (e),(f) |
| R and D expenditures on energy | 2 | 2 | 2 | 2 (OECD) | C | (e),(f) |
| Real energy end-use prices by fuel type | 1 | 1 | 1 | 1 (IEA) | A | (d) |
| Total subsidies | | | | (n.a.) | C | (e),(f) |
| Relative taxation in per cent by different fuel types | 1 | 1 | 2 | 1 (IEA) | B | (a),(b) |

Notes:
The following are the codes used by the OECD in the table above:

**Criteria:** 1=Satisfactory
2=Needs development work
**Summary:** A=Immediately accessible
B=Short term accessibility
C=Medium term development
**Future Work:** (a)=Improve country coverage
(b)=extend time series
(c)=standardise definitions
(d)=technical data adjustment
(e)=develop appropriate definitions
(f)=improve conceptual basis

The report indicates that the areas that are causing the greatest concern are those indicators dealing with environmental and social concerns. This comment is to be expected, given the nature of some of the components that are to be measured here. It is however encouraging to note that the OECD see the majority of the problems here as being rather minor procedural problems.

Unfortunately, the reports only discuss the progress towards a few of the proposed indicators. Unsurprisingly, the OECD has chosen to focus on the indicators that are easier to create and measure. There appears to be no formal published discussion of the efforts that are being made to address the concerns regarding the other proposed indicators so that it is difficult to comment further on the programme. Given the nature of the OECD and New Zealand's obligations towards it, this proposed set of indicators should be a fundamental building block in the development of a set of sustainability indicators for New Zealand. This is not however to be taken as implying a need to slavishly follow the lead of the OECD, as there are a number of major differences between New Zealand and the majority of the countries in the OECD.

The second published way that the OECD records energy statistics is via its country-based environmental performance reviews. The review of Germany is discussed below, as a report that is indicative of these reports.

The 'OECD Environmental Performance Reviews: Germany' contains a chapter on energy usage in the reunified Germany.[100] According to the OECD, the interface between energy and the environment is best evaluated by three types of indicators.[101] These are essentially the same as the indicators developed under the reports mentioned above, namely:

- development of the energy sector;
- environmental pressures from energy production, transfer and use; and
- energy prices and economic trends.

Indicators from the list of indicators proposed at the two indicator workshops discussed above have been selected to measure each of these major issues. For energy sector trends,

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[100] *'OECD Environmental Performance Reviews: Germany', OECD, Paris, 1993, ch. 6.*

[101] *Above, p. 117.*

the indicators are energy mix of total primary energy supply,[102] and energy intensity on both a per capita and per unit of GDP basis.[103] Measurement of environmental pressures records emissions of $SO_x$, $NO_x$, particulates, $CO_2$, CO and volatile organic compounds.[104] Energy economy interactions are measured via changes in taxes on energy prices which are somewhat unexpectedly measured in nominal rather than real terms.[105]

This report takes a rather narrow focus of energy's impact on the environment, concentrating on pollutants as it does. The indicators of energy sector development measure changes in the major institutional factors, namely energy types and energy efficiency. Analysing energy taxes in the report is appropriate, as these do have an impact on economic considerations, especially as they impact on the price of energy. However it is the price itself (as a reflection of the range of features that are involved in price setting) that has the impact, not the tax element on its own. The concern with energy taxes may be indicative of a European outlook where oil products are viewed as important and their governments claim a large percentage of the final selling price as taxes.

Having analysed the efforts of various foreign governments and international organisations in collecting statistics and monitoring energy use, the final logical step before proceeding to develop a set of indicators is to analyse the monitoring programmes of various major players in the New Zealand energy system.

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[102] *Above, p. 126.*

[103] *Above, p. 122.*

[104] *Above, p. 117.*

[105] *Above, p. 125.*

CHAPTER SIX

# MONITORING BY NEW ZEALAND ORGANISATIONS

There is a paucity of data available about energy sustainability in New Zealand at present. The majority of the governmental organisations that collect energy supply and demand data only collect the type of 'engineering data' that is used to construct the basic OECD/IEA matrices. The other major group of energy data collectors and users are the energy supply companies. They are more concerned with engineering and economic data, which is understandable given the environment that they operate in.

The net result is that there are only four organisations in New Zealand that collect data which relates to energy sustainability.[106] They are the Electricity Supply Association, the Energy Efficiency and Conservation Authority, Statistics New Zealand and the Ministry for the Environment. These organisations and their data collection programmes are discussed below.

## Electricity Supply Association of New Zealand[107]

The Electricity Supply Association (ESA) is the industry body for the individual local electricity supply authorities who supply the majority of electricity consumers in New

[106] *The other major energy monitoring programmes in New Zealand are discussed briefly in appendix one. This discussion is included for completeness, given that they are not programmes of sustainable energy management monitoring.*

[107] *Unless otherwise indicated, the information for this section was obtained from a personal interview with Brian McGlinchy, Senior Executive Engineer, Electricity Supply Association of New Zealand.*

Zealand. Its objectives include the development and promotion of policies that further the effective production, distribution and utilisation of electricity.[108] Other objectives are concerned with furthering the interests of its members and provision of information.[109]

Other than occasional papers, there are two ESA publications that contain statistics. They are the ESA Annual Report[110] and 'Electricity Supply Industry Statistics'[111]. The emphasis of both reports is clearly on engineering and commercial aspects of the production and distribution of electricity, as demonstrated by the inclusion of statistics such as added supply costs, customers per employee, sales per employee, units purchased and generated, total assets and total capital expenditure in the Annual Report. The 'Electricity Supply Industry Statistics' has an even more commercial focus, with tables showing a breakdown of the sales by region, supplier size and density, average retail price, assets and liabilities and profit ratios.

The ESA collects a range of statistics for internal use, some of which are not published. Like the published reports, these statistics are concerned mainly with 'performance and technical efficiency'. The main measures are some of the same ones that appear in the annual report, namely average price, electricity sold per employee and employees per line kilometre. No measure is made of outage time. Instead, security is measured in terms of a 'gold plating index'. This is the ratio of the total transformer capacity to the number of customers or total transformer capacity to the total system maximum demand.

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[108] *'Constitution of the Electricity Supply Association of New Zealand Incorporated', 1989.*

[109] *Above.*

[110] *As the name indicates, this is published annually by the ESA in Wellington.*

[111] *'Electricity Supply Industry Statistics 1988-89 and 1989-90', Electricity Supply Association of New Zealand, Wellington, 1990.*

The final statistic that is collected is the density of customers per circuit kilometre of line. This measure is used as a basis of grouping supply companies by size. It is also used in a regression equation of 20 elements which is used to determine the optimum (economic) performance of the different supply authorities that are members of the association.

The ESA's monitoring programme appears to be driven by considerations of engineering and economics. The 1992 Annual Report notes that the ESA is concerned about the sustainability of the electricity supply, but this concern does not appear to be carried through into the monitoring programme. All of the indicators are appropriate to some of the objectives of the ESA. The issue is whether they focus on a broad enough base of the ESA's objectives. Most importantly, there appears to be no measure of the 'effective utilisation of electricity' and this goal appears to have been subsumed by the promotion of profit making policies.

**Energy Efficiency and Conservation Authority**[112]

The Energy Efficiency and Conservation Authority (EECA) was set up in 1992 as an independent government funded authority charged with developing policies and implementing programmes aimed at increasing energy efficiency in New Zealand. EECA's monitoring programme involves a five-fold approach, pursuing objectives of:

- regular energy efficiency monitoring;
- quantifying the energy efficiency potential within New Zealand;
- sectoral surveys;
- database development; and

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[112] *Unless otherwise indicated, the information from this section is derived from the transcript of the address given to the IPENZ 1994 Annual Conference in Nelson by Nigel Jollands of EECA.*

- a review of energy statistics.

Many of the specific outputs sought under these objectives have yet to be achieved or in some cases even commenced. A description of EECA's intentions is still useful in constructing an overall picture of the monitoring situation in New Zealand.

EECA has established four key objectives relating to energy efficiency in New Zealand. The first objective is concerned with providing information about trends within New Zealand and providing a basis for international comparisons. The intended output is the development of annual statistics providing indicators of energy efficiency (as distinct from energy sustainability). The first output to be delivered was a report on New Zealand's energy intensity published in April 1994.[113] It is anticipated by EECA that the outputs from this programme will initially be on an ad hoc basis because of data availability.

The second objective is the quantification of cost effective energy efficiency potential. This is concerned with identifying the nature and size of the energy savings that are possible in the New Zealand economy. A literature review has been completed[114] and an experts group has been convened. It is envisaged that the information generated here will be used in the preparation of long term strategies and will be made available for general use.

Objective three is to conduct surveys of the energy use of different sectors of the economy. Surveys are already being undertaken for the household and transport sectors, whilst surveys of the industrial and commercial sectors are on-going. The objective of these surveys is to

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[113] *'Updating New Zealand's Energy Intensity Trends - What has happened since 1984 and why?', M. Patterson and C. Wadsworth, Energy Efficiency and Conservation Authority, 1994.*

[114] *'New Zealand Energy Research 1970-1993:An annotated bibliography', N. Isaacs, Energy Efficiency and Conservation Authority, December 1993.*

identify sector specific problems in the data that is available and to obtain as complete a picture of energy usage of the individual sectors as is possible. These surveys therefore necessarily involve a combination of new and existing data.

Database development involves "developing and maintaining New Zealand's most accurate and accessible energy end-use database". The database is intended to be a conglomeration of data collected by EECA and other sources. It is an ongoing project the output of which is the generation of a database.

The final objective is the energy statistics review. EECA aims to make inputs into the statutory review carried out by the Statistics Department, carry out general reviews of its own and conduct interim energy end use surveys. This objective relates more to the management of the monitoring process rather than actual monitoring. The results of the latest review of energy statistics are discussed below.

**Statistics New Zealand**

Until recently, Statistics New Zealand (as the Department of Statistics is now known) has not collected and published energy statistics, presumably to avoid duplicating the Ministry of Commerce's work. Statistics New Zealand is however in the process of conducting a review of the energy statistics that it collects and energy statistics do appear in a publication released in October 1993 called 'Measuring Up: New Zealanders and the Environment'.[115]

A significant portion of the basic, energy production and consumption-orientated data contained in 'Measuring Up' is sourced from the Ministry of Commerce and Electricity

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[115] *Statistics New Zealand, Wellington, October 1993.*

Corporation of New Zealand. Other information involving comparisons between New Zealand and other OECD countries appears to be from either New Zealand's annual returns or the volumes that the OECD produces as a result of those returns.

Despite the title of the report, there are actually no statistics that directly link energy usage and the environment. The vast majority of the statistics are concerned with simple measures of the total product from the different energy types that make up the New Zealand energy supply system. Whilst these can be said to show an indirect link to the environmental effects of energy usage, the link is not made clear in the report. Given the target audience of this volume, this omission is perhaps a failing of the report.

The closest that the report comes to providing energy sustainability statistics is via energy intensity and self sufficiency measures. The former is recorded in terms of an index comparing New Zealand to the rest of the OECD and in terms of the percentage change that has occurred from 1970 to 1988. The latter is measured in terms of imported oil as a percentage of primary energy and in terms of self sufficiency of liquid fuels.

The levels of various aerial pollutants are measured in chapter one of the report. The pollutants measured are $SO_2$, $NO_x$, suspended particulates, lead, acid rain and the common greenhouse gases. Whilst the major source of some of these pollutants is obviously energy use (for example, tetra-ethyl lead released from burning leaded petrol), the report does not explicitly link the release of these contaminants and the use of energy, as the Norwegian reports did.[116]

Overall the report is unsatisfying as it adds little to the state of energy indicators in New

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[116] *See previous chapter.*

Zealand and omits to deal with energy-environment interactions, despite the report's purported intent.

The review that Statistics New Zealand is currently conducting is a requirement that the Department has under the Statistics Act 1975 and is the first review of energy statistics that the Department has undertaken since 1983.[117] It is currently in its draft stages.

The review recognises that energy statistics in New Zealand are inadequate and are dominated by a supply side focus. It also notes that the range of agencies that collect energy statistics results in the needs of many of the users of energy information being poorly met.

Some of the gaps in energy data that the report recognises are the lack of information about reserves of fossil fuels, the lack of production and supply information about renewable energy types and the lack of end use data. The report is equivocal about the state of data on emissions, noting that a review may be in order, but also noting that present levels of information may be adequate. The Ministry of Commerce's energy matrix (from the 'Energy Data File') is criticised in terms of its accuracy, utility and timeliness.[118] One suggestion that the report contains is to make the matrix available on Statistics New Zealand's 'INFOS' computer database.

One of the most exciting suggestions that the review raises is the possibility of conducting detailed industry by industry surveys of energy use along the lines of the 'Fuel and Electricity Survey' conducted by the Australian Bureau of Agricultural and Resource

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[117] *'Energy Statistics Review', Statistics New Zealand, 1994.*

[118] *Above, p. 4.*

Economics.[119] This survey is conducted every two years in Australia and provides a detailed analysis of a number of key sectors of the economy. Such a programme would enable specific efficiency monitoring programmes to be developed and would assist in focusing macro-level indicators. At present, EECA is developing a recommendation about this type of monitoring programme to put to Statistics New Zealand.

Despite recognising that the interests of users of energy information are wider now than they were at the time of the last review, the draft review does not recognise monitoring of sustainable management as one of the 'emerging and likely future needs for energy statistics'.[120] The report does however recognise environmental issues, energy efficiency and conservation and natural resource accounting, although the latter is viewed as being concerned primarily with non-renewable resources and the portion of return on investment that is derived from the resource. Environmental issues are limited to emissions of gaseous pollutants, while the discussion on efficiency is solely concerned with the issue of what basis to measure efficiency on. Concepts such as the use of renewable energy and transmission or conversion losses are not mentioned.

The report ends with a list of specific recommendations for each of the sectors that are analysed in the report, but does not indicate a timeline for analysing and implementing those recommendations.

While the review identifies a number of the criticisms and deficiencies which exist in the energy statistics that are collected at present, it omits a number of important matters. For example, the section on environmental effects completely omits to mention solid wastes and

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[119] *Noted at pp. 23 and 24 of the draft report.*

[120] *Above, pp. 14-18.*

various spillages and losses of energy into the environment. It also fails to recognise the inadequacy of the statistics that are currently collected on gaseous emissions (as national figures are only available for $CO_2$). The review also indicates a continued preoccupation with the issues of fossil fuel supply and the efficient operation of energy markets. This may reflect the prevailing attitude of some of the organisations that participated in the review process (for example, the Treasury and the Ministry of Commerce).

The list of emerging uses has a very limited scope, being largely a continuation of the status quo. There is brief mention of environmental concerns, but no mention of sustainable management of energy as one of those uses. Given the attention that is being given to sustainable management of all resources in New Zealand and globally at present, this cannot be passed off as a mere oversight. It is to be hoped that the review recognises this concept before it is released in its final form.

On the positive side, the review does identify many important policy areas that are in need of improved information coverage. The most important of those is the investigation of the possibility of conducting an in depth, sector-by-sector analysis of energy use. Similarly, the suggestion of making more energy statistics available in a more accessible and timely manner on INFOS must be welcomed.

**Ministry for the Environment**

The Ministry for the Environment (MFE) has produced the two leading New Zealand works on state of the environment reporting and sustainability indicators in conjunction with the Department of Statistics in 1990 and 1991.[121] These reports investigated the theoretical

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[121] *Above.*

and logistical issues surrounding the development of state of the environment reports without actually attempting to develop a potential first set of indicators. A brief to develop a set of indicators of sustainability was issued by MFE in 1992. Instead of developing a set of indicators however, the result was a further intellectual treatise on indicators[122].

The Ministry is in the process of developing a state of the environment report, one chapter of which will focus on the environmental impacts of energy. The draft version of this report is mainly concerned with identifying the types of problems that may arise as a result of energy impacts rather than developing ways of measuring them.[123] One of the most useful aspects of the chapter is Table 2, a matrix detailing an inventory of potential impacts from energy[124]. This table is very broad, looking at all stages of the energy type's 'life-cycle', although a number of the concerns included in the table are more closely related to the technology used to refine or use the energy rather than the energy form itself. The first column in the matrix, referring to potential impacts from 'energy source and access', is difficult to understand. The impacts listed are related to difficulties associated with the earliest stages of 'extraction' and 'refining' (both terms being defined as appropriate for the energy type in question), yet impacts from these activities are also included as a separate class in the second column of the matrix. Some of the potential impacts are very tenuously linked to the energy form in question, such as the potential of scalding accidents from uncontrolled coal or wood heated wetbacks, and are more properly the concern of the type of micro-level management that local authorities and other similar regulatory bodies undertake than the macro-policy approach that is MFE's area of concern.

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[122] *See Dialogue Consultants, above.*

[123] *Reference to 'the draft' refers to a copy provided by the author of the chapter, Ian McChesney, to MFE in September 1993. The author has been told that this report has been completed. Enquiries at MFE have not however been able to confirm whether this is correct.*

[124] *Above, pp. 12-14.*

It should be noted that the definition of environment used in the proposed report appears to be the same broad definition that is used under the Resource Management Act 1991, namely looking at both human and non-human aspects of the environment.

Given the criteria for indicator development and the definition of energy sustainability that were developed in chapters three and four and the guidance that is provided by assessing the various monitoring programmes noted in this chapter and the preceding chapter, the next logical step it the development of the indicators themselves. This will be done in two stages, with the next chapter focusing on the framework and chapter nine developing the indicators.

CHAPTER SEVEN

# DEVELOPING A FRAMEWORK FOR ENERGY SUSTAINABILITY INDICATORS

The development of a preliminary set of indicators can be broken into two basic parts. The first part is the development of the framework that the indicators will be used in. The framework is the basic model that is to be created and involves the various layers of indicators and the weighting to be given to each of the component parts of sustainability. The second stage is the development of the indicators themselves, which involves the application of the criteria discussed earlier. The framework will be discussed here, while the indicators will be developed in chapter 8.

## THE FRAMEWORK

As noted by Braat, indicators can be viewed as fitting within a triangular hierarchy structure.[125] That hierarchy is depicted in Figure one and is reproduced again below for completeness. The different levels in the hierarchy reflect the different levels of aggregation and specificity required by different users of the indicators.

As the framework illustrates, the bottom tier is the most scientifically rigorous. This layer of the framework would be of most relevance to those people charged with developing the actual methods of implementing policies. In the instant case, this layer would involve measuring as many of the individual factors that contribute to the particular tenet of

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[125] *Braat, above, p. 59.*

sustainability and which are useful to policy makers in as detailed a form as can be practically measured. Examples could include measuring emissions on a per sector or per energy conversion process basis.

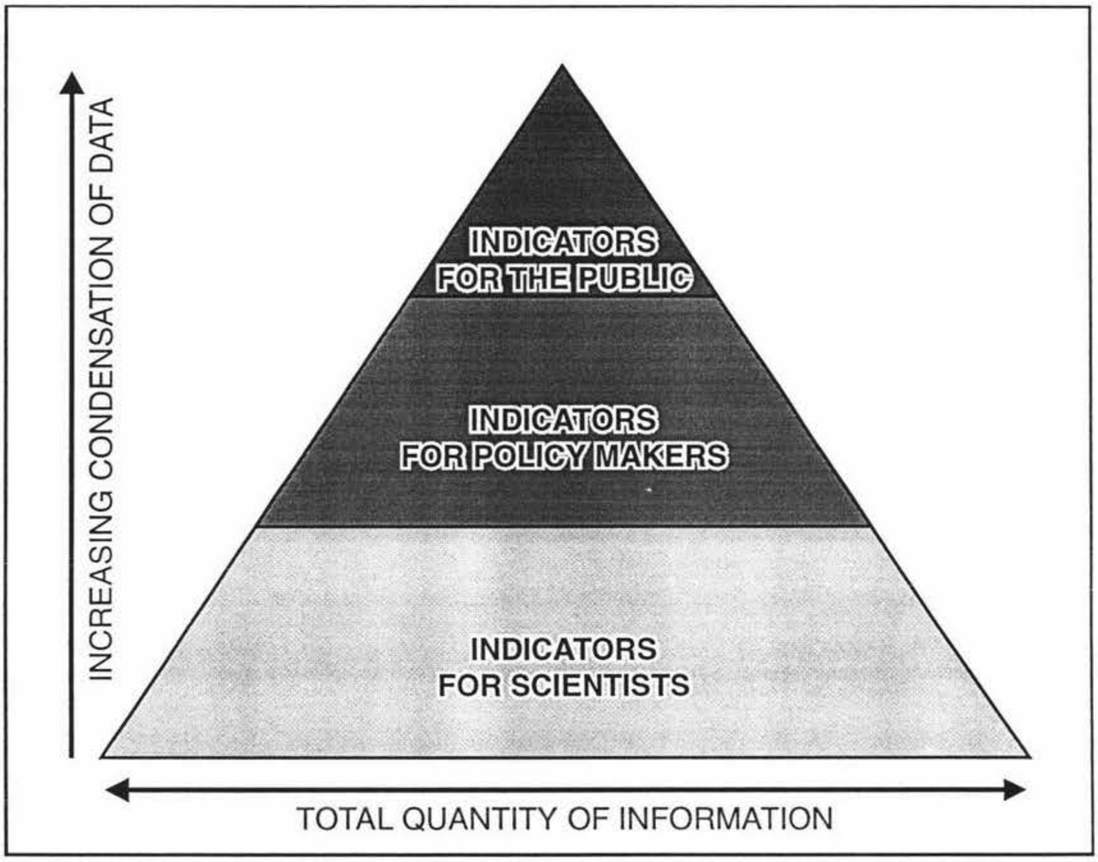


*Figure Two: Indicators, data and information*
*(Source: Braat, above)*

The mention of practicality is not to imply a desire to avoid the 'hard issues' but rather is a recognition that there are some factors which are presently unable to be measured because the data costs are too great or there is presently no feasible means of measuring the particular parameter. It is possible that some factors may remain unmeasurable. Whether or not it is impractical to measure a factor is a function of the difficulties involved in measuring it, whether measuring other factors is a sufficiently acceptable alternative and the importance of the particular factor to the issue of sustainability.

The second layer of the framework is a more concise representation of the factors that are measured at the first layer. The most practical way to achieve this conciseness is through aggregation, as that approach summarises the information by including the matters that are in the previous layer rather than by excluding them. This layer would be of most interest and use to politicians and those people charged with formulating objectives and policies (who may not be the people who actually develop methods of implementation for those policies).

The top level of the framework is the most summarised. This is the level that is intended for public presentation. It contains all of the relevant information in a highly aggregated form but can still be used by lay people to chart the progress of the country towards a sustainable state. This level and the second level could be published together so that the components of change can be understood by members of the public who wish to delve deeper into the reasons for a particular state. Publishing these two levels together is analogous to the preparation of a number of economic indicators which are published along with information about the various components which make up those figures. It is envisaged that it would be unnecessary for the majority of users of the indicators to go beyond this combined level of information.

A further consideration with indicators is whether to publish a series of indicators or to amalgamate them into a composite indicator. It is also possible to prepare both, as is done with economic indicators such as the consumers' price index. Present practice seems to favour the publication of a series of indicators when environmental factors are being measured.

If indicators are to be aggregated into a composite indicator, then two disciplines are imposed on the development of indicators within the framework. The first discipline is that all of the individual indicators must be consistent with regard to the magnitude of the measure. Care must therefore be taken to decide in advance whether high numbers on any particular scale will reflect desirable or undesirable outcomes. The second discipline is to ensure consistency of scale. For example, it is pointless attempting to aggregate energy intensity measured in tonnes of oil equivalent per million dollars (a figure that is measured in units between 0 and 0.5 in New Zealand) and the total amount of $CO_2$ released in a given year (a figure in the millions). The need for a commensurable scale may result in extensive use of indices, as was suggested in the OECD reports on energy-environment indicators.[126] This approach has the disadvantage of creating a further layer separating the users of the model from the actual figures. The biggest problem however is that using indices (and therefore focusing on percentage changes) can end up disguising the actual absolute level of the effect. This problem can be addressed by publishing absolute levels of key variables as a separate series and comparing both changes and absolute figures with statistics on other countries. If this approach is taken however, it can call into question the benefit of aggregation in the first place. It should also be noted that, with sustainability indicators, the intention is initially to bring about change and later, when the desired levels have been reached, to prevent change from a dynamic steady state. As such, changes in levels can be more relevant than the absolute levels of factors.

In this thesis, the intention is to focus on the middle level of the hierarchy and to develop a series of indicators rather than a composite index. In some ways, it is possible to argue that deciding to develop a series of indicators automatically favours this level of specificity.

This approach was chosen because it provides an appropriate level of detail to enable the sustainable management of energy in New Zealand to be addressed. As an example, little

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[126] *Above.*

benefit would result from aiming for a high degree of specificity regarding sources of $CO_2$ emissions in New Zealand, as it is possible to intuitively identify the major sources of these emissions.

The decision to use a series of indicators rather than a composite was further influenced by the degree of overlap between the different components of energy sustainability that have been identified in this thesis. For example, addressing the issue of the renewability of sources of energy also addresses many of the issues relating to emissions of pollutants. The series approach is also favoured because of the highly subjective and highly political nature of the issue of assigning weights. The fact that the different component parts of the energy sustainability equation make different contributions to energy sustainability in general means that it is not possible to take a simple average of the results from each indicator. The task of assigning weights carries with it an implication that one is deciding the relative importance of the different factors, so that policy makers could misdefine the scope of issues and could prejudge response strategies. The issue of weighting can easily detract from the real issues surrounding energy sustainability in New Zealand.

Using a series of indicators rather than a composite indicator is also favoured because, despite being part of a single umbrella concept, the components of energy sustainability are sufficiently disparate to make the aggregation of the different heads problematic. As one of the key differences relates to the speed with which systems respond to management incentives, this factor has significant management implications. Matters are further complicated by the fact that the threshold for what constitutes a significant change for each of the phenomenon are significantly different. As well as having different scales and orders of magnitude, the variation that occurs in the shape of the issue of sustainable management over time means that aggregation is not favoured. The latter factor can result in weightings needing to be constantly re-assessed, which decreases the ability of an indicator to illustrate changes over time.

In developing these indicators, it should be noted that the indicators and the framework that are suggested here are only one possible solution. It should also be remembered, as was noted in the section on the criteria for indicator selection, that the exact nature of the set of indicators that is used should be constantly reviewed as the issues that are being assessed change.

Given these decisions about the framework that the indicators are to be developed within, the next stage is to develop indicators to measure the ten components of sustainable energy management that were identified in chapter four.

CHAPTER EIGHT

# DEVELOPING INDICATORS OF ENERGY SUSTAINABILITY

In chapter four, ten areas were identified as being the primary areas that need to be addressed by indicators of energy sustainability. Those areas are:

(1) proportion of total energy supply provided by renewables;

(2) minimising environmental impacts of energy supply and consumption;

(3) proportion of household income spent on energy;

(4) economic rent accruing to energy suppliers;

(5) diversity of sources of energy supply;

(6) safety margin or redundancy in the system;

(7) the impact of energy pricing on economic activity;

(8) remedial expenditure required;

(9) output per unit input;

(10) end-use matching.

Each of these areas will be discussed in turn and, where possible, an indicator or indicators will be suggested to measure the key concerns that were identified earlier.

The discussion on each of the indicators follows a common format. Firstly, the issue itself is identified and briefly discussed again. Secondly, those indicators that are currently used or mooted as potential measures of each phenomenon are discussed. In those cases, where there are no indicators that are either in use or that have been promulgated, this stage is omitted. The third stage is the suggestion of possible indicators and a discussion of why they have been chosen. Finally, each of the suggested indicators is checked against the criteria that have been developed in chapter two of this thesis.[127]

Not all of the indicators that are developed below may be able to be developed at present, for a number of reasons. In some cases, the data is either too difficult or too expensive to collect or else is not currently considered to be necessary. In other cases, data has not been collected because the information relates to companies and other organisations who are not prepared to release it for reasons of commercial sensitivity. This lack of data should not in any way detract from the indicators that are developed and should be seen as a form of encouragement to begin collecting the type of raw data that is required. In those cases where the concepts to be measured mean that it is difficult to collect data it is hoped that the discussion here encourages further debate and focuses attention on the issues that are at present causing difficulty.

## PRELIMINARY INDICATORS:

### (1) Proportion of total energy supply provided by renewables

This is one of the simplest aspects of energy sustainability to understand. An energy supply system that is based on non-renewable fossil fuels will not be able to function over the long term so that it cannot be said to be sustainable. The solution is to increase the use of renewable energy sources, provided that the other requirements of sustainable management are not violated.

[127] *This assessment will be conducted in chapter nine.*

There do not appear to be any countries or organisations that use indicators of the proportion of the total energy supply that is supplied from renewable sources.

Two forms of data are useful for this indicator. The first is the actual amount of renewable energy sources that are used. The second is the percentage of total energy use that is supplied from renewable sources. Both indicators are used to isolate the effect of changes in the overall level of energy supply that would be masked by solely using the percentage indicator.

The indicator of the actual amount of renewable energy that is used in New Zealand in a given period is simply a total of all forms of that energy. The formula for the percentage indicator is conceptually extremely simple, as it entails expressing a measurement of the proportion of the total energy supply that is provided from renewables as a percentage. In practise, the process is complicated somewhat by the issue of how to calculate the units that the energy supply is measured in. The argument centres on whether to measure energy in heat units or in an equivalenced measure.

Using heat units is a matter of simply counting the units of energy output of each energy type and adding them to those of other energy types, irrespective of the quality of each energy type or the type of work that can be done with it. Expressing energy supply in terms of heat units therefore understates the contribution of higher quality energy types (such as electricity) whilst overstating the role of lower quality energy types (such as solar). This is directly relevant to the issue of renewables use, as many renewable energy types utilised in conversion processes that are relatively inefficient. In some instances, the nature of the conversion process and the diffuse nature of the energy inputs mean that these inefficiencies are unavoidable.[128]

If heat units are not to be used, the alternative is to convert the energy supply figures to a unit of measurement that takes account of the quality differences between different energy types. Equivalencing would involve measuring all inputs in terms of the OECD's TOEs.[129] This would result in the relative contribution of electricity being increased and the contribution of many of the renewable sources being decreased.

The proportion of energy inputs derived from renewable energy sources will be measured in terms of heat units for two primary reasons. The first is the degree of dissatisfaction and lack of agreement that surrounds the use of TOEs. This dissatisfaction centres around such issues as the correct conversion factors to use and the validity of using a fuel such as oil as the base unit of measure. The second reason relates to the fact that in many instances renewable energy sources are matched closely with the task they are used for, so that the issue of the quality of the consumer energy derived from them is not relevant. This reason relates especially to such processes as the use of fuel wood for space heating and the use of solar energy to heat water. The position of renewable energy sources that feed into national supply networks (such as the use of hydro-electricity in New Zealand) can provide an argument for using quality equivalents. This argument would be more valid if the purpose of the overall series of indicators was not also to change the focus of the energy supply system from a centralised large scale production and supply system to a more robust locally oriented system. For these reasons, energy units will be measured in terms of heat units.

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[128] *The inefficiencies may however be less relevant for many of the renewable energy types because of the continuously renewable nature of the energy sources and the nature and usual location of the energy conversion technologies.*

[129] *Other equivalenced units have been suggested, however these systems have not received the degree of acceptance that TOEs have, presumably because they do not have the weight of an organisation such as the OECD to support them.*

The formula for calculating indicators of the proportion of renewables is:

$$R = \left(\frac{E_R}{E_T}\right) \times 100$$

where:

R = the proportion of renewable energy used (expressed as a percentage); and

$E_R$ = the amount of renewable energy used in a given period (expressed in heat units); and

$E_T$ = the total amount of energy used in a given period (expressed in heat units).

**(2) Minimising the environmental impacts of energy supply and consumption**

This aspect of the nature of energy use is not of concern for reasons that directly impact on the sustainability of the use of energy itself, as energy supply systems can still operate in a polluted environment - albeit far less efficiently than in an unpolluted environment. Rather this issue is of concern because of its impact on sustainability and the continuation of life on Earth in general.

There are two main options for the focus of energy-environment indicators that are to be developed here. The first option is to focus on macro-level indicators. These indicators look at the effects of energy in terms of major level environmental impacts such as the release of pollutants. The principle alternative to this approach is to focus on micro-level effects.

These would be the effects of energy supply and consumption on more detailed factors such as localised species loss and impacts on a particular natural feature. Focusing on micro-level effects would imply the use of a Leontief Matrix approach to the measurement of the environmental effects of energy use. There are of course a number of options that lie in a continuum between these two principal options and contain differing degrees of each of them.

The indicators that are developed in this thesis to measure energy-environment interactions will have a macro-level focus. This approach is taken for two principle reasons. The first of those is simplicity. Developing a Leontief Matrix for a particular site when analysing a specific project can very easily result in a matrix that measures over one hundred different elements. If this level of information is scaled up to account for national level analysis - which would be necessary to keep the indicators developed here in line with the rest of the analysis - the task would quickly become unworkable, as both users and providers of the data would be overloaded with information.

The second reason for the macro level focus is that management agencies have indicated a preference for dealing with more specific environmental effects on a site-specific, case by case basis. This focus reflects both the nature of the environmental management agencies' statutory jurisdictions and the nature of most environmental effects. The majority of the localised environmental effects of energy are directly related to the macro-level effects that will be measured here. An example of this is the loss of aquatic habitats due to overgrowth of plant life as a result of global warming. Many of the micro-level effects can also be dealt with more simply and effectively through the resource consent application process under the Resource Management Act 1991, as many of the effects are able to be avoided or mitigated by careful selection of sites, equipment and processes.

For these reasons, the focus in this thesis will be on macro-level indicators.

The production, transmission and use of energy impact on the environment in two broad ways. The first is the use of the environment as a waste sink. The second is the use of the environment as a resource or a facilitator in an energy process. Even though the two types of effects are interrelated, they are sufficiently different that they should be dealt with separately. Each head will be the subject of the next two parts of this section.

*(i) Emissions of pollutants:*

This is the area of energy-environment interactions that has been given the most attention, as it is both a highly visible, important impact of energy use and is the easier of the two heads to measure and address.

Measurement of the emission of pollutants is a relatively simple issue, as is setting the parameters of the issue which are to be addressed. A number of countries are already measuring the level of emissions of various types of pollutants.

The fullest discussion of the different aspects of energy-environment interactions is provided by the OECD.[130] Of the twelve indicators that were postulated by the OECD, two do not apply to New Zealand, as they are concerned with radioactive waste.[131] Another is an indicator of aerial pollutants and will be discussed below.

Of the remaining nine indicators, one indicates the numbers of people killed or injured by

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[130] *OECD, 1993, above.*

[131] *This conclusion assumes that there will not be any change in New Zealand's anti-nuclear policy.*

energy activities. This indicator is more properly categorised as a social or economic concern about energy use. Notwithstanding that factor, it would be a useful indicator, albeit one that presents numerous conceptual difficulties (for example, boundary issues and showing causal links). In the present series of indicators, this concern is more correctly a component of the indicators relating to remedial expenditure than an environmental effect, even allowing for the breadth of the definition of environment. A fuller discussion of the issues surrounding this type of effect is therefore contained in the section on remedial expenditure below.

Eight of the OECD's proposed indicators are useful and could be employed in New Zealand to some degree, or with some modification. Six of those indicators apply to emissions of pollutants. The other two, which deal with resource use, are discussed below. None of these indicators are explained in detail in any OECD reports that are publicly available in New Zealand. The proceedings of the committee that is charged with the development of these indicators only report the status of the development work of the proposed indicators in terms of five factors, as is noted in Table Two above.[132] As a result, the following interpretations of their intended purpose are, to a considerable extent, the result of the author's interpretation of the likely purpose in light of the overall issues of energy sustainability.

Those indicators that the OECD has proposed that apply to pollutants are:

(a) tons of oil released through accidents; and

(b) tons of oil released on a continuous basis.

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[132] *See p. 79, above.*

The tons of oil released due to accidents or on a continuous basis (the latter term is not defined) could be expanded to include the total level of energy that is released into the environment during the extraction, conversion and transportation of energy to a place and a state where it is able to be consumed. This would apply to all energy types and would include things such as electricity transmission losses and the volumes of gas that are flared during petroleum exploration, although care would be needed to ensure that effects were not double counted. Such a focus is a means of encouraging efficiency in the production and extraction of energy and the decentralisation of the energy supply system (which leads to increased security). Expanding the scope of the indicator in this way has the additional advantage of obviating the need for a separate measure of the efficiency of energy production and transmission.

This indicator would be most meaningful if the total amount of each energy type that is released is expressed either in physical units that are appropriate to the energy type, or in terms of the percentage of the total use of that energy type in New Zealand in a given period. The former approach is favoured, since it is in producers' interests to keep the level of losses very small in comparison to the total level of use of each fuel type.

The total level type of indicator is also favoured because expressing losses in percentage terms will often require information to be presented in numbers that go to many decimal places, which may deter a number of less technically oriented users of the information. There is also likely to be something of a shock value in having larger numbers for the amount of energy lost, which can be used to spur some action out of the same group of users. Using absolute amounts enables percentages to be calculated very easily, should they be considered to be necessary.

At present, the OECD considers this indicator to be relevant to policy making but the conceptual base, data quality and comparability and data availability all need further work. The areas that the OECD considers need attention are the country coverage (as not enough countries are collecting the necessary base data) and the time period covered. Appropriate definitions also need to be developed, implying that very little work has been done on this indicator. This conclusion is supported by the fact that the OECD considers this to be a 'medium term indicator', which is the longest time period that the OECD use in the report. Those concerns that relate to international consistency are of less relevance if the indicators are to be used solely within New Zealand. Paying attention to what other countries do is relevant however, as it provides a basis for New Zealand to be able to compare its performance with its trading partners and competitors.

(c) volume of solid waste from energy production; and

(d) volume of solid waste per unit of GDP.

Like the indicators of tonnes of oil released, these two indicators are closely related to each other. In this context, solid waste is assumed to mean spoil, tailings and other products that are associated with extractive processes involved in the obtaining of primary energy resources. This assumption is based on the inclusion of particulates in the aerial emissions category and the consequent need to avoid double counting.

Measuring effects in terms of units of GDP appears to be a preoccupation of the

OECD and most other economic agencies. Leaving aside the issues of the propriety of GDP as more than an economic measure and whether it is possible to have 'purely economic' transactions - both of which are beyond the scope of this thesis - it is questionable whether GDP is an appropriate unit of measure in this case. The use of GDP is acceptable when the phenomena measured are purely economic in nature. However, when economic organisations move beyond purely economic phenomena, as the OECD has done in this instance, the usefulness of GDP as a measure decreases rapidly. Smaller ratios can be achieved either through an improvement in the conditions or due to an increase in GDP. The latter is obviously not a factor of energy management and can therefore be said to distort the results.

Some form of equivalencing is required in this measure (such as GDP per capita) to enable countries of different size to be compared on a more similar basis. Equivalencing does not however answer the question of the relevance of GDP in the equation and the results are still very much dependent on the nature of the economy and the means that it uses to generate its GDP. This indicator should therefore not be used.

The volume of solid waste from energy production on the other hand is a potentially useful indicator that is the equivalent of the indicators that measure the levels of the various aerial pollutants. It is also an area which is presently completely ignored in New Zealand, both in terms of energy policy and waste policy.[133] Inclusion of this indicator is necessary for completeness. As stated above, it is assumed that the types of solid waste measured would be tailings from mining and ash from combustion processes.

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[133] *Personal communication, Ministry for the Environment.*

The OECD considers that this indicator needs work before it becomes relevant for policy making purposes. The conceptual basis and data quality are both satisfactory, although the data availability is limited. The problems with the data are the country coverage, the time period covered and the lack of standard definitions between the various OECD countries. Again, those concerns relating to international consistency are slightly less relevant to developing indicators for use solely within New Zealand. This indicator is considered to be accessible in the short term.

(e) emissions per unit of GDP; and

(f) emissions per capita.

These indicators are similar to indicators that have been developed by Canada in its preliminary set of environmental indicators.[134] As noted there, these indicators can disguise a number of factors and can also reflect changes in non-energy part of the indicator at least as clearly as they reflect the energy issues. It is also considered that the fact that most emissions are sourced from a few identifiable sources (both point sources and generic sources) means that these indicators add little to the information that can be derived from a total emissions graph. They should therefore not be developed further.

A number of aerial pollutants are also relevant in measuring the effects of energy production and use on the environment. The OECD suggests measuring $CO_2$, $NO_X$ and $SO_X$, as indicators of the greenhouse effect and acid rain, respectively. While these effects are relevant to New Zealand, they are necessarily generalised to ensure their applicability to the majority of OECD countries. As with all of the indicators that are developed in this thesis,

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[134] *See pp. 71-73, above.*

the specific details of the New Zealand energy supply system should be taken into account. Therefore, the aerial pollutants that should be monitored in a New Zealand sustainable energy management monitoring programme are:

- Carbon Dioxide
- Sulphur Oxides
- Nitrogen Oxides
- Particulates

It is possible to argue that methane should also be included in this list, since it is a pollutant associated with the extraction and production of oil and is included in other countries' monitoring programmes. Oil production is however an insignificant contributor to New Zealand's emissions of methane, the majority of which come from agriculture and decomposition of vegetal matter.[135] This fact is graphically illustrated by the fact that agricultural emissions of methane for the Taranaki region are over twice the amount of the national level of emissions of methane from oil and gas exploration and transportation.[136] A further factor is that the majority of the methane released during hydrocarbon exploration and extraction is flared, so that it is measured by proxy by measuring carbon dioxide emissions. Methane emissions are also addressed when the issue of increasing renewable energy use is addressed.

It will be necessary to identify the different sources of each of the pollutants for analysis and management purposes. For the purposes of constructing a publicly released indicator however, it will only add a complication to the calculation process that is not warranted by

[135] *'A Taranaki Response to the Enhanced Greenhouse Effect', Taranaki Regional Council Technical Report 93-23, Taranaki Regional Council, May 1993, pp. 8-13.*

[136] *Above, p. 12.*

the added information that is provided. This is partly due to the fact that all of the above pollutants are derived principally from the extraction, production and consumption of fossil fuels. This fact automatically limits the number of sectors in the economy that are relevant for analysis purposes, as there are a limited number of sectors which use these fuels to a significant degree.

Although emissions of each of the different pollutants are measured in terms of units of weight, they use differently scaled units. For example, carbon dioxide is commonly measured in millions of tonnes (or tons in countries using imperial measurement), whilst nitrous oxide is measured in terms of thousands of tonnes (or tons). As a result, it is possible for a minute change in the level of carbon dioxide to completely swamp a major change in the level of one of the other pollutants. This swamping of changes is one of the principal reasons for favouring the production of a series of indicators over a composite indicator.

*(ii)* *Resource Use*

This head of environmental impacts has been given far less attention than the other category of environmental impacts, largely because of two specific difficulties associated with developing policies and solutions to this issue. Firstly, the measurement of the various impacts required is more difficult than for the emission of pollutants, as measuring resource use is not simply a matter of measuring levels of outputs from a system. Problems arise as to where to draw the boundary of systems and the types of resources that are used. The boundary problem is of specific concern in dealing with those resources that are not actually used in a process but which facilitate that process.

The second difficulty that this class of environmental impacts presents regards the solutions required. Issues of resource use entail addressing the very basis on which modern economies are created and the patterns of society that are built on that base. Whilst most people are happy to address the issue of smokestacks belching black smoke, fewer people are prepared to go without a second car or the trappings of a throwaway consumer society.

As these issues illustrate, resource use can be a very broad concept. There are three heads of resource use that are of concern in developing indicators of energy sustainability.

As the name implies, resource use includes issues of how much of each type of a particular energy resource is used in a particular energy conversion process. This concept is measured by assessing the amount of energy that is used in a country in a given period. As well as being a measure in its own right, this indicator fulfils useful reference and explanatory functions for the other variables in the series.

Total primary energy supply will be used to measure this phenomenon. The most important reason for this is that measuring total primary energy supply captures that portion of energy that is used by consumers as well as the portion that is lost in conversion processes along the way to that final use.

It could be argued that the concept of depreciation of natural capital should be included here. This concept would make adjustments to New Zealand's stock of natural resources to recognise that a certain proportion of those resources have been irretrievably used in the economy over a period. The idea of natural capital depreciation was first suggested by

Repetto[137] and was developed further by Pearce.[138]

The concept of depreciation of natural capital is contended to be of limited utility in assessing the use of energy resources. Those resources come into one of two categories, namely renewable and non-renewable energy types. With the exception of geothermal draw off and fuel wood, it is not meaningful to talk of depreciation of the former type of energy source. Wind or solar energy cannot be depreciated by using wind turbines or photovoltaic panels. With hydro resources, the limits that may be exceeded are the capacity to harness the energy in water, not the energy of the water itself. Geothermal energy is currently either utilised on such a small scale or is controlled by ECNZ in New Zealand so that it is easily managed through the resource consent process. The efficacy of this form of management was demonstrated by the bore closures in Rotorua in order to protect the Whakarewarewa thermal area. It is acknowledged that fuel wood usage is a type of energy use that lends itself well to the notion of natural capital, being a sustainable resource that can easily be managed unsustainably. Fuel wood is not however a major energy source in New Zealand and there are no shortages, due in part no doubt to the fact that much fuel wood is a by-product of building and other industrial uses of wood.

Turning to the use of non-renewable energy sources, there is limited utility in measuring the depreciation of the natural capital of these energy types. By definition, every usage of a non-renewable energy source must decrease the natural capital that is held in terms of reserves of that energy type. The only way to avoid this depreciation is to avoid using the resource altogether. This situation is to be contrasted with the situation regarding renewable

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[137] *'Earth in Balance; Incorporating Natural Resources in National Income Accounts ', R. Repetto, in: 'Environment', 34:7, 1992.*

[138] *'Blueprint 3: Measuring Sustainable Development', D.W. Pearce, Earthscan Publications, London, 1993, pp. 34 to 38.*

resources where the concern is to ensure that levels of use are kept within renewability thresholds. Attempting to extend field life and the like by analysing the current rate of energy use is related to the concept of thresholds, although with the significant difference that there will always be a limit to field life. As noted above, this parameter is already able to be measured simply by comparing energy use for a given period with the known reserves. It is not considered that a recognition of the loss of resources in terms of depreciation of natural capital will add anything to the promotion of the use of renewables.

Given the factors that are discussed above, depreciation of natural capital will not be measured in relation to sustainable energy use in New Zealand.

The second head of resource use is the use of resources to facilitate the operation of a particular system. The best example of this is the loss of land, habitat and amenity that occurs with the creation of a lake for a hydro-electric power scheme. On a macro level, the use of land as a facilitatory resource is not an issue for New Zealand. A generous assessment of the proportion of New Zealand land used for energy related projects puts that figure at considerably less than 1% of the available land. The problem with land use arises because of the competing uses of the land that is sought to be used for energy purposes. These competing uses often relate to habitat, recreation and amenity values.

As noted previously, there is no national level database of the impacts of development on these values, with the relevant consent authorities preferring to deal with these impacts on a case-by-case basis. Given the small proportion of New Zealand's land area that is used for energy purposes and the largely localised effect of these projects, it is prudent to continue to deal with these impacts on a case-by-case basis. A national level perspective is provided by the Department of Conservation, which has a structure that operates both nationally and on a regional basis. This means that the details are captured and can be collated or compared on a national level. The Resource Management Act 1991 also includes reference to national level matters. As discussed above, a site specific approach has the advantage of being administratively simpler than attempting to detail all impacts on a national-level basis.

A further problem with measuring the use of resources that facilitate energy conversion processes is where to draw the boundary of the system. In some cases the boundaries are relatively clear. However, in all systems the issue of the capital equipment and the resources that go into the construction of that equipment will always add a complication. Care must be taken to draw the boundaries narrowly or else the users of information will be overloaded with information for a very limited additional benefit.

The third head of the resource use issue is the use of the environment as a waste sink. This reflects the theory of conservation of mass, whereby the inputs to a system must equal the combined total of useful outputs and waste matter. This third head is the complement to the measurement of the emission of pollutants. There is little to be gained from the measurement of the waste absorption capacity of the environment as calculation of that capacity is based on empirical models and the level of pollutants that are emitted, so that it is simpler just to measure those emissions. There is a further disadvantage in that measuring waste assimilation capacity can lead to complacency and can divert attention from the minimisation of harmful emissions in the first instance if the environment appears to be satisfactorily assimilating the pollutants emitted. It is also not possible to fully chart and understand the implications of the absorption of some pollutants in the environment. While it may appear that certain pollutants are absorbed and are rendered harmless, they may in fact be bioaccumulating or being converted to a form that is at least as toxic as the form that they were released in.

It is suggested that a more sound approach to recognising and monitoring the waste assimilation capacity of the environment is to measure the emissions themselves and to concentrate on minimising their levels while leaving aspects of the absorption capacity to specific environmental management programmes and the like.

The OECD's proposed energy-environment indicators include the proven reserves of oil and gas, measured in tonnes of oil equivalent as a resource use indicator.[139] This indicator is not truly an environmental factor, as it is difficult to see how the present and future state of the environment can meaningfully be said to either impact on, or be affected by, the level of proven oil and gas reserves. Obviously, all ecosystems and biogeochemical cycles are related, but this level of abstraction is surely beyond the scope of the intended indicators. Similarly, while the rate and means of extraction of oil and gas both impact on the environment, these are not measured by measuring the size of proven reserves. The usefulness of measuring reserves is further limited by the fact that only proven reserves are measured and that the process of assessing petroleum reserves is an inexact science. The comments that are made earlier in this section on the usefulness of the concept of depreciation of natural capital apply here as well.

The final indicator that the OECD has proposed is the land taken up in producing, transporting and transforming energy. As noted above, this indicator does not have a great deal of relevance for New Zealand, given the small proportion of land area that is used in energy production and conversion.

The energy-environment indicators that will be measured in this thesis are therefore mainly emission indicators. The 'final set' is:

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[139] *OECD, 1993, above.*

- aerial emissions: $CO_2$, $SO_X$, $NO_X$ and particulates; and
- solid waste emissions: solid waste per process and per sector; and
- losses of energy: energy released into the environment per energy type.
- use of resources: total primary energy supply

### (3) Proportion of household income spent on energy

This indicator is concerned with the 'human dimension' of energy sustainability. As noted in chapter four, energy sustainability is defined as enabling present generations to satisfy their needs and wants without impinging on the ability of future generations to do the same. One aspect of that concern is the issue of whether all members of a given society (be it a country or the world) are able to satisfy their needs and wants. The proportion of a household's income that each income bracket has to spend on energy in order to provide what is considered to be a basic level of energy services is the principle manifestation of this concern. Affordability of energy is used rather than the availability of energy because New Zealand is a developed country. As such, the majority of energy services are available to all potential consumers who are prepared to pay the prevailing market price for those services. While there are some localised instances of unavailability of energy types, the issue is minor compared to many developing countries, where many types of energy are not available to large proportions of the population.

Work on developing an indicator to measure household expenditure on energy was done by Melhuish in the April Report.[140] She took the amount that was spent by each of three indicative income bands (low, middle and high income) and assessed what percentage of

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[140] *April Report, above, pp. 252 to 292.*

their actual income was spent on energy services. To the best of the author's knowledge, this indicator has not been developed further than this appearance in the April Report.

While Melhuish's indicator captures the essential basis of the issue of measuring the affordability of energy, her method contains a weakness. By using the actual amount spent by households, a non-equivalent comparison is established. This lack of equivalence arises because of the nature of spending across income bands. Lower income groups will, of necessity, spend a greater proportion of their household income on essentials and less on luxury items. For higher socio-economic groups, the position is reversed. In energy consumption terms, this difference in expenditure levels means that higher income groups are likely to be using energy for such things as second or third cars, video recorders and labour saving appliances. Major household energy uses like space and water heating are also likely to be maintained to a higher level than by lower income groups.

This problem can be solved by focusing on an indicative parcel of energy services, rather than the actual amount of energy used. This situation is similar to the method used to calculate the Consumer Price Index, where an indicative parcel of goods is used in the calculations.

Such a parcel of services would require co-ordination of data from a number of sources, including social agencies as well as energy agencies. Despite attempts to develop an indicative parcel, it has not proved possible within the constraints of this thesis. The problems are however more administrative than technical, the most significant technical issue being how to account for changes in the dollar level of each of the income bands over time. It would therefore be a relatively simple matter to develop the necessary base information, provided efforts could be co-ordinated.

As a proxy for this more detailed measure, and for the sake of completeness of the series of indicators that are to be developed in this thesis, the level of actual household spending on energy services has been used in this thesis. Notwithstanding that, the following is the formula for calculation of the more detailed parcel of energy indicator:

$$A = \left( \frac{C_{EI}}{y_I} \right) \times 100$$

where:

| | | |
|---|---|---|
| A | = | the affordability of energy index; and |
| $C_{EI}$ | = | the cost of an indicative parcel of domestic energy services; and |
| $y_I$ | = | the income level of each of the indicative groups. |

**(4) Economic rent accruing to energy suppliers**

Economic rent is related to the concept of payments to the factors of production and the concept of transfer payments. The factors of production are land, labour, capital and enterprise. Transfer payments are the payments that are required to keep a particular factor of production employed in the particular productive use that it is employed in. Any payments to the factors over and above this level are considered to be economic rent, which is a form of bonus payment to the particular factor. Each of the factors can potentially earn economic rent, although most attention is focused on the economic rent that is earned by enterprise. Economic rent is viewed as being a detrimental factor due to the fact that, in economic terms, the total amount of all of the costs of producing a product (all of the factor payments) equal the total amount that consumers have to spend to be able to buy that product. If consumers are paying economic rent, then by definition they are paying a price that is greater than what the market clearing price for the product would be in a perfect market.

Bertram calculated the amount of economic rent that accrues to three energy suppliers in the April Report.[141] That assessment focused on the then newly created Electricity Corporation of New Zealand, the supply of Maui gas in New Zealand and the operations of the Marsden Point oil refinery. In each case, Bertram took an assumed level of rate of return that he deemed to be transfer earnings and classed all amounts over and above this level to be economic rent. This analysis lead to results such as nearly 90% of ECNZ's annual profit being considered to be economic rent.[142]

Bertram's analysis provides a good working model to follow in the calculation of economic rent. In conducting the analysis, it is meaningful to bear in mind a caveat that Bertram noted in his report concerning the use that rental profits are put to.[143] Because some of the energy supply organisations are state owned enterprises, their profits are returned to the consolidated fund. This money is then allocated to various government expenditures, including social expenditure. This expenditure can be viewed as social engineering rather than simply economic rent payments. A case can even be made that these amounts should be removed from the analysis. For present purposes, all profits that are earned over and above the deemed average return will be classified as economic rent, as it has not been possible to obtain data on how those earnings are apportioned by the Government.

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[141] *April Report, pp. 292-325.*

[142] *Bertram, above, p. 305. The calculation relates to the Corporation's 1985/86 profit figures.*

[143] *Bertram, above, pp 314-315.*

There is also limited utility in calculating the economic rent that is paid to capital and land. Capital, that is the machinery used to generate or extract usable energy, is often indistinguishable from enterprise for present purposes. Similarly, land, which includes the minerals and other natural resources used in energy generation, is either generally the subject of a Crown royalty or is provided at a negligible cost. The amounts raised by way of royalties are again transferred to the consolidated fund.

The complexity involved in calculating the level of transfer payments that each labour type earns is not warranted by the extra information that is provided. Given the number of different job classifications and the number of ways that 'parity' can be calculated, this task quickly becomes too onerous. Another reason centres on Keynesian multiplier theory, which states that the money that one consumer spends on products provides a factor payment to other consumers who then provide factor payments to further factors when they spend. This cycle continues as long as money is spent. The net result is that the money that one consumer spends has a greater total effect in the economy than the actual amount that they spend and in that sense serves somewhat of a social function through the rest of the economy. This 'social function' is the trickle down effect that finds favour with many economists at present.

The information that is able to be obtained concerning the amount of rent that the private sector energy suppliers earn is likely to be limited due to reasons of commercial sensitivity and the limited amount of information that needs to be provided to comply with statutory and accounting requirements. As a result, whatever figures are obtained should be taken as being indicative rather than being exact measures of the level of economic rent that is earned.

Calculating the level of economic rent that is received is simply a matter of subtracting the costs that a particular undertaking has incurred from the revenues that it has earned. This gives the net profit for the operations, inclusive of any rent payments. The next stage is to subtract 'normal profits' from this figure. These are the transfer earnings and reflect the amounts that the organisation considers to be its break-even operating levels. The residual amount is the economic rent.

Mathematically, the formula is:

$$R = \left( \left( \frac{\pi}{S} \right) \times 100 \right) - r$$

where:

| | | |
|---|---|---|
| R | = | economic rent (percentage); and |
| $\pi$ | = | pre-tax net profit; and |
| S | = | total sales; and |
| r | = | level of transfer earnings. |

While the mathematics of the calculation are simple, the process presents some difficulties. The principal concern is the setting of the level of transfer earnings. In some cases, break even levels are known. These are the minority of cases, given the understandable reluctance of business people to reveal this sort of information. In the case of State Owned Enterprises, the level of dividend that the Government requires can serve as an indicator of this level.[144]

The oft cited basis of calculating rates of return and business options is to compare the rate of return from a project with the rate that could be obtained by depositing the same amount

[144] *Depending on the Government's intention when requiring a dividend, this level may however provide the wrong signals.*

of money as was invested in the project in a bank. While this is a simplistic approach, in the absence of better evidence, it will be used in this thesis.

Tax policy has varied significantly over time and there are a number of peculiarities that apply to the tax rules for companies. Pre-tax profit is therefore used in preference to after tax profit in order to remove one more factor that can operate to make comparisons over time more difficult.

### (5) Diversity of sources of energy supply

As noted above, this indicator measures the robustness of the energy supply system. Robustness is defined as the ability of the system to withstand sudden changes in the levels of demand or supply.

The more reliant that an energy supply system is on one or two principal sources of supply (be they indigenous or foreign), the more susceptible it is to external shocks that can unsettle the supply network. The most graphic illustration of this in recent times is the situation that occurred in the winter of 1992 concerning the Waitaki hydro-electric generation scheme. A shortage of water in one principal lake affected approximately 20% of ECNZ's generation capacity. Similar concerns have arisen in the past over oil imports from the Middle East and are likely to arise in the future over the availability of natural gas from the Maui field.

The notion of diversity of sources of supply includes the idea of not having too much of a particular energy type supplied from one source and also the idea of being as self sufficient as possible. In terms of measurement, these indicators are intrinsically simple, as both are percentages. The formula for each is the amount of any particular energy type that is derived from a particular source divided by the total amount of that energy form that is supplied. As the same type of energy is used for both the denominator or numerator, it does not matter whether the energy is measured in terms of physical units, heat units or quality equivalents, so long as the same calculation basis is used for both numbers. There is little benefit in calculating the diversity of supply for the energy supply system as a whole (rather than calculating it for each energy type), because it is unlikely that a single factor will affect all of the sources of energy supply at one time.

Expressed mathematically, the formulae are:

$$D_I = P\ (\ x \geq y\ )$$

given that:

$$x = \left( \frac{E_e}{E_T} \right)$$

where:

| | | |
|---|---|---|
| D | = | the diversity of supply sources for each particular energy type; and |
| x | = | the proportion of the total energy supply for an energy type that is provided by any given source; and |
| y | = | the preset safety margin; and |
| $E_e$ | = | the amount of energy provided from a particular supply source; and |
| $E_T$ | = | the total amount of each particular energy type that is used in the country. |

Security from overseas price shocks is calculated to be:

$$x = \left( \frac{E_M}{E_T} \right)$$

where:

x = the ability of the energy market to withstand supply shocks from overseas; and

$E_M$ = the amount of each particular energy type that is imported; and

$E_T$ = the total amount of each particular energy type that is used in the country.

The difficulty with these measures comes in determining what is an acceptable level of reliance on a particular source of energy. That is an essentially political decision, although aspects of engineering and economics are obviously also relevant. Past experience of responses to events such as the oil crises of the 1970's and the Gulf War of 1991 are guides to the level that should be set. The fuel type, the level of bunkering or excess capacity that can be built into the system, and actual and projected demand are all factors that are relevant in setting the level. As a working model, the figure of 10% is used here. The number of energy sources that exceed this level are totalled for each energy type to give the raw figure for the working of the indicator.

### (6) Safety margin or redundancy in the system

This is the second aspect of the issue of security of supply that is of relevance in the development of the indicators. The safety margin in the system is related to the issue of diversity of sources of supply, but is also significantly different. It is possible for a supply system to draw from a large number of decentralised supply sources, yet the system may not be able to cope with the outage of a generating station or increased levels of demand.

An attempt at measuring this aspect of security of supply was made in the 1980's by Lonergan and Cocklin.[145] The measure that they used is a probability relationship that analyses the amount of time that a system is likely to be in a state that is inconsistent with its planned state and the likely duration of the occurrence. Mathematically, the resiliency of the system is:

$$R = \left( \frac{prob\ (\ X_t \in P \cap X_{t+n} \in P\ )}{prob\ (X_t \in P\ )} \right)$$

where:

| | | |
|---|---|---|
| $X_t$ | = | the state of the system at time t; and |
| $X_{t+n}$ | = | the state of the system at time t+n; and |
| P | = | the plan in question. |

Lonergan and Cocklin's measure of resiliency is not actually a measure of robustness. Rather, as they note in their article, it is a measure of the rate of recovery of the system, where recovery is defined as the process of the energy system adapting to the state of a plan. This equation is therefore less a measure of the performance of the system than it is a measure of the performance of energy planning.

By contrast, an indicator of robustness should be more concerned with the ability of a supply

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[145] *'In the Aftermath of the Energy Crisis: New Zealand Energy Policy in the 1970s and 1980s', Lonergan and Cocklin, in: 'Energy Policy', Jan./Feb. 1990.*

system to be able to withstand unforeseen events, regardless of their duration. It is more logical to require a plan to pay cognisance to the actual conditions that prevail than to require those conditions to behave exactly as specified in a plan. Robustness may involve a movement towards a planned or original state, although it is equally likely that it could involve movement towards a new 'base state'. This phenomenon is the type of factor that will be measured in this thesis.

Lonergan and Cocklin's resiliency measure is further weakened by the fact that it assumes that the probability of all of the possible deviations occurring and the alternative responses to those deviations are known. In practise, this will not always be possible, especially in a deregulated energy market such as New Zealand has at present. When Lonergan and Cocklin wrote their article in the mid-1980's, the process of deregulation had just commenced. Therefore, the type of indicators that they propose would have been more workable than in the current environment.

The first issue that must be considered with the notion of supply safety margins is that not all energy types provide for supply security in the same way. For example, there is no excess supply or special bunkering with the gas supply system, as the entire supply network is viewed as a reservoir.[146] Another issue is the fact that the different measures lead to different safety levels being set. The electricity supply system, for example, calculates its safety margin on the basis of a one in a hundred year event, while the oil industry keeps bunkers equivalent to a certain number of days of demand.

The foregoing discussion highlights the fact that this indicator should not be a measure of the level at which a particular safety margin is set, as it will have been developed by the

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[146] *Interview with Dr. Eric Palmer, Technical Director, Gas Association of New Zealand, 8th April 1994.*

organisations which operate the energy supply system to meet the perceived needs of managing the particular energy type. Rather, the indicator should measure the efficacy of the particular safety levels. This can be done by measuring the number of occasions when energy demand gets to within a given percentage of the maximum capacity of the supply system and when supply reservoirs are used plus the number of occasions when extra amounts of the particular energy type have to be produced or otherwise obtained.

The first of these measures is self explanatory. Constantly pushing the limits is not a good management technique and is not sustainable in the long run as it can lead to renewability thresholds being exceeded. Similarly, utilising supply reservoirs is equally unacceptable as it implies mismanagement even more clearly than constantly pushing the limits of the system. The third measure is a reflection of the ultimate transgression in terms of production planning.

Mathematically, the measure is:

$$S = \sum ( s_L ) + \sum ( S_{ES} ) + \sum ( s_M )$$

where:

S = the security or robustness of the energy supply system; and

$s_L$ = the number of times that the supply system for each particular energy type pushes to within defined limits; and

$s_{ES}$ = the number of times that the supply system for each particular energy type utilises emergency supply reservoirs; and

$s_M$ = the number of times that supply has to be supplemented by extra amounts of each particular energy type.

The issue of where the limit of the energy use is set in relation to the system maximum is largely a political question, as it is for (5) above. Again, the figure of 10% is used in this thesis.

### (7) Economic impacts of energy use

As well as having social impacts, the price of energy has an impact on economic activity. The impact is generally not particularly significant for many industries, although the price of energy is crucial to many heavy industrial businesses (for example, the aluminium smelter). It is however directly relevant to economic activity in general due to the role of transport in the New Zealand economy.

While the composition of the energy price is relevant, it is the actual price level that is responsible for the magnitude of the impact on the economy, regardless of how it is composed. It is very important for the achievement of sustainability that the full costs of resource management decisions are provided to resource users. In the present framework, accounting for external impacts is provided by the range of energy environment impacts and the indicator of remedial expenditure required. These two sets of indicators contain the information that is needed to enable the broader environmental costs of energy use to be assessed (although price information would also be required if a purely monetary cost was to be developed). As a result, only the internal cost of energy remains to be monitored.

When measuring the energy price level, the inflation adjusted (or 'real') price level should be used rather than the nominal price level. As noted previously, the real price provides a less distorted picture of the actual cost of energy to consumers, removing the impact of inflation. The changes in the real price of each of the energy types should be measured individually as there are certain energy processes that are inextricably tied to a particular energy type.

Real prices are calculated by multiplying the nominal price level (the price level that has not been adjusted for inflation) by an 'inflationary deflator'. As the name implies, the 'inflationary deflator' is a factor that is used to adjust the nominal price level to account for changes in inflation. It is equal to the change in an index from a particular specified base year.

It is also informative to measure changes in the general energy price level. In calculating the general price level, weightings should be imposed on each energy form to accord with the proportion of the total energy supply that it provides. This adjustment avoids the situation where a large change in a certain energy form that only has a relatively small niche market can distort the overall change in energy prices. This measurement should be calculated in heat units, as the indicator is concerned with the actual amounts of the different types of energy that are used rather than the amount of work that can be done.

Two levels of data are needed, one for the specific price changes and the other for the general price level changes. The formula for the specific energy type price change is:

$$p_e = ( p_n \times i )$$

where:

$p_e$ = real energy price for each particular energy type; and

$p_n$ = nominal energy price for each particular energy type; and

i = inflationary deflator

The formula for the general level of energy economy interactions is a simple weighted average, namely:

$$p_{\Re} = \sum ( p_e \times M_e )$$

where:

$p_{\Re}$ = real general energy price level; and

$p_e$ = real price level for each particular energy type; and

$M_e$ = market share for each particular energy type.

### (8) Remedial expenditure required

This indicator is a means of measuring certain externalities. As discussed in earlier parts of this chapter, measuring actual environmental impacts is at least as satisfactory as a measure of the impact of energy use on the environment as measuring external environmental costs. Measuring impacts directly may even be a better measure due to the fact that it does not attempt to assign market prices to unpriced (and sometimes priceless) natural resources. This indicator does not therefore seek to measure the phenomena that are measured under the environmental effects indicator. Rather, it seeks to assess the on-going expenditure that is required solely because of society's use of energy. The type of expenditure that is incurred includes such matters as health care due to respiratory diseases brought about by smog, cleaning up oil spills and maintenance on buildings due to acid rain. While the examples and perhaps the indicator itself are shaped by Northern Hemisphere experiences with energy use, the concept is equally applicable to New Zealand.

Investigations have failed to reveal any countries that are measuring this phenomenon, although it has been suggested as a possible measure by the OECD and indicative assessments have been calculated in academic literature. Partly, this lack of development could be due to the fact that this indicator is in many ways a 'correction' of overstated Gross Domestic Product measures, which generally does not find favour with mainstream economic thinking.

The mathematics of this measure are inherently simple: "add up all remedial expenditures to get a grand total". The difficulty arises with what types of expenditures to include and where to draw the boundaries. For example, are the hospital costs due to an exploding petrol tanker that was hit by another vehicle energy related remedial expenditure or should they be classed as a result of the road accident?

The approach that has been taken in this thesis is to define the 'system boundaries' tightly, requiring a direct causal link between the energy related activity (that is, extraction, production, transportation and the like) and the expenditure. This test is a variation of the standard test for liability in negligence law, where it is used to exclude events that are too distantly related to the harm that is incurred. The focus is on whether damage of this particular type would have occurred but for the production, transmission or consumption of energy not on whether the particular damage would have occurred to this extent. This distinction is important.

To apply this logic to the above example, the expenditure would not have been incurred but for the car hitting another vehicle (the tanker), rather than being due to the tanker containing petrol. This expenditure is therefore outside of the scope of the indicator. If however the tanker's contents had entered a stream, the clean up costs would be counted in this indicator.

All aspects of society that can be impacted on by energy use and that meet the proximity test above should be studied. This means that social remedial expenditure (the cost of health care, loss of life, loss of homes and the like), economic remedial expenditure (the cost of lost worker productivity, additional maintenance expenditure and the like) and environmental remedial expenditure (the cost of oil spill clean ups, removal of mine tailing and the like) should all be included. The justification is that all of these expenditures are viewed as adding to national net worth in the GDP figure when in reality, they are all 'negative' expenditures.

In order to be able to create an indicator that is comparable over time (point two of the criteria from chapter three), the particular heads of expenditure that fall within the system boundary need to be defined. Using the test developed earlier in this chapter, the heads of expenditure that have been identified to be included in this series are:

- environmental clean up operations;
- environmental protection measures (including protection measures and contingency planning);
- expenditure on energy related health conditions (including expenditure due to injuries);
- maintenance on buildings and other equipment due to depreciation and damage from energy use.

The mathematical formula is therefore:

$$X_R = \sum ( X_r )$$

where:

$X_R$ = total remedial expenditure required; and

$X_r$ = remedial expenditure required for each of the individual heads identified above.

**(9) Output per unit input**

Energy efficiency would come a close second to the greenhouse effect as the aspect of energy use that is given the most attention by policy makers. Discussion and analysis on the topic has mainly focused on the engineering notions of energy efficiency or on macro-level economic factors. That is, the debate has focused on the mechanics of the process that is using the energy or on economic output measures such as energy intensity.

Both engineering and economics based measures have aspects that make them either inapplicable or inappropriate areas of attention for policy makers. The engineering measures are not particularly relevant to policy makers for the simple reason that they are outside of policy makers' realm of control. The efficiency of processes and machines are determined by the designers and the laws of thermodynamics. The area that policy makers should be focusing on is on ensuring that the most energy efficient equipment available is being used in any given process. While there is an argument for saying that policy makers provide the impetus for development and innovation and are therefore concerned with the implications of energy use, it can be argued with equal strength that there are sufficient other factors at work that can provide the impetus for innovation. Examples of these factors include the profit motive and consumer pressure for 'green' products. This second argument has provided impetus for a shift to measuring and addressing energy intensity and other hybrid energy-output measures.

The two most commonly used non-engineering measures of energy efficiency are economic measures and physical output measures. Of the economic measures, the most widely known are energy intensity and energy productivity. These are essentially inverses of each other, with energy intensity measuring energy used per unit of output and the energy productivity measuring output per unit of energy input. Both of these measures have the same weakness, namely the use of Gross Domestic Product (GDP) as a unit of measure for output.

The difficulty lies less in the use of GDP than with the measure itself. GDP has been criticised for failing to account for a number of economic transactions because they are not considered to be a part of the producing economy. Most notably, this applies to the outputs from the residential sector and from the 'black economy' (that is, criminal and unrecorded transactions). There are also problems with making international comparisons due to the potential for different values and bases of production in similar sectors of different countries. GDP does however have the advantage of providing a common base for the aggregation of dissimilar outputs from different sectors of the economy.

The alternative to using economic measures is to use physical measures of output (for example, litres of diesel per tonne/kilometre or Joules per tonne/kilometre). This form of measurement has the advantage over GDP of enabling all of the outputs of most sectors to be identified and compared with other countries without the distortion that GDP entails.

While it can capture some sectors' outputs completely, it is better suited to manufacturing processes than to most sectors of the service industry. It also has the disadvantage of making aggregation of the outputs of different sectors very difficult due to the different units of measure that are used.

The use of physical units as opposed to monetary units as the base measure in energy intensity is favoured by the OECD when developing its sectoral energy intensities.[147] However, the OECD still favours the use of the energy to GDP measure in the calculation of economy wide energy intensities.[148] The bases that the OECD uses for sectoral energy intensities are:

- Industry: TOE per unit of value added;
- Residential: TOE per capita;
- Commercial and Public Sector: TOE per square metre;
- Transport: TOE per vehicle/kilometre.

The major criticism with this basis of calculating energy intensity is the lack of comparability of the figures. It is not meaningful to compare an intensity that is calculated in terms of TOE per vehicle/kilometres with one that is calculated in TOE per unit value added. Problems can also arise with comparisons within the sectors. For example, the floor space of different service industry businesses varies considerably, without any particular correlation to energy use. Analysing the sectoral breakdown of energy intensity would be further complicated if sectoral energy intensities were measured in physical terms while the national intensity is measured in economic terms.

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[147] *OECD, 1990, p. 5 and OECD, 1992, p. 8.*

[148] *OECD, 1992, p.8. This indicator does not appear in the earlier report.*

Given the reservations noted above, it is suggested that the most appropriate measure for energy efficiency is energy intensity in terms of units of energy per unit of GDP. This decision is based on reasons of comparability and consistency of a series of indicators rather than because of any particular strength of economic measures or because of any correlation between energy use and economic activity.

The approach that will be taken here is to use the measures that Patterson and Wadsworth used in the 1993 report on energy intensity.[149] This report used energy intensity as a measure of energy efficiency for the sectors that were able to be measured in economic terms and used population as a proxy measure for output in the residential sector. While it is recognised that this is an imperfect situation, the approach is still used, as improving on the situation would require a major revision of the notions of measuring GDP and the basis of the collection of statistics in New Zealand, both of which are beyond the realm of this thesis.

As an aside, there is another means of calculating and measuring energy efficiency. This approach would focus on the equipment used in individual processes and would involve comparing it with the most efficient equipment that is technically available. A further factor would be included to account for the time and cost that would be involved in replacing current capital equipment. This method requires a far greater degree of information than the formulation that is discussed above but has the advantage of enabling direct operationalisation of the policy targets rather than the overall analysis and setting of those targets. If the information could be prepared on a 25 sector basis a very detailed analysis of national energy use could be conducted. The base information that would enable this indicator to be developed could be provided by a study like the Australian Fuel and Electricity Survey that EECA and Statistics New Zealand are discussing introducing into

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[149] *Above.*

New Zealand.[150]

The process of developing this indicator is discussed in detail in Patterson[151], and Patterson and Wadsworth.[152] A number of difficulties were encountered in the preparation of the second of these reports because of the unavailability of data and changes in the basis of data collection in the mid-1980's. Most notably, problems were encountered due to the scaling down of the government's data collection and the fact that much information that was previously publicly available is now claimed to be commercially sensitive. These are matters that should be addressed in the future preparation of this and other indicators.

A detailed discussion of the mathematics behind the measurement of energy intensity is provided in either of the reports noted above. In general terms however, the formulae that are used are:

$$I = \left(\frac{E_C}{Y_{\Re}}\right)$$

and, for households:

$$I = \left(\frac{E_C}{P}\right)$$

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[150] *See pp. 89-91, above.*

[151] *Patterson, M.G., 'Energy, Productivity and Economic Growth: An Analysis of New Zealand and Overseas Trends', Market Analysis Report 89/1006, Ministry of Energy, Wellington.*

[152] *Above.*

where:

| | | |
|---|---|---|
| I | = | energy intensity; and |
| $E_C$ | = | consumer energy (measured in heat units); and |
| $Y_{\Re}$ | = | real Gross Domestic Product adjusted to 1985-1986 constant dollars; and |
| P | = | population. |

Consumer energy is used because it captures efficiencies in the end-use of energy better than using primary energy, as primary energy must be converted to a consumer energy form before it is used. It is also unnecessary to use primary energy as the losses in the initial conversion process are captured by the indicator above dealing with the release of energy into the environment. Measuring consumer energy has the added advantage of being able to capture structural changes in consumption and changes in the energy using technology more fully than can be achieved by using primary energy.

### (10) End-use matching

The concept of end-use matching has been given much attention by Amory Lovins and others at the Rocky Mountain Institute. It focuses on matching the quality of the energy type that is used with the level of energy that is actually required to carry out that task. Despite the discussion that has accompanied this issue, there has been little detailed development of the concept.

There are essentially two ways that this indicator can be calculated. The first of these is by analysing every task that is performed using energy and comparing the energy type or types that are used with the energy type or types that would be used in an ideal, energy end-use matched system. By definition, this involves a value judgement about the types of energy that should be used and the proportions that they should be used in. This measure is similar to the detailed energy efficiency measure that is described above, so that the limitations and potential difficulties in operationalising this indicator are also similar to those described there.

The second means is more aggregated and involves analysing the broad proportions of the energy types that should be used on a nationwide scale. These would then be compared to the actual market shares of the energy types. This method has the disadvantage of being very rudimentary and very aggregated in the information that it provides. It is also reliant on the establishment of a standard that can be used to determine what the best possible distribution of energy use types are.

These two methods can be seen as being complimentary, in much the same way as the different energy efficiency measures that are discussed above can be seen as being complimentary. While the former measure of end-use matching is definitely more accurate and more fully reflects the degree of matching that is achieved, there is little point in policy makers measuring the individual processes when the rest of the indicators in the framework have focused on the macro-level picture. Operationalisation of policy in individual management programmes however requires a greater level of disaggregation and specificity. Given the expertise of EECA and energy supply companies and the case specific nature of many of the solutions, this side of end use matching is better left to case specific monitoring programmes. It is therefore recommended that this indicator is not developed further at this stage.

CHAPTER NINE

# APPLICATION OF SELECTED INDICATORS TO THE NEW ZEALAND ENERGY SUPPLY AND DEMAND SYSTEM

This chapter will operationalise those indicators that have been developed in chapter eight for which there is sufficient data available to enable a time series to be developed. Whether or not a particular indicator is able to be developed further at this stage is detailed in the table below summarising how the various indicators satisfy the criteria of indicator development that were developed in chapter three.

Each of the criterium is measured along a three star system as follows:

- * = poorly satisfies criterion
- ** = satisfies criterion well in some regards and poorly in others
- *** = completely satisfies criterion

Explanations are included in some of the criteria as to why the particular indicator does or does not satisfy the criterium in question. In most cases, the reason for non-compliance is that the base data is no longer collected or is collected but is no longer freely available for reasons of commercial sensitivity.

Table 3. Assessment of suggested indicators.

| Indicator | Representative | Spatial and temporal trends[f] | Optimise information and cost effectiveness | Unbiased | Clarity of message |
|---|---|---|---|---|---|
| Proportion of renewable energy used | **[a] | *** | ***[j] | *** | *** |
| Total renewable energy use | **[a] | *** | ***[j] | *** | *** |
| $CO_2$ emissions | ***[b] | **½[g] | ***[j] | *** | *** |
| $SO_X$ emissions | *** | *[h] | *** | *** | *** |
| $NO_X$ emissions | *** | *[h] | *** | *** | *** |
| Particulate emissions | *** | *[h] | *** | *** | *** |
| Solid waste from energy use | *** | *[h] | *** | *** | *** |
| Energy released into the environment per energy type | *** | * | *** | *** | *** |
| Proportion of household income spent on energy | *** | *** | ***[k] | *** | *** |
| Economic rent accruing to energy suppliers | *** | **[i] | ***[l] | *** | ** |
| Diversity of sources of energy supply | *** | *** | *** | *** | *** |
| Safety margin in the energy supply system | *** | ** | ** | *** | *½[m] |
| Real energy prices | **[c] | *** | ***[j] | *** | **½[n] |
| Remedial expenditure required | **[d] | ** | *** | *** | *** |
| Energy intensity | **[e] | ** | **[m] | *** | **[o] |

**KEY:**

a = Geothermal energy is included in the data on hydro energy
b = Assumes that theories on the green house effect are correct
c = No information is available on coal or gas prices
d = Heads of expenditure included in this indicator have been selected individually
e = Only truly effective for those sectors that have a measured economic output
f = Certain of the trends are limited by the fact that with privatisation, some information is commercially sensitive and other information is no longer collected
g = Information needs to be calculated from base information
h = Only localised surveys available
i = Note that accounting practises often change over time
j = Available from 'Energy Data File'
k = Available from Statistics New Zealand's Household Expenditure Survey
l = Available from annual reports for ECNZ only
m = This information is derived from a number of sources that cannot be aggregated
n = Total expenditure is also required. This information is provided to a degree by the household expenditure indicator.
o = This information and the way that it is obtained may be too technical for some users

The assessment of the criteria in the table clearly indicate that it is not possible to operationalise all of the suggested indicators, or that some could be operationalised, but would provide erroneous or incomplete information. As a result of this analysis, the following indicators will be developed in this chapter:

- proportion of renewable energy in total energy supply
- percentage of total energy provided from renewable sources
- emissions of $CO_2$ from energy sources
- proportion of household income spent on energy
- economic rent accruing to energy suppliers (for ECNZ only, due to data availability)
- diversity of sources of supply (oil only)
- safety margin in the system (electricity only)
- real energy prices (electricity and oil only)
- energy intensity

The following indicators will not be able to be developed, with the reasons for that decision being given in brackets:

- $SO_X$ emissions (lack of spatial and temporal data)
- $NO_X$ emissions (lack of spatial and temporal data)
- particulate emissions (lack of spatial and temporal data, no specific identification of energy sourced particulates)
- solid waste produced (lack of data about quantities produced)
- energy released into environment (lack of data, commercial sensitivity of information)
- safety margin (commercial sensitivity, those figures that are reported are so close to 100% safety that there is no benefit in analysing them)

- remedial expenditure (lack of data, commercial sensitivity)

As the data that is used to develop the indicators is collected by a number of different organisations, there will sometimes be differences in the basis that the indicators are developed on. These differences apply most particularly to the year end date that is used for the different series. A further complication is caused by the deregulation of the energy sector (including the disestablishment of the Ministry of Energy) in the mid-1980's. Data for this period (and some subsequent data) has sometimes been collected on a different basis to that which it was previously collected. In some cases therefore, adjustments have been required to establish data series on a consistent basis. Where this type of adjustment has been required, this fact has been noted in the introduction to the discussion and an explanation of the steps required to adjust the data has been provided in appendix two.

The following discussion will deal with each of the operationalised indicators separately and will explain the changes that have occurred in the relevant phenomenon over the period measured and the reasons for those changes. Chapter ten will provide an overall assessment of energy sustainability trends in New Zealand.

**Total primary energy supply**

As discussed in chapter eight, the total primary energy supply is a measure of the total amount of energy that is used in New Zealand in any given year. Total primary energy supply is recorded in Figure three below.

This graph will not be discussed in detail, as the discussions of each of the other indicators contained in this chapter draw heavily on the material that is contained in this graph. These

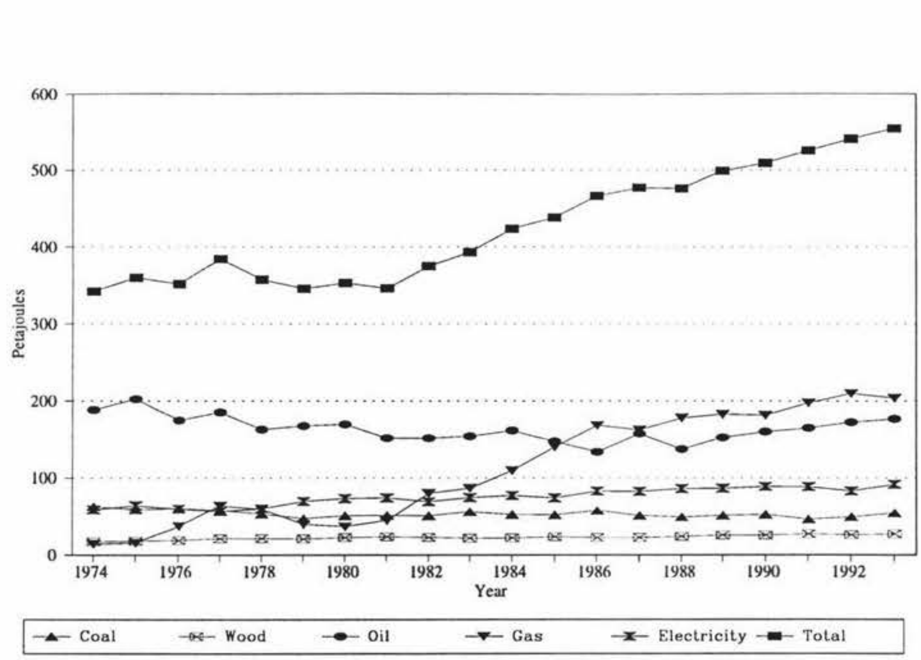


*Figure three: Total Primary Energy Supply*

sections take these matters further than a discussion in this section could (or should). As such, this indicator has an important role as a reference for the other indicators in this series.

### Renewable Energy Use

Renewable energy use is measured by two indicators, the actual level of renewable energy that is used in New Zealand and the percentage of the total primary energy supply that is provided from renewable energy sources. This information is provided in Figures four and five below.

Figure four clearly indicates that the level of renewable energy use has remained relatively static over the period measured. Breaking down the figures into the consumption patterns

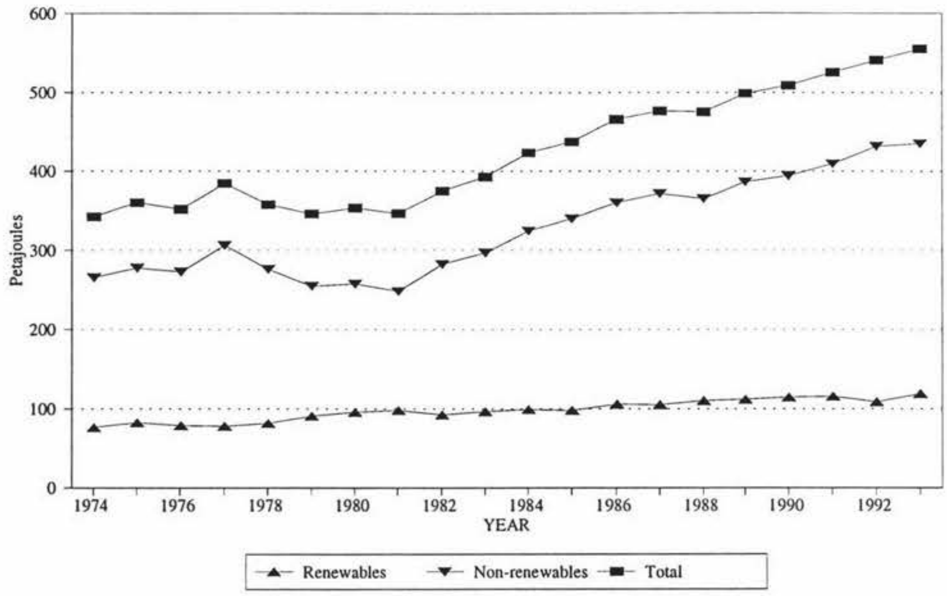


*Figure four:Proportion of Renewable Energy in Total Energy Mix*

of wood and hydro energy[153], it is clear that there has been no significant change in the level of use of either energy type. It is also interesting to note that the dip in the hydro use line during 1992 is very minor, indicating that the 'Electricity Crisis' of that year was possibly over-rated, or at least was quickly forgotten. Overall, this graph indicates that renewable energy is the 'poor cousin' to other, often cheaper, energy forms that are presently abundantly available (even if their supply in the future can be called into question). This type of short run focus is clearly not sustainable.

Figure five indicates that the percentage of renewable energy in the overall energy supply is determined not by the level of renewable energy itself as much as by changes in the level of the other fuels that make up the primary energy supply. The increase in renewable energy

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[153] *The basis of data collection means that figures on hydro energy include geothermal energy.*

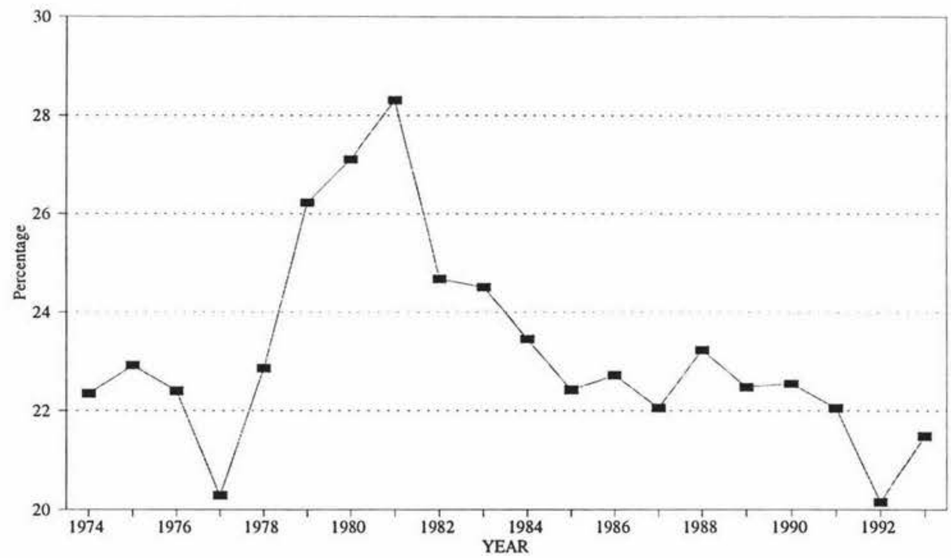


*Figure five: Percentage of Renewable Energy in Total Energy Supply*

percentage in 1974 and 1975 is due to the first of the oil shocks, when energy consumers changed away from the use of fuel oils as the price of those fuels increased. Similarly, the increased percentage of renewable energy use in the period 1978 to 1981 coincides with the second energy crisis and the longest period of consistent government energy conservation education and facilitation over the period that is graphed.

Renewable energy percentages decreased again in 1982 with the coming on-stream of the first of the 'Think Big' projects and the consequent increase in the use of gas. Deregulation of the energy market saw a continued decrease in the percentage of renewables, although the single biggest cause of the decrease over this period remains the commissioning of further 'Think Big' projects. The peak in 1988 is due to the variation in oil use between 1987 (an unusually high year) and 1988 (when the usage was less than average). It is assumed that this use pattern reflects a 'seasonal variation', as there are no significant external events that can explain it. The decrease in renewable energy use in 1992 is a result of the increased use of gas for electricity generation as a result of the 'Electricity Crisis'.

When figures four and five are interpreted together, the picture that is provided is of a policy of giving the use of renewable energy a low priority. The percentage use graph shows a lack of policies supporting the use of renewable energy in New Zealand. Rather, the graph demonstrates that there is a combination of crisis management and a determination to use those fuels with the lowest short run marginal cost, regardless of the long run implications of that strategy. Given that renewable energy use has essentially remained static over the period measured, while the number of energy consumers in New Zealand has increased (due to increases in population and business activity), the clear signal is that renewable energy is losing ground. In this regard, New Zealand is clearly not moving towards more sustainable energy use. In fact, the opposite is occurring.

**Environmental Effects of Energy Use**

As noted in the introduction to this chapter, the available base data that relates to this area of concern is limited. Therefore, the only indicator that is able to be developed further is the level of energy sector carbon dioxide emissions. Even so, the base information for this indicator had to be derived using co-efficients of $CO_2$ emissions per petajoule of energy.[154] Given that all of the gaseous pollutants are released as a result of combustion of fossil fuels, it can be assumed that the figures and trends that are obtained for the release of carbon dioxide will mirror those that would be obtained for the other aerial pollutants if the data was available. However in making that assumption, it must be remembered that emission control technologies for the different pollutants develop at different rates and have different levels

[154] *See Appendix Two.*

of efficacy.

Figure six below shows the trends of energy sector carbon dioxide emissions since 1974.

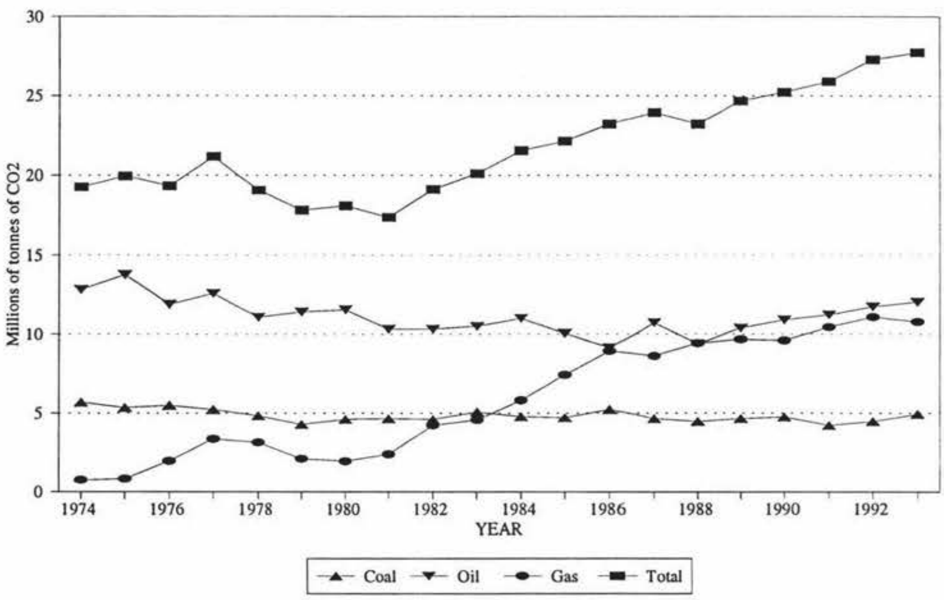


*Figure six: Energy Related $CO_2$ Emissions*

As can be seen in the graph, energy sector carbon dioxide emissions have been increasing steadily over the past twenty years. The single biggest cause of this increase has been the increased use of gas. Gas related emissions of carbon dioxide in 1993 were nearly 5 times the 1981 level. During this period, gas use has increased due to the commissioning of the Kapuni ammonia urea plant, the Waitara Valley methanol plant, the Motonui synthetic fuel plant and the Huntly power station. The continued expansion of the petrochemical plants and ECNZ's policy of using gas fired thermal generation have meant that this trend is continuing.

Emissions from oil products decreased slightly over the period, although they have started to rise again since 1988. The principle reason for the initial decrease in emissions is a change in the uses to which oil products have been put. The use of oil for various space heating functions has largely been replaced by the use of gas, electricity and wood. Oil burning thermal power stations were also converted to run on gas after the first oil shock. Over this period, there was a general change in the type of cars that were driven in New Zealand. In 1974, six or eight cylinder cars were prevalent.[155] As the effects of the two oil shocks were felt, there was a general shift in attitude as smaller, more economical cars found favour. The pattern of car use also changed, due to such schemes as carless days and a general change in attitude regarding the use of the car as it became more expensive to run. The increase in emissions since 1988 is also vehicle related, as it reflects the deregulation of the car sales market and the increased number of cheap Japanese imports on the used car market. The increase in the use of private vehicles and the consequent increase in the use of oil products has led to an increase in the emissions of carbon dioxide and other pollutants. The deregulation of road freight transport will also have increased the use of oil products as the amount of diesel that is used by trucks is greater than the amount that would have been used by diesel electric trains.

Emissions from coal use have remained relatively static, reflecting the fact that coal use has changed little over the period measured.

The increase in carbon dioxide emissions over the period closely mirrors the increase in energy use overall. Those measures that have been taken to address the release of carbon dioxide appear to be unsuccessful, so that the government's stated aim of reducing carbon

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[155] *This conclusion is based on data detailing the level of imports of vehicles of different engine sizes that is presented in Statistics New Zealand's 'INFOS' database.*

dioxide emissions to 1980 levels by the year 2000 is looking less likely to be achieved. The principal factors to be addressed if the level of carbon dioxide emissions are to be decreased are the policies surrounding the use of gas and the use of motor vehicles. Both contribute approximately the same total amount of carbon dioxide to the total emissions, meaning that both are an equal priority for remedial action.

**Energy Efficiency**

The following discussion of the changes in New Zealand's energy intensity over the period 1970 to 1992 draws heavily on the study done for the Energy Efficiency and Conservation Authority by Patterson and Wadsworth.[156] The section below will summarise the factors that are responsible for the overall energy intensity ratio for the economy changing and the major influences in each of the five sectors studied. Readers who require a full account of the methodology and the conclusions that were reached in that study are referred to the published report.

The major energy intensity changes that have occurred over the period are summarised in figure seven below.[157]

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[156] *Above.*

[157] *The units that are used in the graph are those used in Patterson and Wadsworth's report. They differ from the units that are used in this thesis, in that they draw on International Energy Agency data rather than Ministry of Commerce data. Despite the difficulties that were encountered by Patterson and Wadsworth in attempting to use Ministry of Commerce data, that data base was considered to be the more appropriate of the two data sets to use in this thesis, primarily to achieve consistency in the other indicators that have been developed here.*

*The use of different units highlights one of the advantages of using a series of indicators rather than a single composite index, as the messages that can be derived from the data remain the same as if the same data set had been used throughout. The difference in the "accounting base" only really becomes relevant for policy makers in developing strategies to address the issue itself.*

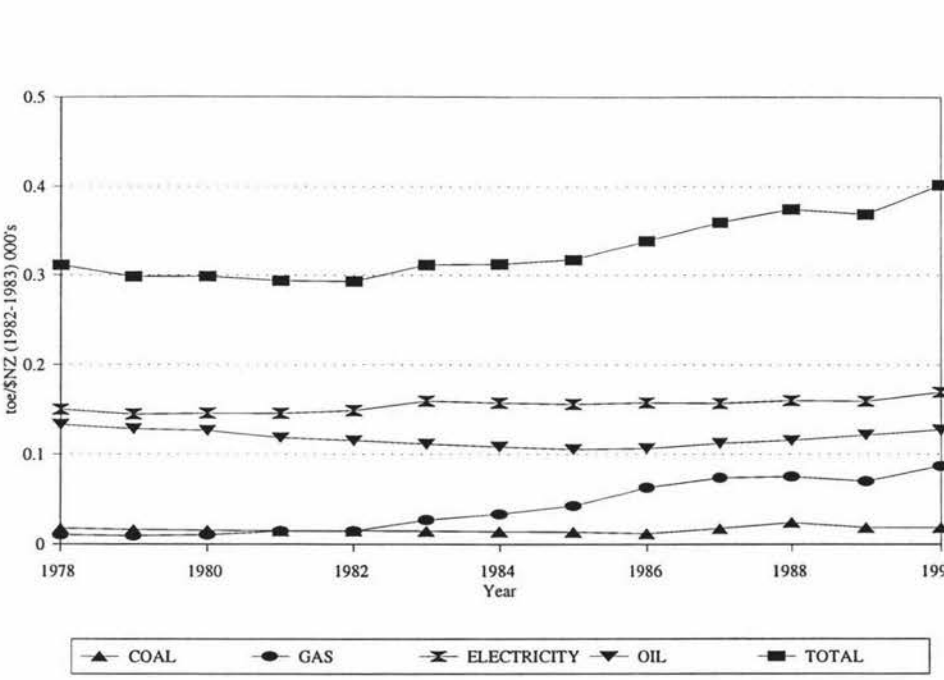


*Figure seven: Energy Intensity*

Overall, New Zealand's energy intensity ratio has increased by 37.82% over the period studied, with the result that New Zealand has slipped from place 15 to place 22 out of the 24 OECD nations.[158] The two biggest factors that have caused this change in the ratio are the commissioning of the 'Think Big' projects and the deregulation of energy markets. The former led to a marked increase in energy use for a much smaller increase in GDP. The main factor here was the coming on stream of the petrochemical projects[159], although the basic metals sector[160] still showed a greater increase in energy use than the rest of the economy. While it is only one sector of the economy, the effect of the 'Think Big' projects

[158] *In making this assessment of New Zealand's performance, it should be noted that in each of the years measured, place 24 was held by Luxembourg. This placing is usually ignored, as the small size of Luxembourg and its position means that a large amount of the energy used is actually used by vehicles in transit. New Zealand can therefore be viewed as having the second worst ratio in the OECD.*

[159] *These are the Kapuni ammonia urea plant, the Waitara Valley methanol plant and the Motonui synthetic petrol plant.*

[160] *This sector is the Glenbrook steel mill and the Tiwai Point aluminium smelter.*

period measured. The effect of the increased use of gas in these projects has also helped to move the energy intensity ratio upwards. The deregulation of energy markets has contributed to increasing the energy intensity ratio as it has meant that New Zealand consumers have developed a relatively elastic response to price changes. The most elastic responses have been to the lowering of oil prices in the 1980's and to those energy suppliers who have been actively promoting the increased use of their products.

There appears to be no capital for labour substitution effect when measured on an economy wide basis, although a significant effect has been measured for the service sector. Both the household residual and the technical change residual increased over this period, indicating the increased use of household appliances (or more correctly, the increased range of appliances that are able to be used) and a general lessening of the technical efficiency of energy use.

On a sectoral basis, agricultural energy intensity decreased over the period 1979 to 1990[161], although there has been a slight increase in intensity in 1989 and 1990. This pattern is due to the restructuring that was taking place in this sector over this period, as the technical efficiency of energy use improved markedly in the primary sector over the period. The slight increase in energy intensity at the end of the period was due to the agricultural sector beginning to recover in 1989, with a consequent increase in energy use. The fact that petroleum exploration is also included in this sector and that exploration increased significantly over this period will also have contributed.

The industrial sector, which includes all industrial and manufacturing activities except the

[161] *The available data necessitated a shorter time period for the individual sectoral discussions than for the overall analysis.*

major projects (see below), demonstrated an 8.67% improvement in its energy intensity ratio. While some of this improvement can be credited to changes in the energy types used, it appears that there have been improvements in the efficiency of energy use in this sector. Specifically, oil usage initially decreased after the second oil crisis and has now plateaued at a lower level than at that time. Coal and gas usage have remained relatively constant, representing maximum market penetration of those fuels. Electricity usage is however starting to increase, representing a trade off between labour and capital in this sector.

The energy intensity ratio of the major projects sector has shown the greatest increase of any of the sectors studied. Obviously, the single largest increase has been in gas usage, reflecting the commissioning of the petrochemical plants. It should be noted that this ratio decreased somewhat at the end of the period as commodity prices started to increase. The electricity ratio has been similarly affected by a slight firming in the market price for aluminium (the largest user of electricity in this sector). Coal use has been relatively static, except for a slight increase to coincide with the commissioning of the Glenbrook steel mill expansion. Oil usage has remained static at a level that is a fraction of the other energy types.

The single biggest factor in the changes in the service industry energy intensity has been the increase in the electricity ratio as electricity has displaced other energy types as the energy of choice in this sector. The increase in the ratio at a time when electronic equipment such as computers have made great inroads into the existing capital indicates that two factors are at work. Firstly, there has been a more extensive use of HVAC and other systems that do not directly contribute to the output of the sector (although they are a significant factor in both consumer choice and staff productivity). The second is that there has in some areas been a degree of automation that is greater than was required or that is not being fully utilised, so that it is also not contributing to the output of the sector.

Apart from a small showing by gas when the National government promoted the use of alternative fuels in the 1980's, the only energy type that has an impact in the transport sector is oil products. The energy intensity for this sector remained relatively stable over the period 1978 to 1892, with a slight decrease after the oil shock of 1978. The ratio started to increase again after 1984 due to a combination of the decreasing international oil prices, the deregulation of road transport and the removal of tariffs on imported vehicles leading to an increase in the number of vehicles on New Zealand roads.

The household sector is equally dominated by one energy type, although in this case it is electricity that is dominant. Over the period[162] there has been a marked increase in energy intensity ratios. This increase can firstly be put down to a greater affluence in the early 1960's as more households became two income households, enabling (and in some cases requiring) more to be spent on labour saving household appliances and household comfort. The other major factor that influenced the ratio is the increased number of appliances and electronic equipment that have been developed over this period. Notable examples are spa pools, computers, video recorders and microwave ovens (although microwave ovens actually save energy relative to conventional ovens). A localised increase was caused by the shift from oil for space heating after the oil crisis of 1974. This oil crisis also led to a slight decrease in the rate of change of the ratio over the period 1975 to 1980 as conservation messages were observed.

**Energy Prices**

Base information is only available on prices for oil products and (retail) electricity. It would

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[162] *Available data means that the residential energy intensity graph is measured over the period 1960 to 1992. Note also that the ratio is calculated in terms of energy per capita rather than per dollar, reflecting the lack of available information on the economic output of the residential sector.*

therefore be inappropriate to calculate a single figure that represents a general energy price level as the coverage of energy types is too narrow.

Retail electricity prices are shown in Figure eight below. In interpreting the graph, it should be noted that until the creation of ECNZ as a state owned enterprise in 1986, electricity prices were set solely by the Government. The Government still has a role in the level of prices, both through influencing the ECNZ board and through the fact that price increases are tied to inflation rates. This control is however significantly less than the control that was exercised prior to 1986.

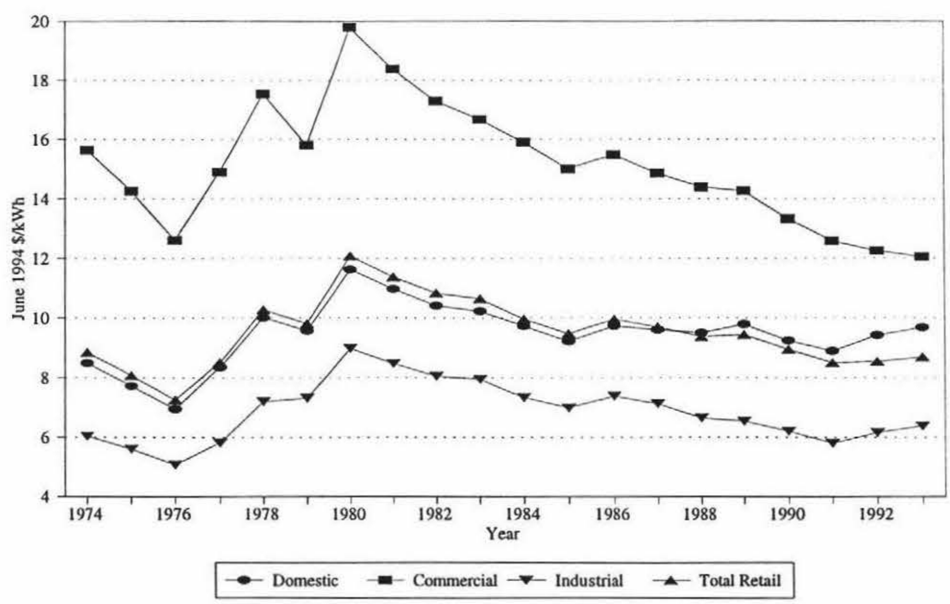


*Figure eight: Retail Electricity Prices*

All four prices show a period of marked annual variation and increase from 1976 to 1980. This pattern is likely to be due to two factors. The first was the need for extra capital to enable the construction of further generating capacity. As the majority of the capacity that was being built during this period was thermal, electricity prices needed to be increased to justify the higher marginal cost of the plant. Capital was raised through increases in the general tariff as part of a government policy to make the Electricity Division of the Ministry of Energy as self funding as possible.[163]

The second reason for the increase was related to the second oil price shock. Prices were changed as a part of an overall energy efficiency programme and also as the demand for non-oil energy products increased[164], increasing the cost of the inputs to the electricity generation system. During this period there was also a final switch from the use of heating oil to electricity, which placed further demands on the system and put further pressure on the construction of further generating capacity.[165]

The most notable feature of the graphs has been the decrease in real electricity prices in the commercial sector. Especially noteworthy is the relative reduction compared to the industrial and domestic sectors since the establishment of ECNZ as a state owned enterprise in 1986. This reduction has coincided with a very successful marketing campaign that has seen commercial electricity use increase dramatically over this period.[166]

The industrial sector price has been relatively constant, reflecting the competition in that

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[163] *The reasons for increases in the general tariff are detailed in each year's edition of the Report of Ministry of Energy to Parliament. In each case, the general policy of self sufficiency is briefly noted. The few other specific reasons that are given relate to this general policy.*

[164] *Rather than contradicting the accepted laws of supply and demand, this increased price in response to increased demand is a reflection of a constrained supply system. As the electricity supply system does not have the flexibility to instantly adjust to meet increased demand, prices increase both to attempt to dampen demand and also as more expensive plant is used to meet demand.*

[165] *This pressure was somewhat lessened by a subsequent shift to reticulated natural gas in many centres.*

[166] *It should be noted that a certain amount of this increase has been due to the increased automation of this sector, although some of that automation has not contributed to output (see discussion of energy intensity above).*

sector from gas and coal.

Domestic sector prices have also remained relatively constant since 1986, reflecting the effect of linking changes in domestic electricity price to changes in the rate of inflation. As the inflation rate has remained relatively static over this period, so the size of the price level change that the various governments have allowed ECNZ have been limited. The increase in prices from 1991 is due to the pressure that ECNZ brought to bear on government for the removal of cross subsidisation of the domestic sector.

In theory, the general reduction in real electricity prices that has occurred over the majority of the period that has been graphed should mean that electricity consumers are better off now than they were in the mid to early 1980's. When the amount of electricity that is used annually is included in the analysis however, the picture is that the situation has actually worsened. The combined result of lower real prices, a general shift towards the use of electricity and supplier's marketing strategies has been a marked increase in the use of electricity. This has seen the total amount that is spent on electricity increase (excepting the decrease over the winter of 1992). This increase in electricity use has had a negative impact on the economy, as the total amount that is spent on electricity is greater.[167]

The change in consumption patterns reflects a negative effect of lower prices, namely that they encourage consumers to ignore questions of efficiency of use. This effect happens because the energy type is viewed as being cheap and is more prevalent in a market where prices are falling sharply, and consumers have become conditioned to spending a certain total amount on energy products. As a result, consumers increase their consumption, with the knowledge that the amount they are spending on energy is not going to increase. While in

[167] *This is a natural mathematical consequence of the equation 'units used times price'.*

some situations this increase in consumption is a natural consequence of having a higher level of discretionary income to spend on items that increase consumers' quality of life, it is more often reflected in less efficient use of energy to provide the same level of services as were provided prior to the decrease in price. The classic example of this effect is people who buy a car with a bigger engine when petrol prices decrease.

Both of these repsonses to decreasing prices have occurred in New Zealand, implying a reduction in this economic and social facet of the sustainability of electricity use.

Oil product price movements are also monitored, although data for diesel prices stops at 1989, and are shown in figure nine.

There are four major factors that are reflected in all three of the series on the graph. They are the first oil shock, the second oil shock, the energy policies of successive governments (including pricing policies) and the worldwide decrease in oil prices over the last decade.

The first oil shock shows itself in the marked increase in prices from 1974 to 1975. The diesel price continued to increase over the next year as well, possibly reflecting the fact that the majority of the diesel used in New Zealand in the mid 1970's was imported. This factor is significant because New Zealand returned to pre-shock prices and consumption patterns more quickly than many other countries. The trough that occurred from 1975/1976 to 1979 further reflects the re-adjustment to pre-shock conditions.

The effect of the second oil shock was more sustained than the first shock, a phenomenon that was felt around the world, as consumers and governments felt that 'this time was for real'. This time, the increased prices were felt for four years, from 1978 to 1982.

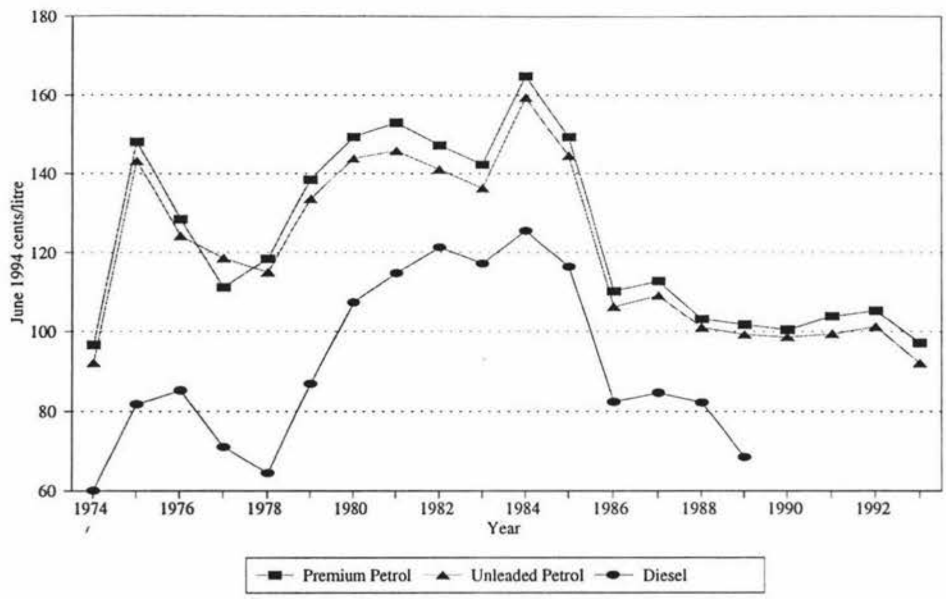


*Figure nine: Retail Oil Product Prices*

A further factor that needs to be weighed in the assessment of oil prices is successive governments' policies on energy pricing. Until the deregulation of the New Zealand oil market in 1986, the government had a major role in fixing prices, through both regulation and tax policy.

Oil taxes have long been one of the traditional budget night tax changes (along with the 'sin taxes' on tobacco and alcohol). Taxes were imposed to provide revenue for other aspects of fiscal policy and as a means of controlling demand for oil products. Significant tax changes have occurred over this period with the introduction of levies for the 'Think Big' projects in the early 1980's and the much vaunted 'green tax' of the early 1990's.[168] The following changes in the tax on petroleum products have been imposed through successive

[168] *The latter was imposed by the Local Government Amendment Act (No. 2) 1992.*

'Budgets' since 1974:[169]

Petrol:

| | |
|---|---|
| 1975 | 4.7 cents per litre increase |
| 1978 | 3.0 cents per litre increase (1 cent per litre from the reserve account) |
| 1982 | 3.5 cents per litre increase for premium petrol |
| | 3.0 cents per litre increase for regular petrol |
| 1984 | 2.5 cents per litre increase |
| 1986 | 6.0 cents per litre decrease |

Diesel:[170]

| | |
|---|---|
| 1979 | 0.5 cents per litre increase |
| 1982 | 7.1 cents per litre increase |
| 1986 | 4.0 cents per litre decrease |
| 1990 | removal of all duties on diesel |

Each of these tax level changes is clearly illustrated in the graphs above, showing the importance of government policy in oil product prices. If these changes are discounted, the clear indication is that New Zealand is a price taker in terms of the oil products that it consumes, which is logical, given the relative size of the New Zealand supply and demand markets when compared to world markets. It also implies that, given the present falling market, New Zealand could benefit from leaving the known domestic oil reserves in situ and importing sufficient stocks to meet present demand. The oil should only be removed at such

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[169] *The information here has been obtained from the copy of 'The Budget' for each of the years in question. The amount that is specified is the sum total of all taxes on fuel products, regardless of the intended purpose of the tax in question.*

[170] *Diesel users are also subject to a road user tax. This is not included in the tax changes recorded here.*

time as international market prices mean that domestic oil can be extracted and refined for substantially less than the cost of imported oil. This situation is unlikely to arise, given that the oil reserves are owned[171] by commercial companies who are concerned about their commercial future rather than the net social benefit to New Zealand society.

The 1984 Labour government deregulated the oil market in 1986 as a part of its general market reforms policy. This resulted initially in increases in the general oil price level in 1987 as the oil companies adjusted prices to reflect the costs of transporting products to various parts of the country. After the initial adjustment, prices decreased for two reasons. The first reason was an increase in the level of competition as the companies attempted to increase their market share. The second factor was the fourth of the major trends that is reflected in the graph, namely the overall reduction in world oil prices. Of the two effects, the latter has had a more persistent effect.

World oil prices have tended downwards since the early 1980's, subject to an isolated increase around the time of the Gulf War. This trend has coupled with the steady strengthening of the New Zealand dollar over the period (after an initial post-float weakening) to create a general and sustained decrease in oil prices.

Again, assessing the overall sustainability effect requires that the level of oil products used are factored into the equation as well as the price level. As with electricity, the total amount spent on oil products has increased as the price has decreased. This increase has been contributed to by factors such as the removal of limits on road transport distances and the deregulation of the second hand car market (and consequent imports of Japanese second hand

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*[171] All minerals are of course owned by the Crown. The right to extract and sell those minerals is owned by the holder of a licence that is obtained from the Crown.*

cars). Again efficiency and economic performance have suffered.

The changes in total spending on electricity and oil products indicate that there is a need for education in New Zealand about the costs of using energy. A detailed analysis of the factors that consumers analyse when they make purchasing decisions could enable strategies to be developed to increase the sustainability of the use of both energy types.[172] It appears that purchasing decisions are made on a combination of the unit price and the total cost that does not accord with accounting sense. The major factor appears to be the total cost. Consumers expect to pay a certain amount for energy and are prepared to make their purchasing decision on the basis of that cost, rather than on the basis of the units that are used. This leads to inefficient and unsustainable consumption patterns.

Energy demand also appears to be relatively price inelastic, with the major influences being non-price matters. This makes sense to a degree, especially for the domestic sector. There are however a number of price related factors that could be taken to increase the sustainability of energy use. These include responding to petrol and electricity price increases by decreasing car use, installing hot water cylinder wraps and other, more complex, responses.

**Source of oil consumed in New Zealand**

The robustness of the New Zealand energy supply system is best measured by separate indicators for the different energy types. For oil, the robustness measure is the self sufficiency of New Zealand or, alternatively, the proportion of oil that is imported. This is

[172] *Although it is not possible to use oil sustainably since it is a fossil fuel and a stock resource, it could still be used more sparingly to provide more of a bridging function to a fully renewable system.*

sufficiency of New Zealand or, alternatively, the proportion of oil that is imported. This is graphed in figures ten and eleven.

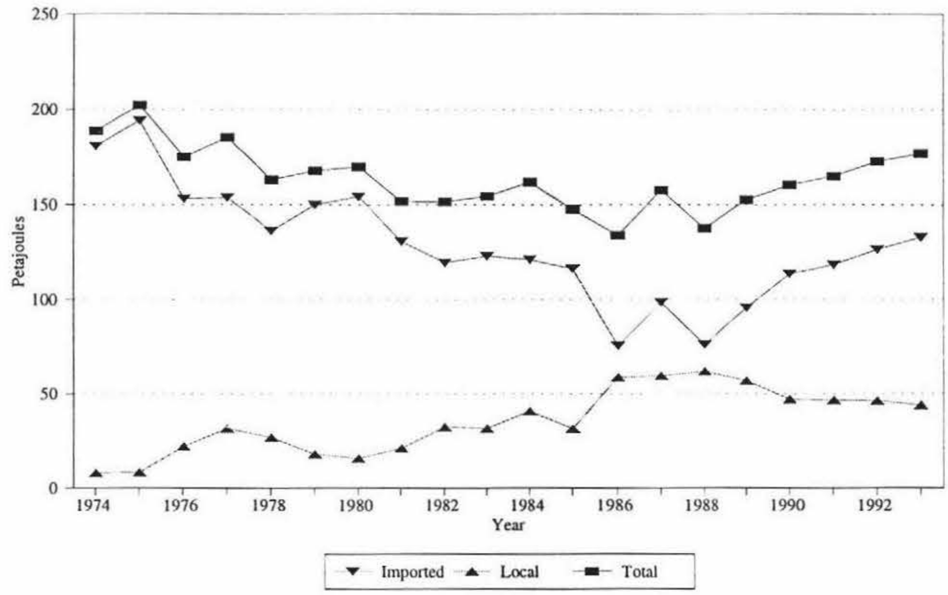


*Figure ten: Source of Oil Consumed in New Zealand*

The small percentage of local oil that was consumed at the start of the period represents the output of small local fields around the country. An example of this output is the 'Peak' brand petrol that was sold in Taranaki at this time. The increase in local oil in the mid-1970's is the result of the extraction of condensate from Maui and Kapuni fields as the gas in these fields was commercially extracted. As the bigger of the two fields, the Maui field was particularly responsible for this increase.

As the price of oil increased internationally in the early 1980's as a consequence of the second oil shock, the overall level of consumption of oil products decreased. The proportion of the total that was provided from local sources increased slightly at this stage, but was still limited by the small quantities that could be extracted from the known fields at that stage and the impact of this on the commercial viability of exploiting this resource.

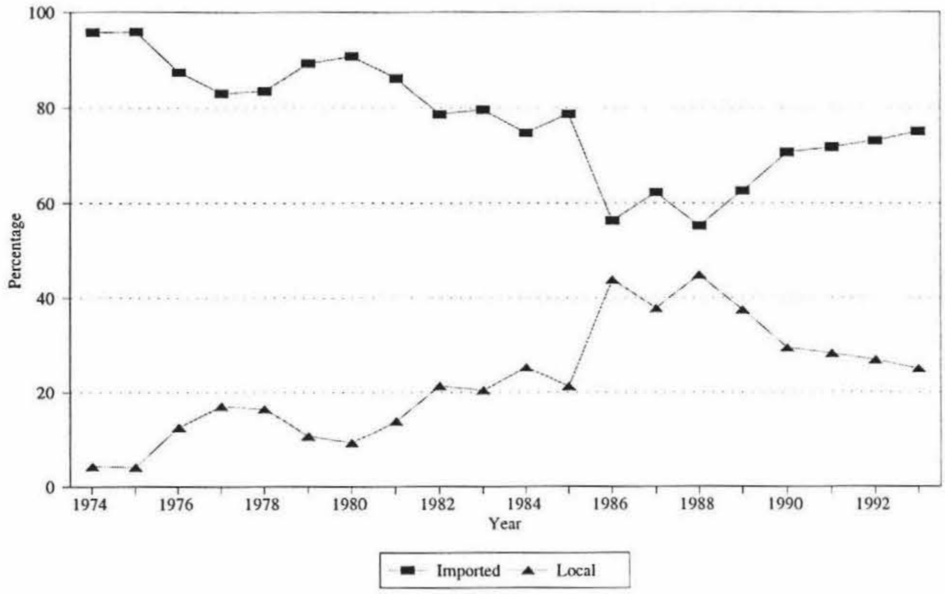


*Figure eleven: Source of Oil Consumed in New Zealand (Percent)*

The early 1980's also marked a turning point in the New Zealand oil industry, as exploration increased and commercial fields were found in Taranaki. When these finds were combined with a government policy of import substitution and self sufficiency in oil products, the net result was an increase in the proportion of locally sourced oil products in the total supply. The proportion was increased further by the coming on stream of the Motonui Synthetic Petrol Plant. While the output of this plant is not included in the figures on locally produced oil (as it is already counted in terms of gas and the products of the plant are consumer energy forms rather than primary energy as is used in the calculations here), its effect was felt in the way that it enabled New Zealand to decrease imports of foreign oil. This event is clearly shown on the graph as the increase in total oil use from 1985 to 1986.

The decrease in the percentage in 1987 is due to seasonal differences in the demand for oil products that had to be met by imported supplies. This discrepancy illustrates that there is a degree of inflexibility in the domestic supply system.

The decrease in the percentage of locally produced oil after 1988 was due to the increased demand that was put on oil supplies by the deregulation of road transport and the motor vehicle sales market. The consequent increase in demand for oil products was more than the local supplies could provide, as indicated by the fact that local supply levels have not actually decreased, although the percentage has fallen away steadily.

Local oil reserves are unable to make a particularly significant contribution to the total use of oil products in New Zealand at present levels of demand. Unless there is a major reduction in the use of oil products in New Zealand or a major discovery of oil, neither of which are credited as being particularly plausible events, New Zealand will always be very dependent on imported oil. This is not to be viewed as a criticism of the management of oil reserves as such, although a comprehensive energy management programme could alleviate this reliance somewhat through fuel substitution and efficiency measures. A hidden failing in the system is the inability of the Marsden Point refinery to process some of the waxy crudes that are extracted from the local fields, meaning that they have to be exported to be refined before being imported. Addressing this technical difficulty could lead to a significant improvement in the overall self sufficiency of the New Zealand oil products market, possibly equal to the improvements that could result from import substitution measures.

**Robustness of energy supply - electricity**

Due to the cost difference between hydro generation and thermal generation and due to the volume of hydro energy that is available in New Zealand, there is an established policy of providing for base load electricity generation from hydro sources and using thermal generation to provide peaking power only. As a result, the level of thermal generation in the system is a good indicator of the security of the electricity supply system and the effectiveness of the management of the resource.

Figure twelve shows the total level of thermal and non-thermal generation. Figure thirteen shows the percentage of thermal generation in total electricity generation in New Zealand.

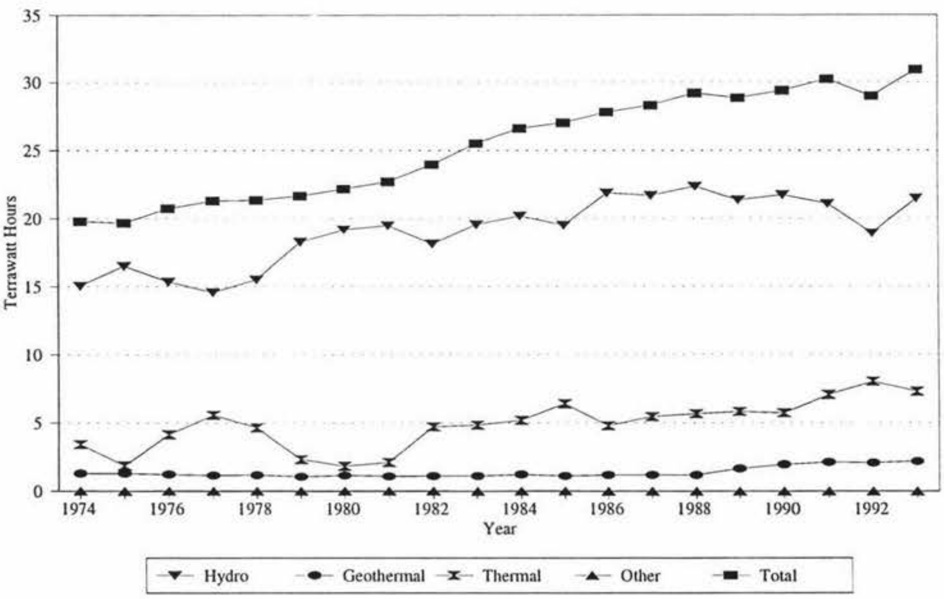


*Figure twelve: Source of Electricity Generation in New Zealand*

The fall off in thermal generation in 1974 and 1975 was due to the effect of the oil price crisis, as at this stage the majority of the thermal capacity in New Zealand was provided from oil fired stations. Understandably, the use of these stations was decreased as much as possible at this stage as the cost of operating them increased markedly. This decrease was helped by the fact that conservation measures meant that the total level of energy consumption decreased as well.

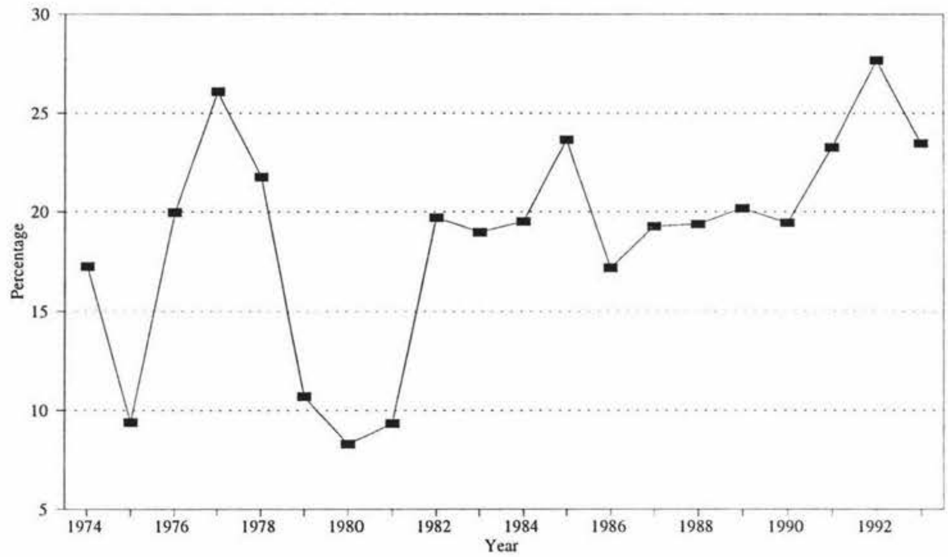


*Figure thirteen: Percentage of Electricity Generated from Thermal Fuels*

The increase in thermal generation in 1976 and 1977 marked the commissioning of the New Plymouth Thermal power station, operating on 'cheap' natural gas. The terms of the supply contracts meant that it was economical to use this gas in preference to hydro capacity in many instances. Climate also played a role, with 1977 being drier and colder than average.[173]

The second oil shock led to a re-evaluation of the thermal generation policy, as gas was diverted to other uses, most of which were focused on direct usage (and hence greater efficiency of use) and protecting New Zealand from the vagaries of the international oil

[173] *Personal communication, Stuart Burgess, NIWA.*

markets.

The Huntly power station was commissioned in 1982. While designed initially to burn coal, it was, like the New Plymouth station before it, modified to burn natural gas. The commissioning of this station led to a marked increase in the level and proportion of thermal generation that was used, and marked the start of a new benchmark level of thermal generation at around 20% of total generation.

Since that stage, there have been two major shocks that have caused a notable variation from this level. The first of those was in 1985, which was a particularly dry and cold year.[174] The second event was in 1991 and 1992. This was the time of the much discussed 'Electricity Crisis'. Water levels in Lake Pukaki led to concern about the continued ability of ECNZ to meet its water right conditions and therefore caused concern about the capacity of the generation facilities that are present on that river and lake system to meet demand. As a result, much more reliance than normal was placed on North Island thermal capacity to meet demand. It is notable that, while the electricity crisis is generally considered to be limited to 1992, there was a considerable increase in the amount of thermal capacity that had been used in 1991 as well as 1992, which indicates that the management signs were not properly heeded by ECNZ. This calls into question the overall management efficacy of the Corporation and the robustness of the generation system.

More can be told about the robustness of the electricity supply system by the single event of 1992 than the whole of the rest of the period that is graphed. The usual operating level of thermal generation at approximately 5 PJ to 7 PJ per annum appears to be a sustainable level of production (in terms of robustness of supply, not in terms of the fuels that are used).

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[174] *Personal communication, Stuart Burgess, NIWA.*

However, the security of this level of supply is immediately drawn into question in anything other than a typical year. The 1992 'crisis' illustrated that either the supply system or the management of that system cannot cope with the pressures that are put on it in an extreme year. That said, it is important to note that the increase in generation that was required was almost 50% of the typical operating level and that the situation was exacerbated by the lack of recognition of the signs in the previous year.

**Household expenditure on energy**

The following graphs are derived from the Household Expenditure Surveys conducted by Statistics New Zealand. They record expenditure in the 'domestic energy and heating' category. This category includes all energy expenditure on household operations, but does not include expenditure on private motor vehicle operation. This information is not able to be separated from the other items in the 'vehicle operating expenses' category.[175] While the absence of motor vehicle expenditure is obviously a limitation in the data, it should be noted that the majority of household energy expenditure is captured with the graph as it is at present. All of the amounts are recorded in 'May 1988 dollars'.

The average weekly expenditure on energy across all household groups is recorded in figure fourteen below.

The graph demonstrates a marked increase in the average weekly expenditure across all household groups. When this graph is combined with the overall decrease in electricity prices that was shown in Figure eight above, the implication is that domestic consumers are increasing their consumption of energy. This increase in consumption will in part reflect

[175] *Personal telephone communication, Information Management Unit, Statistics New Zealand.*

increases in the level of consumption due to the penetration of energy using, labour saving and recreational appliances. Appliances that are included in this category are dishwashers, clothes driers, video recorders, 'compact' stereo systems and the like.

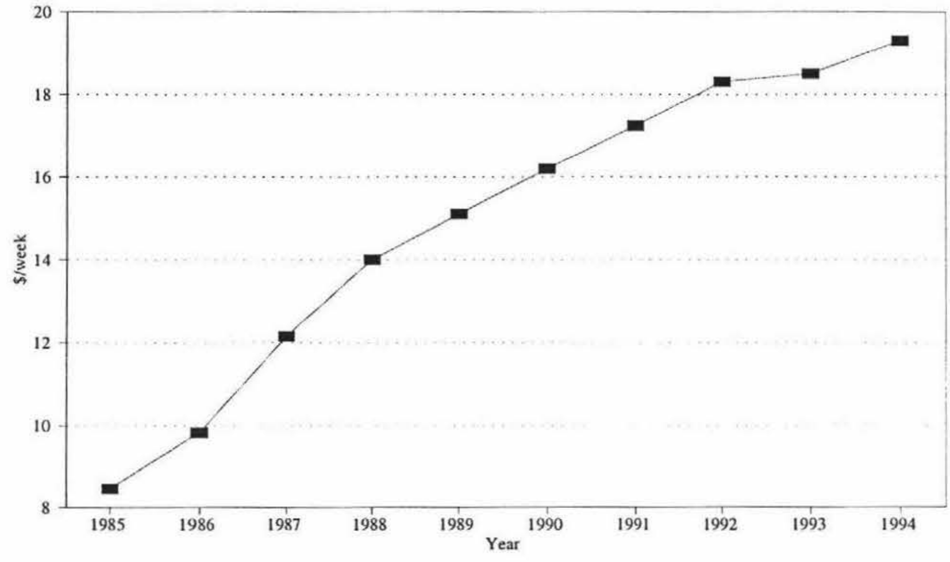


*Figure fourteen: Average Weekly Energy Expenditure Across All Income Groups*

It should also be noted that during this time there has been a change in the charging basis for domestic energy. Fixed line charges have been introduced over this period and have led to an increase in the overall cost of domestic energy. These charges have distorted the amount that is spent on energy by introducing a fixed cost that is unrelated to the level of consumption.[176]

The conservation measures that were imposed and suggested during the 'Electricity Crisis'

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[176] *It should be noted that Electropower in Palmerston North have introduced a stepped charging system that sets different rates of fixed line charge depending on the amount of energy that is consumed. To the best of the author's knowledge, this is the only example of this type of charging system in New Zealand.*

of 1992 caused a plateau in the figures for the year ended March 1993. The continuation of the trend of increased expenditure in 1994 indicates that the messages that were circulated during the crisis were regarded by most consumers as being of temporary relevance only. This decrease may however have been due to a number of other factors that can only be analysed by a full analysis of all household expenditure types and groups.

Figures fifteen and sixteen break the average weekly expenditure down into the different income bands, in this case on the basis of deciles (or tenths).

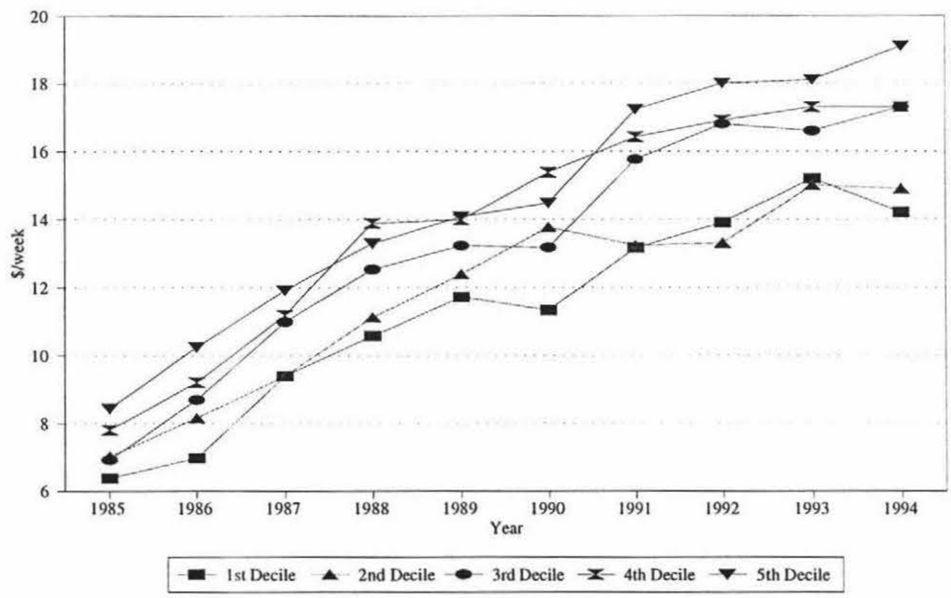


*Figure fifteen: Average Weekly Energy Expenditure, First to Fifth Deciles*

An interesting trend that is illustrated in the graphs is the way that the outlying deciles are trending away from the central seven deciles. While all of the groups are increasing their expenditure on energy, the top 10% of incomes are spending considerably more on energy and the lowest 20% of incomes are spending less. At the start of the period, there was little variation between the groups. This trend of separation supports the contention that a major reason for the increased expenditure on energy is the penetration of energy using equipment. Higher income households can afford to buy and operate this equipment more easily than lower income families, hence the variation.

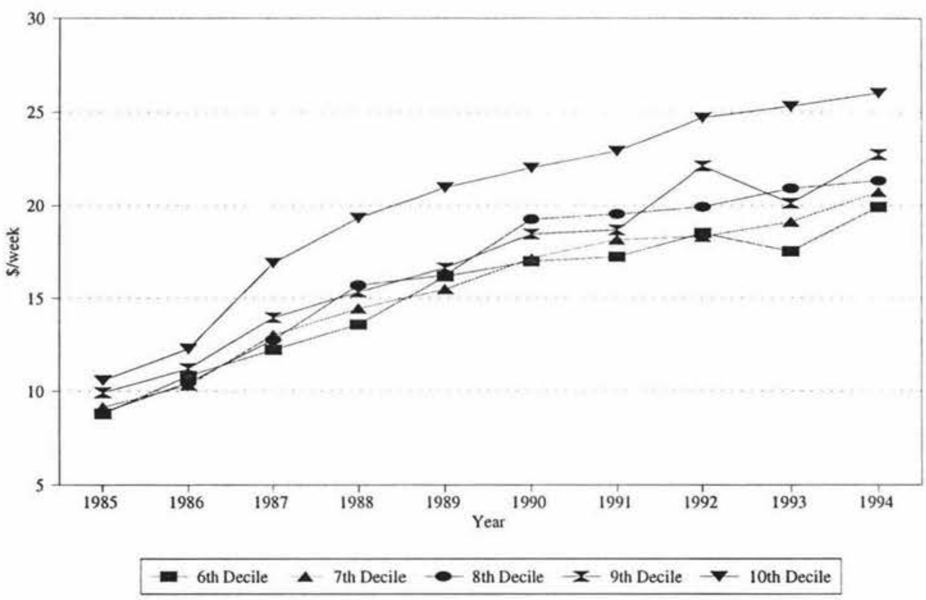


*Figure sixteen: Average Weekly Energy Expenditure, Sixth to Tenth Deciles*

The response of the different groups to the electricity conservation messages that were circulated at the time of the 1992 shortage is instructive as an indication of the likely success of energy sustainability messages. Both the first and second decile groups actually increased the amount that they spent on domestic energy over this period. As the electricity consumption of these groups is likely to be the most inelastic of the entire population, the graph here illustrates the effect of price changes. It should be noted that consumption patterns for this section of the population are expected to be inelastic, as these households do not usually have much discretionary spending power.

Only the third, fifth, sixth and ninth deciles decreased their spending on energy over the period of the shortage. The implication of the annual variation in these groups is that these groups have either been better targeted than the other income groups or else are more aware of the issues that surround energy use.[177] It is possible that a number of the respondents in these groups are either technicians or engineers or are in some way involved with energy management issues.

The remaining income groups exhibit the same overall trend of increasing energy expenditure that is illustrated in the total energy group.

The overall income index is increasing at a slower rate than energy expenditure is increasing, indicating that energy is becoming slightly less affordable. While this is not a major concern for a number of the income groups, the implications are serious for those on lower incomes and many people in the middle groups who are affected by user pays charges.

**Economic rent earned**

In calculating economic rent, an average rate of return of 10% has been used to indicate a 'normal' return or rate of profit. This is the same level that Bertram used in his calculations in the April Report.[178] The Electricity Corporation of New Zealand is the only energy supplier that has been used in calculating this indicator as it is the only energy supplier that publishes a consistent series of accounts that the author has been able to find. The oil companies publish very brief reports that specify after tax profit only, meaning that the data

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[177] *The number of possible combinations that can lead to the same level of household income mean that it is not possible to identify indicative occupation groups that fit within each income band.*

[178] *Above, p. 303.*

is not suitable for present purposes. ECNZ is also the only supplier that has a monopoly position.[179]

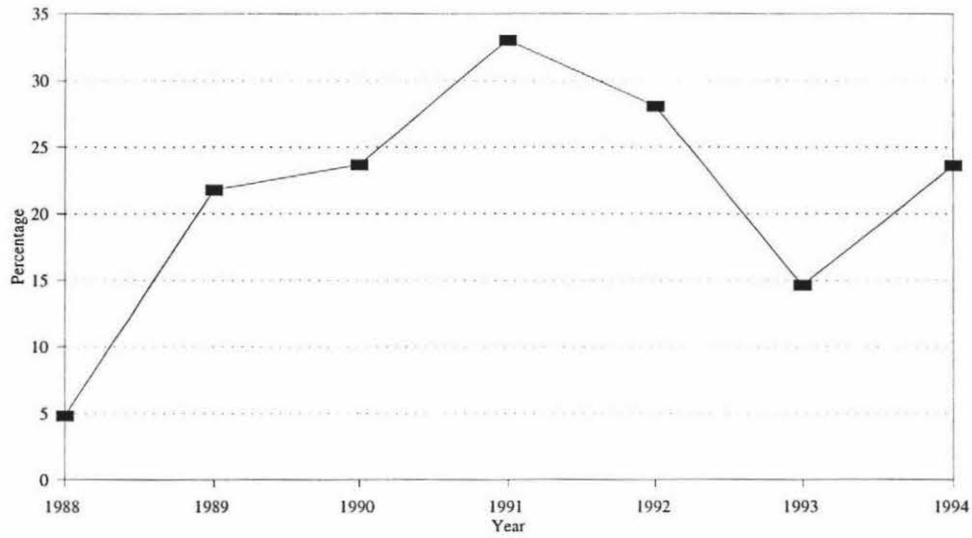


*Figure seventeen: Economic Rent Earned by ECNZ*

The level of economic rent that ECNZ has earned since 1988 is graphed on figure seventeen below.

The graph clearly indicates that ECNZ is making a considerable 'supernormal' profit. As this is defined as being a profit above the level of profit that would be required as a factor payment to enterprise to remain in the particular productive industry or activity, this extra profit can fairly be classified as economic rent.

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[179] *Using ECNZ in this section is not attempting to attack the company in any way, as it can safely be assumed that there are a number of other companies in a number of different fields that are earning a similar level of economic rent to that which ECNZ is earning.*

The level of economic rent at the start of the period is low because ECNZ was being established and had a number of set up expenses, including payment to the Government for the acquisition of the Electricity Division's generating assets. It should also be noted that almost all of the corporation's earnings at that time were from electricity sales. By contrast, later in the period more of the Corporation's profits were derived from other sources. In some years, this 'other income' approached 10% of ECNZ's total income.

Apart from the marked dip in profitability in 1992 due to the extra costs that were incurred in using more thermal generation, the level of rent that the Corporation has earned has consistently remained over 20%. In depth analysis of the variations will not add much to the present analysis, as they are likely to be due to changes in accounting practise, improvements in organisational efficiency and the like, none of which are directly manageable through energy management measures.

CHAPTER TEN

# CONCLUSION

## RESEARCH FINDINGS

The development of energy sustainability indicators involved two stages. The first was the identification of energy sustainability as a concept. As noted in chapter two, the concept of energy sustainability is often discussed in the literature but is rarely operationalised. Much of the debate on the subject deals with the general and more abstract notion, rather than identifying and discussing all of the specific elements of energy sustainability. Paradoxically, it is also very common to find lengthy discussions of the individual elements of energy sustainability. Unfortunately, these in depth analyses are conducted in isolation of the other elements that comprise the definition, so that they provided little guidance when developing the definition that is used in this thesis.

The lack of a widely accepted definition of energy sustainability is an impediment to policy makers addressing the management of energy in New Zealand. Sustainability can currently be interpreted to suit the person developing a particular definition and can then be used to justify an outcome that may not be sustainable. One only has to watch a news bulletin to note the way that the word 'sustainable' is used by numerous parties who recognise that it is the 'buzzword' of the day.

Once a definition is developed however, the concept of sustainable management will be an important ingredient in energy policy in New Zealand. The main reason for its importance and utility is that it forces players in the energy industry to note that their actions have an impact in a number of different spheres. Whether it be sustainable management or some other concept, it is important to shift the focus of energy management to the macro level. At present, it is argued that sustainable management is the best 'umbrella concept' that is available. Its utility derives from the scope of the issues that comprise the concept and the fundamental nature of each of those issues. The concept is beneficial at both qualitative and quantitative (that is, system modelling) levels, due to the scope that it has.

The omnibus nature of the majority of the theoretical definitions that have been developed means that there will be a number of points that are either not applicable or are less applicable to New Zealand. The key task for policy makers is to identify those aspects of the more general definitions that are viewed as being important by the various players in the energy industry. Those players will be very similar to the stakeholders who are identified in the review of energy statistics discussed in chapter six. In developing the core definition, it must always be remembered that it is being developed for the purpose of sustainably managing the New Zealand energy system. It is not concerned with all of the issues that are components of sustainable development, but should be built on the salient features of the New Zealand system. One of the key questions is whether matters beyond the more technical issues of system management (such as equity issues) should be included in the analysis. As noted above, these are matters to be developed in conjunction with the major stakeholders and potential stakeholders in the energy system.

These criteria have been largely satisfied by the use of the definition of sustainable management that is contained in s 5 of the Resource Management Act 1991. That definition has been derived from the body of international reports and discussion that exists on the general definition of the term 'sustainability'. As a result, it has been indirectly subjected to debate and analysis in an international context, as well as being debated directly in New

Zealand. While there are some specific interpretation issues that surround the use of the definition, it is widely accepted. The definition is sufficiently general to apply to most resources and systems that could be subject to sustainable management systems, yet is sufficiently specific to encompass the majority of concerns that relate to those systems.

The identification of criteria for indicator selection and the development of indicators that comply with those criteria was the next stage in the realisation of the first objective of this research. The development of criteria in this thesis identified a number of differences of opinion between writers on the subject. There was however a significant core of agreement about several of the more fundamental criteria. One point that the development of these criteria did identify was that it is important to remember that the development of indicators is not an end in itself. Indicator development should always be guided by the principle that the indicators are developed as a means of providing basic information to policy makers to enable them to manage a particular system or set of systems. In that regard, the end product should not be viewed as being the indicator, rather it should be viewed as being the information that the indicator will provide its users.

The analysis of the different criteria revealed that the debate was generally working itself into ever decreasing circles, with more and more agreement being reached as to the matters that go to make an effective indicator. The next logical step is to recognise that the time has clearly come to take the criteria for indicator selection as read (after a brief discussion of the various suggested criteria, of the type that was conducted in chapter three) and to proceed on the basis of debate as it stands at present. In making this statement, it is important to remember that there will always be differences in some of the criteria, as a result of focusing the indicator to the specific matters that need monitoring.

The key point to come from the development of criteria is that it is paramount to remember that indicators are developed as a management tool to provide information for the management of a particular system. Two consequences flow from this conclusion. Firstly, as noted above, the development of indicators is not an end in itself, it is the information that the indicator provides that is the product of indicator development. Secondly, indicators are not a solution, rather they are a means of charting possible paths that can be taken to reach a solution.

As part of developing indicators, an analysis was conducted in chapters five and six of the monitoring activities of various governmental and non-governmental organisations in New Zealand and around the world. That survey identified a pre-occupation with certain environmental effects of energy use to the exclusion of most of the other elements that make up the concept of energy sustainability. The most comprehensive systems of indicators have been developed by the Norwegian and Canadian governments, yet even those two systems demonstrate a marked pre-occupation with pollution effects. The next most widely studied element is energy efficiency, with the other factors trailing far behind.

The final stage in realising the first objective of this thesis was the development of formulae for the indicators themselves and the operationalisation of as many of the indicators as possible. The development of formulae was a relatively straightforward task, requiring a simple mathematical manipulation of data in most cases. Difficulties arose with those indicators that deal with more amorphous, poorly defined concepts. Specific issues arose as to where to draw boundaries and how to quantify certain concepts. These concerns have always been an issue in the development of indicators outside of the more quantitative science and research areas. The ability to address these issues is limited in part by the nature of the concepts that are to be measured. As a result, there will always be a degree of reliance on the use of salient features to measure concepts, as is done in this thesis in the development of the indicator on remedial expenditure. Care must be taken in the use of this approach to ensure that the features that are included are indeed salient points of the system in question.

The analysis of monitoring programmes and the development of indicators identified some general issues and some more specific issues about data collection regimes that are currently in place in New Zealand.

The general issue concerns the debate about the use of a single composite indicator versus a series of indicators. The latter approach is clearly favoured both overseas and in New Zealand when dealing with environmental or sustainability statistics and is the approach that was taken in this thesis. This approach is favoured because of the nature of the issue of sustainable management of energy. As noted previously in this chapter, sustainable management is somewhat of an umbrella concept, encompassing a number of varied matters. A result of this is that the units of measure of these matters are equally varied and are not readily aggregated, meaning that a composite indicator would make extensive use of indices. This approach would obviously measure changes in the phenomena very well, but would require recourse to the base data to determine absolute levels. Such an approach is in many ways a double counting. It would also require a decision on weighting between the matters that are to be measured. As was noted in previous chapters, the nature of sustainable management is such that it changes over time as the priorities for management change. This variation would require changes to the weightings, which would affect the ability to measure spatial and temporal changes. The issue of weighting is further complicated by the degree of overlap and interrelationship between the various matters that comprise the definition. It is therefore recommended that whatever indicators are developed are developed as a series, rather than attempting to develop a composite indicator.

The practical matters that were identified as a result of the analysis of data collection concern the inadequacy of the data that is available at present. Many of these concerns are mirrored in the draft of the review of energy statistics. Specific deficiencies in the data that presented themselves as a result of the investigations that were conducted in this thesis are:

| | |
|---|---|
| time scales used: | Currently, there are a number of different time periods depending on the type of energy that is measured and the organisation that collects the data. For example, electricity statistics operate on a March year, while coal statistics operate on a December year. |
| level of aggregation: | The classic example of this problem is a Ministry of Commerce report on energy intensity that included approximately 90% of economic activity in a single category. Other, less extreme examples exist, where the level of aggregation is greater than is desirable. |
| cost of data: | Once one begins requesting data that is beyond the scope of the standard reports that are published by the various agencies, the cost of obtaining the data increases rapidly. This point is related to the point below. |
| lack of published data: | Aside from a number of relatively standard series of data that focus largely on energy supply issues, there is little information available about the various aspects of energy sustainability. This lack of data is clearly illustrated by the range of indicators that were able to be operationalised in this thesis. |
| incomplete data series: | This deficiency applies equally to spatial and temporal |

incompleteness. An example of the former is the data that is collected on $NO_X$, which only covers the main centres. One of the major criticisms concerning lack of temporal data relates to inconsistencies that arose as a result of the energy sector reforms in the mid to late 1980's. This criticism obviously makes allowance for the fact that some data series have only recently begun to be collected. The recent commencement of some collection may however be a criticism in itself, depending on how fundamental the data is.

number of collectors: As noted in the first criticism above, a number of organisations collect data about parts of the energy sector. The result is either a feast or a famine, with some data being collected numerous times and other data falling through gaps.

commercial sensitivity: Commercial sensitivity has been used as a reason for discontinuing various data series, as newly privatised and private sector organisations take over key roles in the energy sector. Given the fact that these types of organisations dominate the energy sector, a very large portion of information is now no longer available.

incomplete coverage: Many of the key components of sustainable management of energy are not the subject of data collection regimes. With some of the more revolutionary parts of the definition, this is not surprising. There are however a number of fundamental factors that could or should be the subject of data collection regimes at the present time.

There are other deficiencies in the available data, but they are beyond the control of data collection agencies. One of the clearest examples is the issue of how to quantify amorphous concepts such as fairness or equity. It is also understandable that the data collection system will have its limitations in the early stages of operationalising monitoring sustainable management of energy, or any new subject area for that matter. Discussions of the type contained in this thesis therefore serve a double purpose of developing new systems and identifying deficiencies in existing systems.

In summary therefore, the New Zealand energy data collection regime needs to be revised so that there is one agency that is producing a spatially and temporally complete series of information that is available on a consistent time period in a form that is sufficiently disaggregated to provide full information on public and private sector activities in a readily accessible form and at a reasonable cost to users.

The second part of this thesis focused on recording changes in the indicators that were developed in the first part of the thesis. Analysis of the indicators that have been developed here demonstrates that New Zealand is firmly on a path towards unsustainable use of energy. In some fields, the rate of progress towards that state is actually increasing.

The energy supply system is becoming increasingly dependent on non-renewable energy types. A necessary consequence of the reliance on non-renewable energy is that the environmental impacts of energy use are increasing. A direct economic impact of the current patterns of energy use can be seen in the changes in prices for energy. These have decreased considerably in real terms over the period that is analysed in this thesis, although total expenditure on energy has increased as consumers increase their consumption. The net result for many consumers has been that the price reductions have been negated by this increased consumption. The worsening of the economic and energy efficiency of energy use is demonstrated clearly by the fact that New Zealand has the second worst energy intensity ratio in the OECD (excluding Luxembourg, as noted above). The major cause for this position is the use of gas by the petrochemical plants, although energy intensity ratios have worsened for all but the agricultural sector. New Zealand will always have points of fragility in its energy supply system. The fact that the largest gas field is 40 kilometres off shore in a hostile marine environment ensures that this is the case. Similarly, the size of the onshore oil fields mean that there will always be a degree of reliance on imported oil. The indigenous oil resource has the potential however to be managed in such a way that the reliance on imported oil is not as great as it is at present. The electricity supply system can cope with the usual range of demand that is put on it. The 1992 'crisis' reflects more on the ability of ECNZ to manage resources than on the capacity of the supply system to cope.

Allied to the comments about increasing expenditure on energy as the price of energy dropped, the household expenditure indicators show that the level of expenditure on energy is steadily increasing. While some of the increase is due to pricing policies (most especially the introduction of fixed line charges) and the development of new types of energy using equipment, this does not explain all of the steady increase in energy expenditure. The net result of the increased expenditure on energy is that suppliers are increasing the level of economic rent that they earn.

The major target for policy work should be to address the efficiency of energy use. The linkages and flow on effects that exist between the various components of the definition of sustainable energy management and the fact that this issue is so fundamental to the problems that New Zealand is facing at the moment mean that addressing this factor can almost singlehandedly address sustainable energy management in general.

Increasing energy efficiency will decrease the level of fossil fuels that are used in the supply system for two reasons. Firstly, as with all forms of energy, a lower level of energy inputs will be required by consumers. As well as a direct reduction as energy usage decreases, there will also be substitution as consumers realise that they are able to use other forms of energy that they had previously thought were not able to be used. Renewable energy is a clear example of an energy type that would be affected in this way. Secondly, as fossil fuels are used as a peaking fuel in the electricity sector (the major 'mainstream' user of renewable energy), they would be used less, as there would be less need for the peak capacity that is built into the system. Some form of regulation, incentives or eduction may be required to ensure that renewable energy types are used in place of fossil fuels, as the latter may be favoured in terms of short run cost benefit analysis until such time as the present cost structure is changed.

There are two major flow on effects from the above position. Firstly, the robustness of the supply system would increase, as average demand for energy became an ever smaller portion of the total capacity of a system and as the level of reliance on imported oil products decreased. As noted above, it is extremely unlikely that New Zealand could ever be self sufficient in oil products. It is however plausible that it could approach the levels of self sufficiency that were reached in the early to mid 1980's. The electricity system would cope more easily with the levels of demand that were placed on it, possibly with less recourse to thermal generation than at present (as was noted above). There will always be a level of fragility in the gas system, due to the location of the Maui field. Decreasing the amount of energy that is used however would increase the number of days of down time that are provided by the effective storage of gas in the supply pipelines. While this does not increase the operational security of the system as such, it does effectively decrease the chance of consumers being left without gas.

The second flow on effect is to decrease the environmental impact of energy usage. The direct effect of this is that there will be less pollutants emitted into the atmosphere. As noted above, this assumes a reduction in the level of fossil fuel use. This scenario is not too unlikely, given cost differentials and current policies. Decreased fossil fuels use will mean that the levels of $CO_2$, $SO_X$, $NO_X$ and particulates will all decrease. There will also be less demand for significant habitat areas and wild and scenic rivers to be used in hydro electric projects. The prospect of hillsides and skylines being ringed with wind turbines will also disappear.

Decreased environmental impacts mean that New Zealand's clean, green image remains intact, with positive potential effects for the tourist industry. Other more direct economic results may be harder to map. The price of energy will most likely decrease for some energy types and not for others. It is unlikely that the price of oil products would change greatly as a result of any major domestic changes in the use of energy, given that New Zealand is a price taker for oil. The price of completely domestically supplied energy types such as electricity are however likely to decrease, as consumers find that they can save using a unit of any given energy type for less than it costs them to buy another unit. How much prices drop by would be uncertain, as it is a factor of the cost of production, the supplier's pricing and profit policies, the degree of monopoly power that the supplier has, the level of penetration of efficiency measures and the cost of those efficiency measures. The danger with decreasing energy prices is that there is likely to be a point when the decreased cost starts to encourage consumers to use more, as energy starts to be viewed as being extremely cheap. The magnitude of this effect will be determined in part by the amount that consumers' behaviour changes from a focus on the amount of energy that is used to the amount of energy services that are obtained from a unit of energy.

Along with a reduction in the price of energy, there is also likely to be a decrease in the expenditure on energy by households. The same price effect as is noted for the economy in general will occur for the household sector as well, although the eventual increase in consumption is likely to be more pronounced in this sector. The potential for large increases in household energy use may mean that minimum levels should be put on prices. It also puts an impetus on educating domestic consumers about energy use and energy efficiency. Education is also crucial to overcoming the price decrease syndrome.

Of the indicators that have been developed here, the one with the most uncertain outcome is economic rent. The degree to which that will be affected is dependent on many of the same features as those that will determine the magnitude of the price change. Specifically, it will be affected by the degree of monopoly control (or ability to fix prices) that a supplier has, the amount of price competition in the supply industry, the degree of competition that comes from efficiency measures and the ability of consumers to substitute for another energy type. While this aspect of sustainable energy management may be the hardest to have any management control over, it is the opinion of the author that this is not a significant problem. The issue of the amount of profit that a supplier is earning takes on far less significance when consumers have a choice about the products that they consume.

In summary, New Zealand needs to seriously address its energy use. The country is steadily painting itself into a corner, placing increased reliance on an energy supply system that is becoming increasingly unsustainable. While it may seem that there are a multitude of problems with energy use in New Zealand, it should be remembered that a number of these trends have only developed over the last decade. Reversing those trends therefore should not present too great a problem, provided the country acts now.

## AREAS REQUIRING FURTHER RESEARCH

The final issue that remains to be addressed is to assess which areas require further research and to what degree the aims of this thesis have been attained.

The first part of this thesis develops the theoretical background for the analysis that is conducted in the second part of the thesis. The key aspects of this section are the development of criteria for indicator selection, the development of a definition of energy sustainability and the development of the indicators themselves (including a survey of various energy monitoring programmes that are operational at present). The first two aims were achieved fully, making extensive use of the often limited reference material that is available. While this lack of information made the task somewhat more difficult than it may have been, the novel nature of the issue of sustainable energy management means that it did not create a significant obstacle.

The actual development of the indicators that were charted in the last section of the thesis also provided relatively few problems, although an indicator was not developed for one of the suggested areas for concern. The absence of an indicator of end use matching is not of great concern however, as the decision not to develop an indicator was influenced by the fact that it was considered to be more appropriate in a micro-level energy management programme than in a macro-level set of indicators.

The section of this thesis that presented the greatest difficulty was the charting of the indicators. The single biggest difficulty was an absence of consistent data. In some cases, this problem could be overcome. It did however prevent approximately half of the suggested indicators from being developed. Of those indicators that were charted, the indicator of household expenditure could not be developed in the form that was suggested due to the absence of data. While a proxy was able to be used, efforts should still be made to develop a standard basket of energy services.

Overall therefore, the aims of this thesis have been fully achieved. All that remains to be done to achieve those aims completely is to improve the raw data that is available. Then, attention can shift to turning New Zealand's energy supply and use patterns around.

APPENDIX ONE

# ENERGY MONITORING IN NEW ZEALAND

The monitoring activities that are discussed in this appendix are conducted by various major players in New Zealand's energy supply system. In each case, the matters that are monitored fall outside the scope of sustainable management, hence their inclusion in this appendix rather than in chapter 6.

*Shell Oil New Zealand*[180]

As Shell New Zealand is designed purely as a marketing company (rather than being involved in production or exploration) the information that they collect appears to be centred on profit making and marketing information. The Royal Dutch/Shell Group (Shell Oil New Zealand's parent company) collects basic energy-environment statistics and statistics on the level of energy use worldwide.

*Mobil Oil New Zealand Limited*[181]

Like Shell Oil, Mobil New Zealand classifies itself as being simply a marketing company and also collects only marketing information. Supply issues are not considered to be

[180] *The information about Shell Oil is from personal communication with Deborah Walker, Shell's Media Relations Officer in Wellington.*

[181] *The information about Mobil Oil is from personal communication with Pam Geris, Mobil's Public Affairs Manager in Wellington.*

relevant, as they 'rely on imported crudes" supplemented by "a small amount of light crude obtained from the indigenous fields around New Plymouth".

Mobil "operates around the world with concern and respect for the environment"[182]. Despite this, no statistics are collected about the environmental effects of the production or supply of Mobil's products in New Zealand.

*Caltex Oil New Zealand Limited*

Caltex Oil did not reply to requests for information.

*BP Oil New Zealand Limited*

BP declined to answer the questions on the grounds that they were too ambiguous.

*Gas Association of New Zealand*[183]

The Gas Association is an industry association comprised of the gas supply authorities and various other organisations that have an interest in the New Zealand gas industry (including manufacturers of gas appliances and major users). The Association's main role is as a

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[182] *'Facts About Mobil', undated public relations brochure.*

[183] *Unless otherwise indicated, the information contained in this section is the result of an interview with Dr. Eric Palmer, Technical Director, Gas Association of New Zealand on the 8th of April 1994.*

pressure group to create an environment in which the members are able to function efficiently as profit making activities.[184] As such, the Association is primarily concerned with infrastructural and educational initiatives.

The Association collects statistics on the amount of gas produced and consumed (measured in heat units), the proportion of the total energy supply that is met with gas and the breakdown of natural gas use by end use type. The number of gas customers is measured as a raw figure and also as a proportion of the total number of potential consumers who have access to gas. There is no security measure as such because the supply network acts as a storage system, provided the operating pressure is maintained. The security of the off-shore and on-shore production stations is not monitored, as this is a part of the day to day management of the supply network.

Economic statistics are not collected, either because they fall outside of the Association's role or because they are not considered to be relevant to the Association's members.

Gaseous emissions from the combustion of gas are the only environmental impacts that are measured, all other impacts being considered to be generally minor or quickly dissipated in the environment (excluding mishaps and other environmental disasters) so that these aspects are not monitored.

*Ministry of Commerce*

The Ministry of Commerce took over the role of the Ministry of Energy after the public

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[184] *'A Strategic Plan for the Gas Association of New Zealand', Anonymous, Date unknown.*

sector reforms of the mid-1980's. Aside from occasional reports and papers, the main energy report that the Ministry prepares is the 'Energy Data File'. This is published quarterly and includes the traditional type of energy data that is required by the OECD/IEA. As Wright notes, it is not a particularly thriftily selected volume of energy data and shows a lingering preoccupation with New Zealand's dependence on oil imports[185]. It is however a useful source of engineering type data which can be used in the development of indicators and ratios.

[185] *Wright, above, p. 8.*

APPENDIX TWO

# DATA ADJUSTMENTS REQUIRED TO OPERATIONALISE INDICATORS

Most of the data that was used to develop the indicators in this thesis required some form of manipulation. The explanations here only relate to those indicators that required information from a number of sources or required a complex series of calculations.

*Carbon Dioxide Emissions*

Co-efficients from the 'New Zealand Energy Information Handbook'[186] were used to obtain carbon dioxide emissions. Those co-efficients are:

coal 90.4 $tCO_2/TJ$

gas 52.7 $tCO_2/TJ$

oil 68.0 $tCO_2/TJ$

*Energy Intensity*

Deriving energy intensity information required a series of calculations. Readers who are interested in the mathematics behind this indicator are referred to Patterson and Wadsworth's report for a detailed discussion of the methodology.

[186] *'New Zealand Energy Information Handbook: Energy Data, Conversion Factors, Information', J.T. Baines (ed.), Taylor Baines and Associates, 1993.*

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