PREM

Personalised Residential Energy Model

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Abstract

Climate change is a major world environmental problem accepted by these governments who have ratified the Kyoto Protocol which aims to reduce the amount of greenhouse gases (GHG) internationally 5% below the 1990 level during 2008 to 2012. The Protocol needed the ratification of Russia to get into force as the United States and Australia withdrew from the protocol. The New Zealand government ratified the protocol with the negotiated goal to reduce the GHGs back to the level of 1990. The main driver of this study is to help people reducing their personal GHG emissions in order to meet the government's objective of the Kyoto Protocol.

Many people know about climate change and understand they will need to change their lifestyle significantly to reduce their GHG emissions. The how and where to change is often unclear. People need to be incentivised in order to encourage emission reduction. Some GHG-calculators already exist, but mostly without practical personalised suggestions and financial effects. This study aimed to develop a model which targeted responses by individuals based on their lifestyle and interests.

The Personalised Residential Energy Model (PREM) which was developed in this study uses findings of energy related behaviours from existing psychological and technical research to develop an easy to handle and individualised computer model to assess a person's current energy demand. It includes household and travel demand and assesses the general ecological behaviour. Users will be provided with relevant information to assist them to seek practical and economic solutions in order to reduce their personal CO_2 (carbon dioxide) emissions which is the main GHG in the assessed sectors. Starting with the current situation as a baseline, it establishes which behaviours have the highest probability of being undertaken by the person to lower their energy demand. Information about the financial effect and the CO_2 emission reductions are provided for specific activities. Energy efficiency and conservation are the main focus of the model output. Further research could include the possible use of renewable energy.

Using PREM found changes in domestic dwellings and transportation vehicles to be an important factor in reducing anthropogenic CO_2 emissions. The model is made for New Zealand conditions but can be adapted to suit any other country.

Acknowledgements

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Assoc. Prof. Florian Kaiser was very helpful by discussing the GEB-scale (General Ecological Behaviour), which he developed to measure people's environmental behaviour.

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	File name
PREM-Model	A_28_PREM_Model.xls
Cars 2002	A_29_cars2002_AGO.xls
Cars 2003	A_30_cars2003_AGO.xls
Refrigerators	A_31_refrigerators2003.xls
Dryers	A_32_dryers2003.xls
Dishwashers	A_33_dishwashers2003.xls
Clothes washers	A_34_clotheswashers2003.xls

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1. Chapter Introduction

Global warming has been a serious issue for more than a decade. Although not a general topic of conversation, many people and businesses have began to realise the potential seriousness of the problem. This is particularly the case when they see the floods, storms and droughts in the news that could have been caused by global warming. Some governments are trying to respond through the Kyoto Protocol to reduce the emission of GHGs (greenhouse gases). This protocol would require signatories to reduce six greenhouse gases[1] during 2008-2012 at least 5% below the level of 1990. A high proportion of human produced greenhouse gases are emitted when energy and resources are used. The lower our energy and resource consumption, the fewer the produced GHG emissions.

Every society, government and industry is composed of individuals. To solve a problem such as global warming the majority of people need to recognise the issue. Factors affecting this recognition are primarily impacts on income and lifestyle and the closed eyes for the advantages. Resource efficiency is an attempt to reduce global warming. Seven good reasons for resource efficiency were outlined by Weizsäcker, Lovins, & Lovins (1997):

- Live better: Resource efficiency improves quality of live.
- Pollute and deplete less
- Make money. Resource efficiency is usually profitable: you don't have to pay now for the resources that aren't being turned into pollutants, and don't have to pay later to clean them up.
- Harness markets and enlist business
- Multiply use of scarce capital
- Increase security. Competition for resources causes or worsens international conflicts.
- Be equitable and have more employment

This research study shows how the actual personal energy consumption of a person can be identified, measured and a way found, adjusted to the individual user, to be resource efficient by reducing energy demand and CO_2 emissions.

[1] Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Perfluorcarbons (PFCs), Hydrofluorcarbons (HFCs) and Sulphur Hexafluride (SF_6)

1.1. Objectives

The general aim of this study was to determine the extent to which individual decisions and behaviour contribute to energy consumption, greenhouse gas emissions and cost savings. The thesis aimed to include environmental psychology into a technical based energy model to make it more individualised and subsequently, with the aid of psychological instruments, to determine how a specific person is most likely to change his or her behaviour to reduce GHG-emissions. The specific objectives of this study were to:

- develop a model implemented as a computer program to assess a person's household and transport energy usage, which will be shown in the form of a monthly bill;
- identify psychological methods to make behavioural changes more likely; and
- to add CO_2-emissions and $ values to certain behaviours which have environmental impacts.

Psychological research showed behaviour change is more likely if information is personalised, vivid and specific (Stern, 1992). "People typically over estimate energy use for lights and appliances that are visible and that must be actuated for each use, and they under estimate energy use for water heating or other less visible ends." This is where the connection between psychology and technical energy solutions become important. Using both psychological knowledge and the technical options, this model shows its users where, how and how much energy and hence CO_2 and money can be saved.

The entity assessment of the developed model in this study (Fig. 1) includes the energy use and CO_2 emissions from car models, public transport types and domestic dwellings, in order to identify the energy usage of each service with resulting costs and CO_2 emissions. The analysis of this information was used to calculate the monthly energy cost and emission bill adjusted to the specific person whereby emission will be shown as a dollar value too in order to make it more understandable.

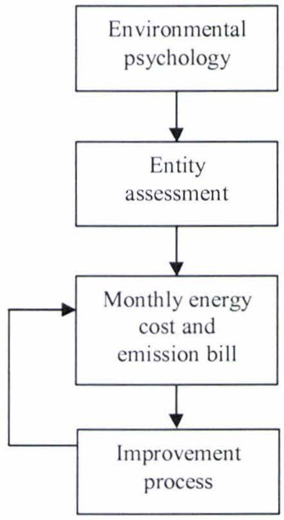


Figure 1: Personalised Residential Energy Model (PREM)

The model[2] allows the user to interact in an easy and slightly guided way as the improvement process (Fig. 1). All changes the user makes will immediately change the energy flows and the emissions. As a result the monthly bill will be adjusted. The model aims to find solutions to improve energy use and resource efficiency for the specific user based on the information provided.

[2] "The model" is always used to refer to the developed model in this study

1.2. Scope

Energy is used in every activity. This study will cover the energy use of a person's residential and transportation sector (Fig. 2). In this section a high proportion of a person's total consumption will be covered. The reason of this choice is, in ones own household and private transportation, the particular person is able to make decisions if desired and to change behaviour. It is also believed, if people see the pros of resource efficiency and its cost savings on their own, cost balance will then lead to more understanding and activities in industrial, agriculture and governmental based resource efficiency improvements.

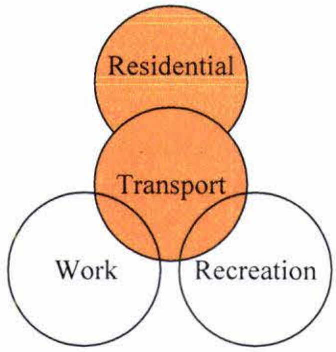


Figure 2: The parts of a person's life subdivided by basic activities. The living and transportation parts are covered in this study.

People use energy with every activity in various forms. To develop a computer model in a Masters thesis with a timeline of a year the study needs to focus. The chosen scope was domestic transport and household energy usage including the utilisation stage of the dwellings.

The residential component contains household energy use with required heating, hot water and other associated dwellings. Topics not included in the study were consumerism (such as buying food and clothes), house construction (embodied and construction energy) and waste treatment from all these services. The transport sector included both individual and public transport for all main travel types (bike, car, plane, train and bus). The work sector was excluded due to the shared responsibility of the employer and employee. However the individual can also make a difference also at their work place. In our society recreation is valued largely and the associated energy use is not expected to be small as a great number can afford hobbies such as riding a motor bike, motor boating, skiing, snowboarding or enjoying a day in an artificially heated pool. The recreation sector was only excluded due to time constraint.

Every technical device contains "embodied energy" as all of them have a life cycle which includes the development, realisation, utilisation and the final stage of disposal (Fig. 3). Each stage needs energy input and has GHG emissions as an output. To fully compare devices most accurately would be to take all four stages into account which requires a life cycle analysis (LCA). This study will concentrate mainly on the utilisation stage after the device is purchased and when it relies on direct energy inputs to provide the desired service.

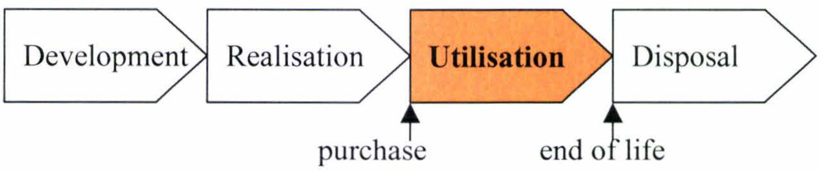


Figure 3: The four stages of a device lifecycle. This study takes only the utilisation stage into account.

1.3. Context

- Chapter 2 sets the scene with the literature review which explains the climate change science, national and international conventions and projects to tackle anthropogenic climate change, the costs caused by natural disasters and what other software in this field was produced.

- Chapter 3 explains the design of the model PREM.

- Chapter 4 shows general findings of environmental psychology and the approach used in this study.

- Chapter 5 provides information on the model's calculations and the data source used to develop the model.

- Chapter 6 describes how the developed model, was verified by using two different types of energy users. Mr. Greeny's and Mr. Carless energy usage were assessed and compared.

- Chapter 7 shows where further research could take place and concludes the thesis, by showing how the objectives were met.

2. Chapter Literature Review

2.1. Introduction

The literature review sets the scene for this study; where it takes place, why this model was developed and what other models in this field have been produced. Climate change, its political outcome, the Kyoto protocol, gave impetus for this study (Fig. 4). The section "New Zealand's situation" verifies where national climate change influences are being researched in the fields of agriculture, industry, transport and residential sectors. To reduce the effects from greenhouse gas emissions energy efficiency and energy conservation are needed, using improved technologies along with an increase in renewable energy.

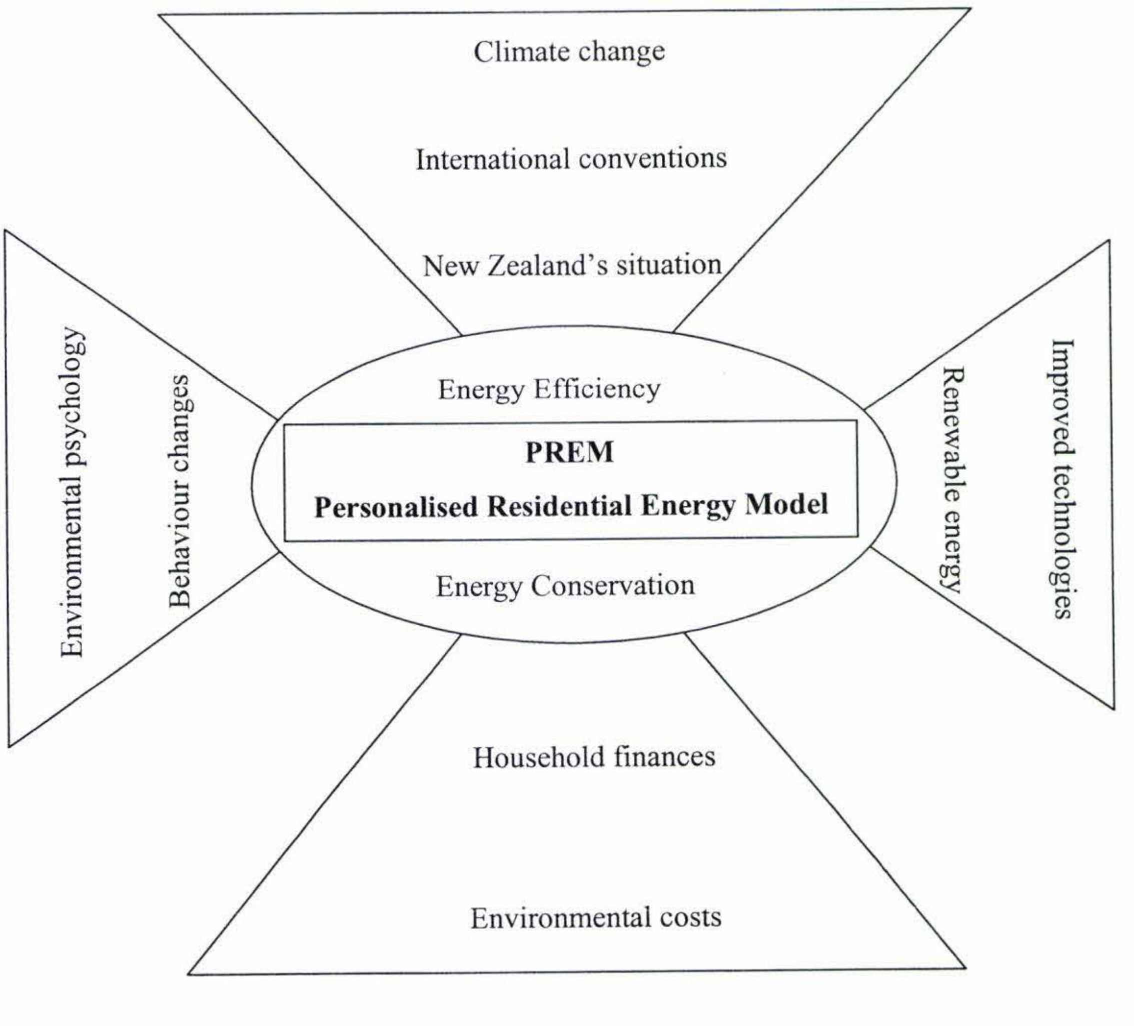


Figure 4: Setting the scene of this study for development of a Personalised Residential Energy Model (PREM)

Environmental costs caused by climate changes relate to environmental damage. These costs are difficult to estimate and even more difficult to predict. Some attempts at estimations were made. The study scope is restricted to the residential and transport sectors with the costs involved classified in the model as "household finances".

Environmental psychology is used in this study to assess opportunities to make the developed model more "individual". The added psychological scale assesses the most feasible improvements for the model user. Some basic findings from previous research were assessed and whenever possible also applied in the model.

2.2. Climate change

Climate change was the main driver of this study. To understand climate change the greenhouse effect needs to be explained first. The natural greenhouse effect keeps the climate at a liveable mean global temperature of 15°C by trapping just enough energy from the sun in the atmosphere, land and ocean to keep a stable climate (Fig. 5) (IPCC, 2001)[3]. The incoming solar radiation is partly reflected by the atmosphere and the earth's surface. The radiation which is absorbed by the Earth's surface is converted into heat and radiated back as infrared radiation into the atmosphere. The infrared radiation is partly reflected back to Earth by the greenhouse gas molecules. This effect warms the Earth's surface and the troposphere. Global warming and climate change occurs when the natural greenhouse effect goes out of balance by adding anthropogenic produced greenhouse gases into the atmosphere which changes its composition. Greenhouse gases (GHG) are mostly water vapour, carbon dioxide (CO_2), nitrous oxide (NO_2) and methane (CH_4). Over the last century the average temperature has increased by approximately 0.6°C. This increase is very fast compared to climate changes in the past. The human influence on the climate is not totally proven but scientific evidence is getting stronger (UNFCCC, 2003)[4].

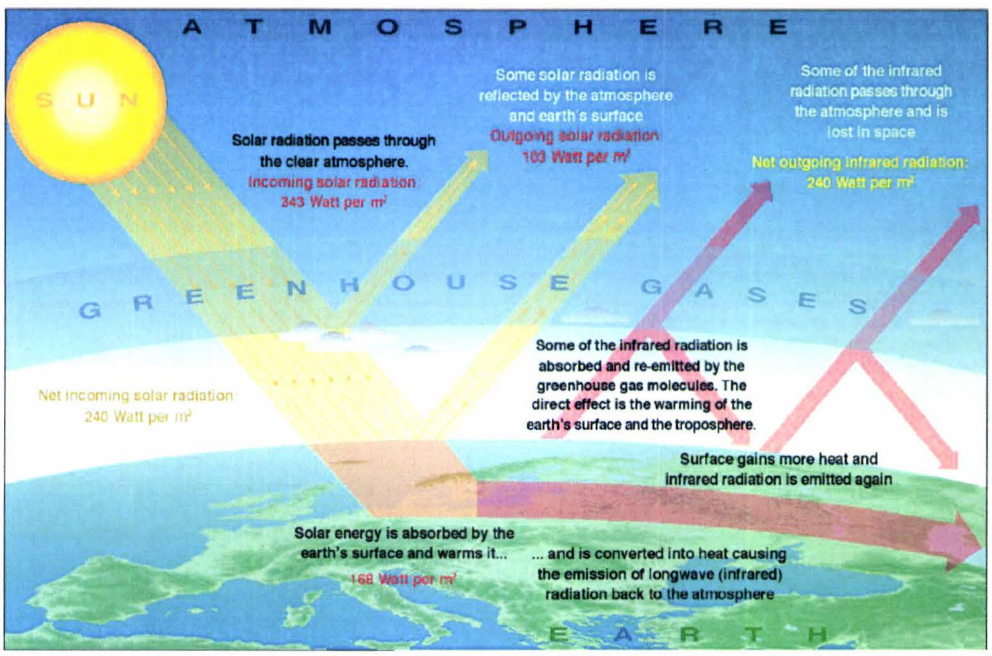


Figure 5: The greenhouse effect. Source: (UNFCCC, 2003)

[3] Intergovernmental Panel on Climate Change (IPCC).Will be discussed under 2.3 International conventions
[4] United Nations Framework Convention on Climate Change (UNFCCC). Will be discussed in section 2.3.

Global temperatures measured using thermometers, recorded since 1861 have increased (Fig. 6). Overall the global surface temperature has increased in the last 140 years by 0.6±0.2°C. It is very likely[5] that 1990 - 2000 was the warmest decade since 1861 and likely[5] that it was even the warmest decade of the millennium (IPCC, 2001). Similar certainties exist that 1998 was the warmest year on record although 2003 might have topped this record with the heat wave in Europe where 21'000 people where claimed to have died as a result.

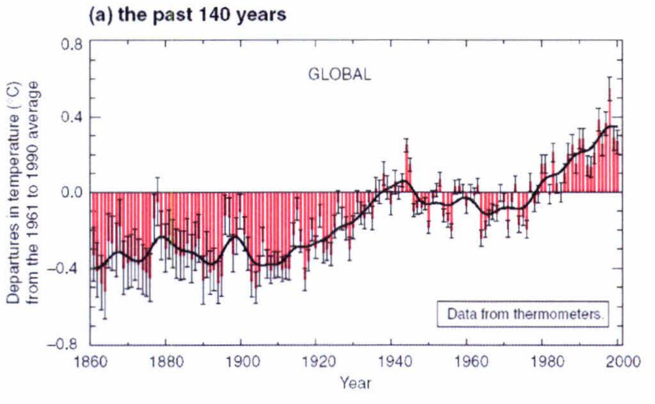


Figure 6: Variation of the Earth's temperature for the past 140 years. The bars are the measured annual mean temperatures and the thin lines mark the uncertainties. Source: (IPCC, 2001)

Temperatures can be evaluated back to the year 1000 by observing tree rings and historical records (Fig. 7). Ice cares can go back 750'000 years. Due to the sources of temperature data, the accuracy is lower than direct temperature measurements. The degree of uncertainty decreases significantly after the year 1600 when temperature recordings began. From the year 1000 AD the temperatures decreased until 1910. The two major temperature increases happened between 1910 and 1945 and then started again in 1976 and did not change further up till now (IPCC, 2001).

[5] Estimations of confidence: virtually certain: greater than 99% chance that a result is true; very likely: 90-99% chance; likely: 66-90% chance. (IPCC, 2001)

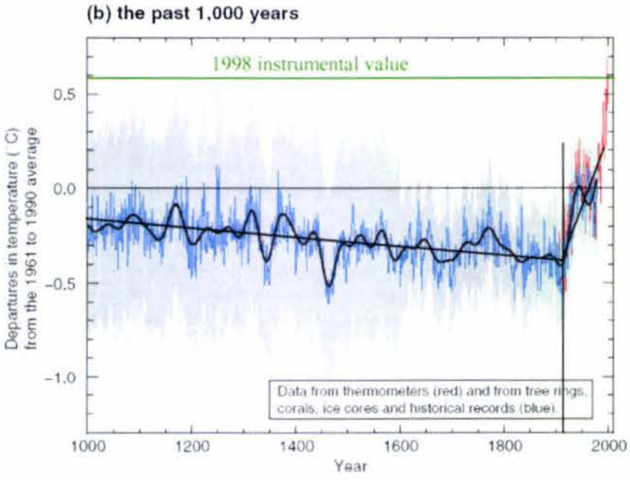


Figure 7: Variation of the Northern Hemisphere temperature for the past 1000 years. The blue scale shows calculated temperatures from sources such as tree rings, ice cores and historical records. The red scale shows thermometer measurements and the grey scale two standard errors. Source: (IPCC, 2001)

The global increase in the temperature does not occur evenly. The largest temperature increase occurred over the mid- and high latitudes of the continents in the Northern Hemisphere. During the same time the north-western North Atlantic and central North Pacific Ocean experienced a cooling. The North Atlantic trend recently reversed. These effects are due to the complex climate system with air and sea flows (IPCC, 2001).

The concentration of GHGs can be assessed back to the year 1000 (Fig. 8) and earlier using ice cores. Once the industrial revolution began in the 18th century, a very significant increase of GHGs occurred. Carbon dioxide has increased since then by over 30%, prior to that an increase could not be found. It is likely that the concentration of CO_2 in the air today has not been exceeded in the last 20 million years (IPCC, 2001).

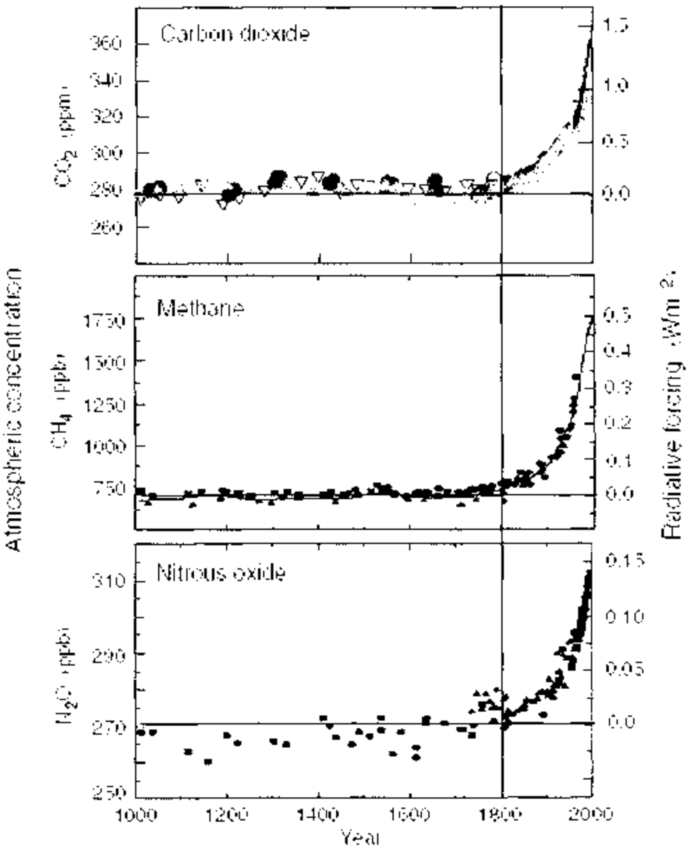


Figure 8: Indicators of the human influence on the global atmospheric concentrations of three well mixed from 1000 AD and since. Source: (IPCC, 2001)

The IPCC scientists also reported the radiative forcing which indicates the amount of heat energy absorbed by the GHGs (Fig. 8, right hand scale). The increasing amount of CO_2 in the atmosphere has had the largest radiative forcing followed by CH_4 then N_2O. In the past century natural factors, solar variation and volcanic eruption, have played a small role in radiative forcing and estimated to be negative. That means they would even work against the increasing warming (IPCC, 2001).

The atmosphere is a very complex system but the understanding of the influence of the various factors on it is increasing. Therefore climate models are also increasing in their accuracy. Those used by the IPCC to simulate temperature changes over the past 140 years compared the findings with temperature observations. A simulation was run first with additional natural forcings, solar and volcanic (Fig. 9a) then the same model was used excluding the natural forces and including the additional anthropogenic forcings of manmade GHGs (Fig. 9b), and then incorporating both (Fig. 9c)

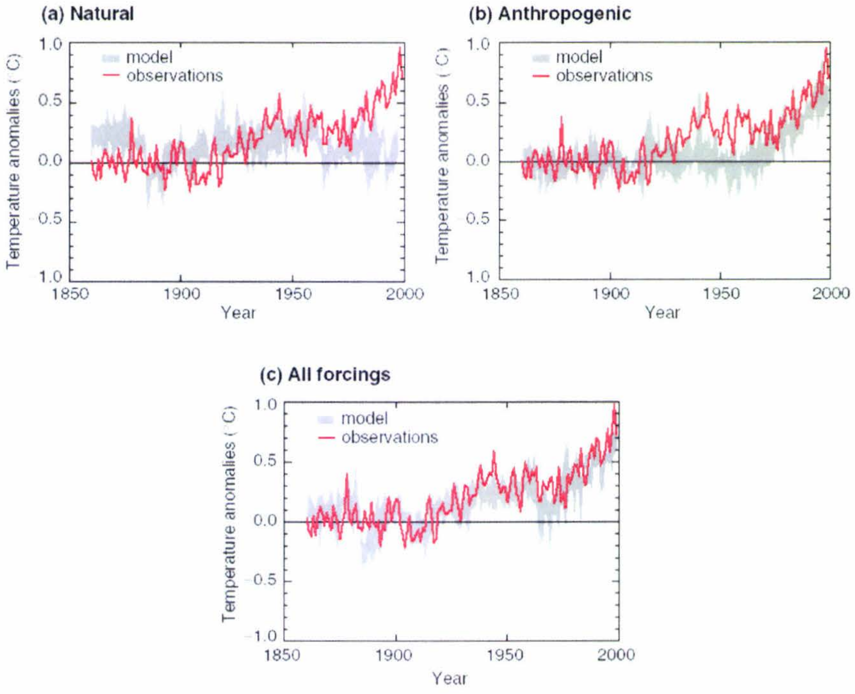


Figure 9: Simulated annual global mean surface temperatures as a result of natural radiative forcing, anthropogenic radiative forcing and both. Source: (IPCC, 2001)

Neither the simulations with natural forcing alone nor the simulation with anthropogenic forcing alone closely matched the observed temperature changes although the better showed an increase in the temperature in the last 50 years approximately. Taking both additional forcings, natural and anthropogenic, into account resulted in the best conformity with annual measurements (Fig. 9c). This indicates quite plausibly the influence of man-made emissions (IPCC, 2001).

The most interesting issue is how climate changes can affect us. Future scenarios have been used to predict future climate events with varying uncertainties such as how people, politics and industry will respond to climate change, whether they will be able to reduce GHGs. The IPCC report relies on observational and modelling studies and on the physical plausibility of future projections across all commonly-used scenarios based on expert judgement (Table 1).

Confidence in observed changes (latter half of the 20th century)	Changes in Phenomenon	Confidence in projected changes (during the 21st century)
Likely	**Higher maximum temperatures and more hot days over nearly all land areas**	Very likely
Very likely	**Higher minimum temperatures, fewer cold days and frost days over nearly all land areas**	Very likely
Very likely	**Reduced diurnal temperature range over most land areas**	Very likely
Likely , over many areas	**Increase of heat index[12] over land areas**	Very likely , over most areas
Likely , over many Northern Hemisphere mid- to high latitude land areas	**More intense precipitation events**	Very likely , over many areas
Likely , in a few areas	**Increased summer continental drying and associated risk of drought**	Likely , over most mid-latitude continental interiors. (Lack of consistent projections in other areas)
Not observed in the few analyses available	**Increase in tropical cyclone peak wind intensities[c]**	Likely , over some areas
Insufficient data for assessment	**Increase in tropical cyclone mean and peak precipitation intensities[c]**	Likely , over some areas

[c] Past and future changes in tropical cyclone location and frequency are uncertain.

[12] Heat index: A combination of temperature and humidity that measures effects on human comfort.

Table 1: Estimates of confidence in observed and projected changes in extreme weather and climate events. Source: (IPCC, 2001)

The predicted climate change effects which are estimated to be "likely" may have important impact on the environment, society and economy. In additional events such as extreme drought or floods can have devastating impacts on human lives, farming, tourism and much more. The cost of coping with these events can be severe (IPCC, 2001).

Swiss Re, a reinsurance company which is looking at the effects of climate changes described the public's behaviour on climate change: "Risk management view the public discussion on climate as a rabbit sitting paralysed in front of a snake – unaware that behind it a fox is poised to strike." (Brauner, 1998)

2.3. International conventions

Climate change is a global issue which can only be solved with international agreements such as the Kyoto Protocol. This global agreement aims to reduce GHG emissions from developed countries and economies in transition by at least 5% below the 1990 level between 2008 and 2012. At the time of writing the protocol is not in force. It requires the signature of at least 55 countries with 55% of the Annex I[6] parties' emissions to become binding. With the withdrawal from the protocol by the United States and Australia which are responsible for 36.1%, 2.1% respectively of the Annex I GHG emissions, the future of the protocol is uncertain. It depends now on the ratification by Russia, with 17.4% of total emissions to reach the required 55% of the Annex I parties' emissions.

As a paradox to the United States current energy policy, the second oil shock (1979-1986) showed that energy conservation and an increase in renewable energies can be profitable for the economy (Hawken, Lovins, & Lovins, 1999). During that time the United States increased renewable energy by 14% and saved 10% energy from fossil fuels. The total energy consumption shrank by 6%, but against all expectations the economy grew by 19%, the CO_2 emissions decreased by one-third and the cost savings in 1986 were about US$150 billion compared to the efficiency level of 1973. Carrying on with such improvements today, the United States would meet its Kyoto target on time and at a profit. The technologies have improved rapidly since 1986, which leads to the assumption that it should be even easier these days (Hawken, Lovins, & Lovins, 1999). Recent studies from the US department of Energy (DOE) found that a 13-17% of GHG emission reduction compared to the business as usual scenario (which estimate an increase of 30%) would be possible at no cost to the US economy. This could be achieved with an increase in research and development, voluntary energy efficient agreements, utilisation of more cogeneration and combined power heat units, a US domestic trade system and a greater role of renewable energy in the electricity sector (Dlugolecki, 2003).

A well know international environmental agreement with a similar scope was the Montreal agreement 1987 which came into force to reduce the increasing size of the ozone hole. The solution was to internationally prohibit ozone-depleting substances such as

[6] The UNFCCC distinguishes between three main groups. Annex I parties include industrialised countries. These are members of the OECD (Organisation for Economic Co-Operation and Development) in 1992 and countries with economies in transition (EIT). (Appendix 9.2)

chlorofluorocarbons (CFCs) which were found to be responsible to a large extent for the increase of the ozone hole (UNFCCC, 2003). This agreement was proved to be successful.

The first world climate conference (WCC) was launched in 1979 as a response to the first indications of human interferences with the climate and the growing public concern about environmental issues (Fig. 10). As an outcome of this conference the World Meteorological Organisation (WMO) and the United Nation Environment Program (UNEP) established nine years later the Intergovernmental Panel on Climate Change (IPCC) to assess scientific information about the issue. In 1990 the first assessment report confirmed the real threat of climate change. This intergovernmental panel produced the IPCC reports to assess the state of knowledge on climate change issues including the scientific basis, environmental and socio-economic impacts and responses strategies. So far the IPCC has published three comprehensive reports (IPCC, 1990; IPCC, 1995; IPCC, 2001) each written by around 400 international experts and reviewed by another 2500. Backed by the first IPCC study the second WCC responded by launching negotiations on a convention on climate change. The intergovernmental Negotiation Committee (INC) was founded.

After fifteen months of negotiations the United Nations Framework Convention on Climate Change (UNFCCC) was opened for signature at the Earth Summit 1992 in Rio de Janeiro. In eight years this convention grew to the most universally supported international agreement, with signatures of 188 nations and the European Community. The ultimate objective of the UNFCCC is: „to achieve stabilization of atmospheric concentration of greenhouse gases at levels that would prevent dangerous anthropogenic (human-induced) interference with the climate system...." (UNFCCC, 2003). Parties to the Convention started to meet annually at the Conference of Parties (COP) to promote and monitor the implementation of the UNFCCC and continue talks how to respond best to climate change (UNFCCC, 2003).

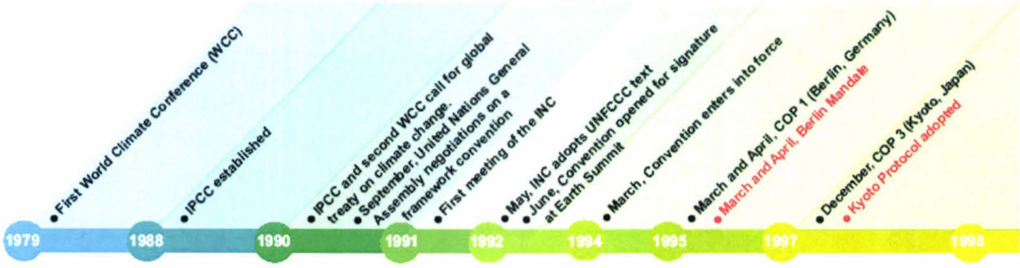


Figure 10: Timeline of the convention and the Protocol from 1979 until 1998.
Source: (UNFCCC, 2003)

After the third COP the parties negotiated a substantial extension to the UNFCCC in 1997. This was the birth of the Kyoto Protocol (KP) which outlined legally binding commitments. The KP sketched out basic rules but did not include any details as how to apply them. It also needs a formal process of signature and ratification until it can enter into force. The following COPs cemented the KP and developed a plan of action with an immense negotiation effort (Fig. 11) (UNFCCC, 2003).

Figure 11: Timeline of the convention and the Protocol from 1998 until 2002.
Source: (UNFCCC, 2003)

The Kyoto Protocol is a supplement of the UNFCCC, and strengthens it. Only parties of the UNFCCC can enter the KP. The ultimate objective is still the same as the UNFCCC first formulated. It shares the same institutions such as the secretariat and the scientific body for the IPCC. The key part of the KP are the legally binding emission targets for Annex I countries as a mean of at least 5% of the GHG emissions from the 1990 level by 2008 – 2012. The KP parties have national and international ways to meet the target. The primary way is to reduce the emissions and increase carbon sinks. Carbon sinks can be forests or other physical, geological sequestrations which take carbon out of the atmosphere. Additional to that, international KP mechanisms exist to give parties the possibilities to invest in cheaper emission reduction projects in other countries which are also part of emissions trading (Fig. 12).

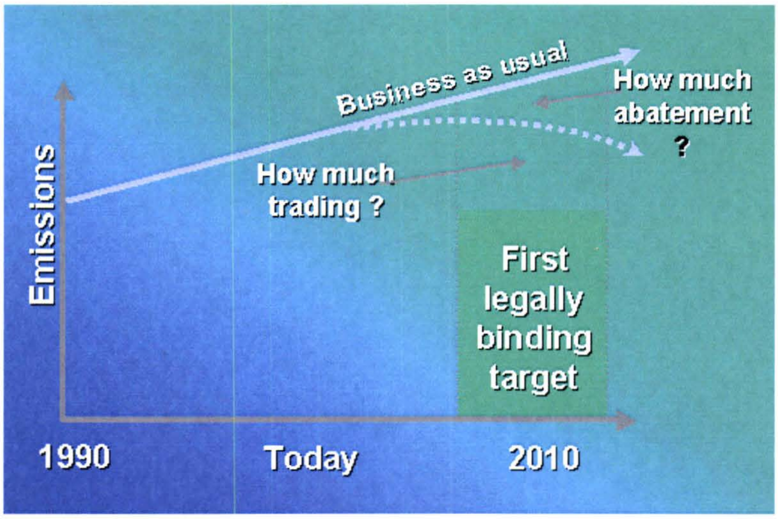


Figure 12: Kyoto Protocol target to reduce GHG emissions compared to business as usual. Source: (Ward, 2001)

Each nation has its individual emission target, which was an outcome of the COP3 in Kyoto in 1987 after intensive negotiations. The targets for each nation can be found in Appendix A.1.

The parties have several possibilities to reduce their GHG emissions:

- Increasing energy efficiency and renewable energy sources nationally.
- Removing GHG by carbon sinks in land use, land-use changes and forestry sector
- Joint implementation, the clean development mechanism (CDM) and emissions trading

Joint implementation (JI) allows Annex I parties to implement projects in other Annex I parties that reduce atmospheric carbon emissions or increase removals using sinks. The emission reduction units (ERUs) which are generated by the investing party can be used to reduce in the national emission targets. The JI projects need to be approved by all parties involved and are to refrain from using ERUs generated by nuclear facilities. ERUs gained from this project may be listed from the year 2000 but can only be issued after 2008 (UNFCCC, 2003).

The clean development mechanism (CDM) allows Annex I parties to invest in approved projects in developing countries (non-Annex I). The obtained certified emission reduction (CER) can be used to meet their own emission targets. The projects under the CDM must lead to real, measurable and long term emission reductions which would not occur without the project. These projects also need to have the approval of all parties involved (UNFCCC, 2003).

Emission trading enables parties to buy assigned amount units (AAUs) from other Annex I parties. This trade enables a reduction of emissions more easily and pursues the cheapest opportunities of reducing emissions or increasing removals wherever those opportunities exist. The parties are required to hold a minimum level of credits at all time to remove the possibilities of overselling (UNFCCC, 2003).

If the Kyoto Protocol comes into force and the UNFCCC is taken seriously international action will increase to meet the commitments. Nevertheless the level of 5% below the 1990 emission is not a guarantee for a stabilised climate. Scientists are fairly certain that the stabilisation of the GHG at this level will be insufficient, they rather discuss about 60% reduction by 2050. The GHG already emitted and which will be emitted until 2012 will stay in the atmosphere for a long time. If GHG emissions were cut down today to zero, global warming would still increase for at least the next 100 years (IPCC, 2003). Also future development such as the increasing economic development of China and other Asian countries would need further negotiations. The Kyoto Protocol would be at least a start to mitigate climate change.

The seriousness of urgent response to climate change is highlighted by Brauner (1998): "The answer given by climatologists leaves no doubt whatsoever. We do indeed have a problem and it is far more serious than would appear at first glance. The problem of climatic change is one of an experienced, methodical, political, economic, technical and cultural nature. Coping with it can not be delegated to individual institutions but has to be tackled by joint effort. And not just anytime but now."

2.4. New Zealand's situation

The Kyoto Protocol was ratified by the New Zealand government in 2002 and is the framework for national actions. "Think global, act local" is the idea behind this mechanism. If the Kyoto Protocol comes into force, New Zealand needs to decrease its GHG emissions back to the level of 1990 during the years 2008-2012. First the largest emitters of GHGs must be identified which are the agriculture and energy sector. Energy is used in various applications to a large extent by industry, transport and residential sectors using mainly electricity and fossil fuels. New Zealand already has 64% of its electricity from hydro-energy, which is renewable. Other renewable sources are increasing but wind and solar are still minor contributors which have the potential to replace or minimise fossil fuels.

New Zealand is especially dependent on a stable climate as its economy is heavily based on primary production, such as agriculture, forestry and fishery, and these sectors could be affected by extreme events caused by climate change. Floods or droughts are extremely negative influences for the entire agriculture sector, forest fires can destroy many hectares and changing ocean circumstances could influence the fishery significantly. The spread of exotic pest and diseases may increase as well. Currently 90% of New Zealand's population lives within 40km of the coast and the largest cities are all at the coastline. Rising sea levels and storms may increase the erosion of vulnerable beaches, increase the need for coastal protection and affect power and water supply. The participation in climate change convention is therefore important and will also increase the image of New Zealand's export products (New Zealand Climate Change Programme, 2001).

New Zealand's GHG emissions are mainly methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O) (Fig. 13). The trend of the total GHG emissions measured in CO_2 equivalents[7] since 1990 is still increasing.

[7] Carbon dioxide (CO_2) equivalents or global warming potential (GWP) are GHG compared to the climate change impact of carbon dioxide over 100 years. 1t methane is equivalent to 23 tonne of CO_2. 1t Nitrous Oxide (N_2O) is equivalent to 310 t of CO_2. (IPCC, 2001)

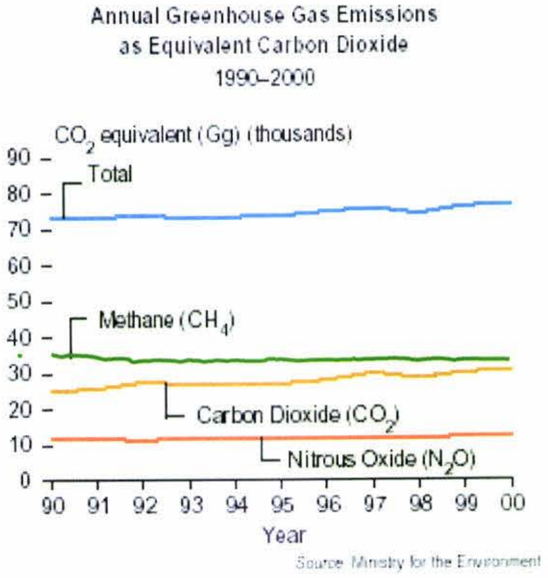


Figure 13: New Zealand's GHG emissions during the period 1990 until 2000. Source: (Statistics New Zealand, 2002)

The report "National Communication 2001" written under the UN Framework Convention on Climate Change found that New Zealand's emissions in 1999 were 54% from the agriculture sector (mainly methane and nitrogen oxides), 38% from energy (including transportation fuels), 4% from industrial processes and 4% from waste (Fig. 14) (MfE, 2002a). The proportions have changed since 1990 as the agriculture sector was able to reduce its emissions by reducing stock number, whereas the energy sector has increased its emissions.

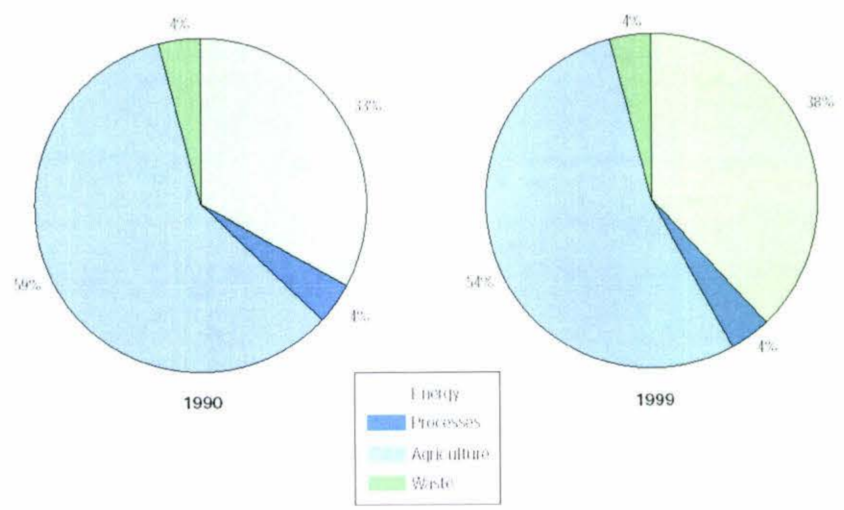


Figure 14: GHG emissions in New Zealand by sector. Source: (MfE, 2002a)

During the period 1990 until 2000, the energy sector increased its emissions by 23.3% (Fig. 15). During the same time industrial processes only increased by 2.5% and the agriculture and waste sector decreased their emissions by 3.1% and 17.7% respectively (MfE, 2002a).

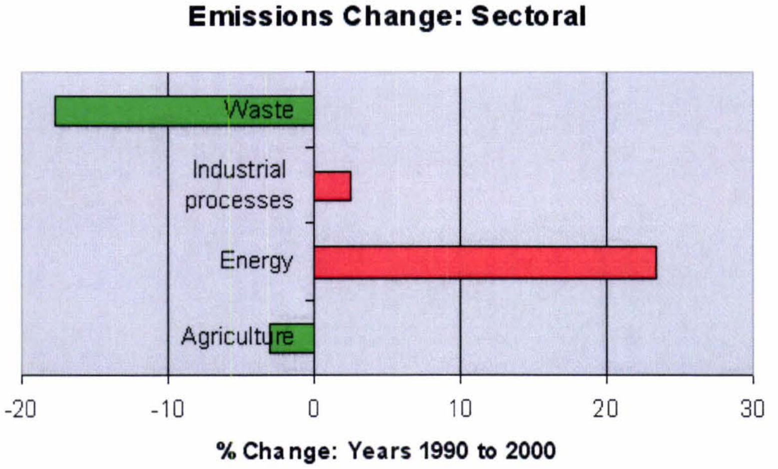


Figure 15: Changes of GHG emissions in New Zealand from 1990 to 2000 by sector. Source: (GPCNZ, 2003)

The energy sector needs drastic action to decrease the emissions back to the level of 1990 being greatest in domestic transport. The increase of around 27% in the energy usage between 1994 and 2000 was also significant (Fig. 16). Domestic transport energy comes exclusively from fossil fuels, such as diesel and petrol. To convert these fuels into useful energy they need to be burned which results in large amounts of CO_2 emissions. The second largest energy consumer is the industrial sector, then the residential, commercial and agriculture sector (GPCNZ, 2003).

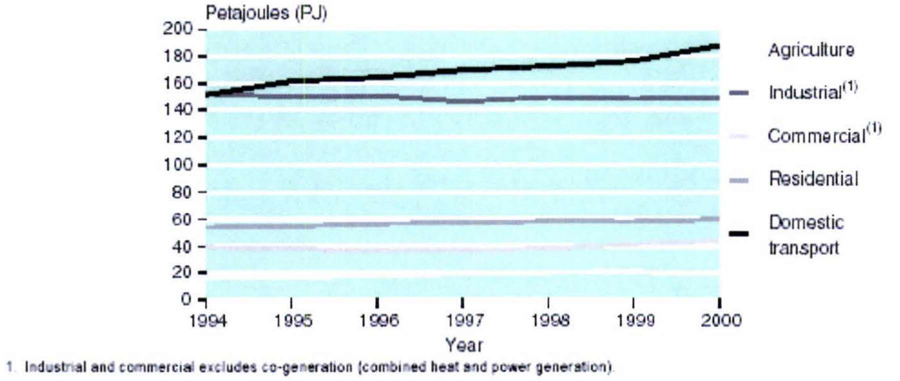


Figure 16: New Zealand's total consumer energy use by sector 1994-2000. Source: (Statistics New Zealand, 2002)

The GHGs from the energy sector of main concern is mainly carbon dioxide (CO_2) (Fig. 17). Therefore action in this sector needs to be focused on reducing CO_2 emissions.

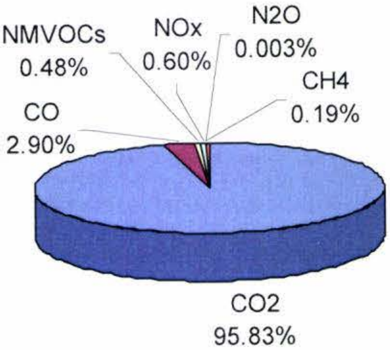


Figure 17: Energy sector GHG emissions 1999 measured in Global Warming Potential (GWP). Source data: (MfE, 2002a)

The energy sector CO_2 emissions increases have been identified as one of the largest challenges to meet the Kyoto Protocol. The energy sector consists of seven sub-sectors (Fig. 18). The largest emitter is the domestic transport sector which increased CO_2 emissions significantly by 24.5% between 1990 and 2001. The category "other transformation" compromises emissions from fuels burnt by energy-producing industries, petroleum refining, oil and gas extraction and processing, and synthetic petroleum production. This category has decreased its emissions by 60% since 1990 mainly due to the cessation of synthetic petrol production by Methanex New Zealand Ltd in 1997. However energy required by industry increased by 31.7% between 1990 and 2001 mostly as a result of increasing production. Emissions from the "other sector" which contains the commercial, residential, agriculture and forestry subsectors decreased by 1.7%. The emissions of the residential sector account for 17% of this sector. The category "fugitive emissions" describes emissions which are not from the combustion of fuel to produce useful heat rather from processing and flaring/venting of gas at oil and gas fields, and heat use from geothermal fields. The emissions of thermal electricity generation increased 83.3% between 1990 and 2001. Although 56% of the electricity was produced by hydro stations, the amount of thermal electricity generated was significant, especially when looking at the emissions (MED, 2002b).

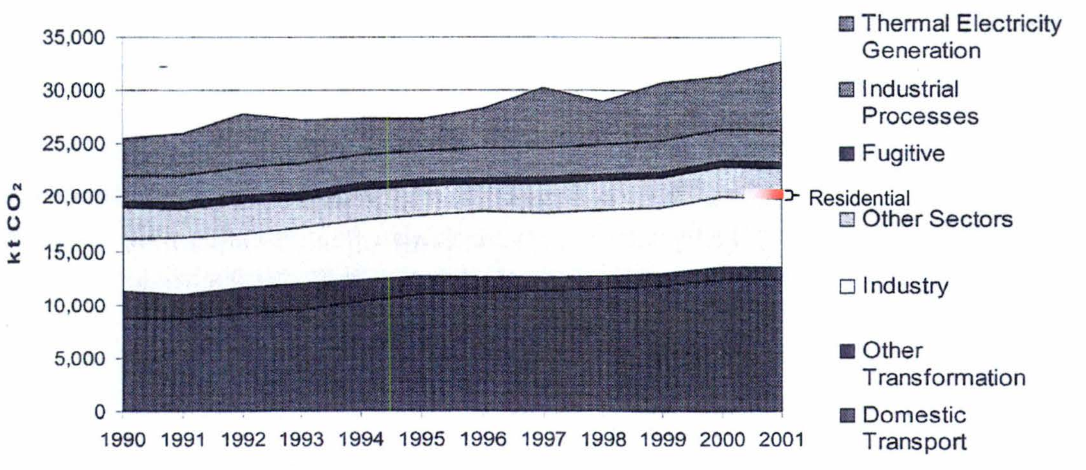


Figure 18: Gross CO_2 emissions of the New Zealand energy sector 1990-2001. Source: (MED, 2002b)

2.5. Environmental costs

"Climate change poses a major risk to the global economy." (UNEP Finance Initiatives, 2003). The losses due to the increasing extreme events are obviously high. All these costs are carried by tax payers and national economies. Future economic development needs to be sustainable. This can be achieved more quickly by harnessing market mechanisms with supporting policies and measures. Therefore the financial sector has a key role to delivering market solutions to combat climate change (UNEP Finance Initiatives, 2003).

"The Kyoto Protocol, under which many industrialised nations have pledged to curb their emissions of GHGs by 2012, is an important step but does not go nearly far enough." (UNEP Finance Initiatives, 2003)

Capitalism is driven by economic growth and various cost factors. Up to now environmental damage costs caused by emitting energy sources have not been included in the purchasing price of goods and services. Also in capitalism, politic is an important factor of the pricing. A way of including some of the environmental cost into the energy price is a carbon tax (Section 5.4).

The costs caused by environmental damages are covered by some insurance companies for special events such as floods and fires. These costs are summarised by the international reinsurance company Swiss Re and presented in this section. These include studies of the economic losses caused by environmental damage. Other cost of environmental damage were not assessed in this study such as the governmental catastrophe institution such as the fire brigades, catastrophe management and military efforts.

World wide economic losses due to natural catastrophes are doubling every ten years. These losses have reached almost US$ 1trillion over the last 15 years. Annual costs of economic losses are estimated to come close to US$ 150 billion in the next decade (Dlugolecki, 2003). Around 30% of the total economic losses during 1970-2002 were due to floods and similar amounts occurred by storms and earthquakes. Only a fraction of the economic losses appear in the insurance statistics because not every industry and household is insured for these losses and the statistic only shows the insured losses (Swiss Re, 2003).

Swiss Re showed (Swiss Re, 2003) the insured losses from the cost of natural disaster are becoming dominant over man-made catastrophes (Fig. 19). The insured losses peaked in 2001 due to the terrorist attacks on the World Trade Centre and Pentagon in the USA which resulted in the war against terror. In all the other years the proportion of the natural disasters, likely to be caused to a large extent by climate change, was larger. If the same amount of awareness and money spent for the war against terror would be paid into actions to solve the climate change problem, sustainable development would increase drastically and as a result the danger of climate change could be minimised.

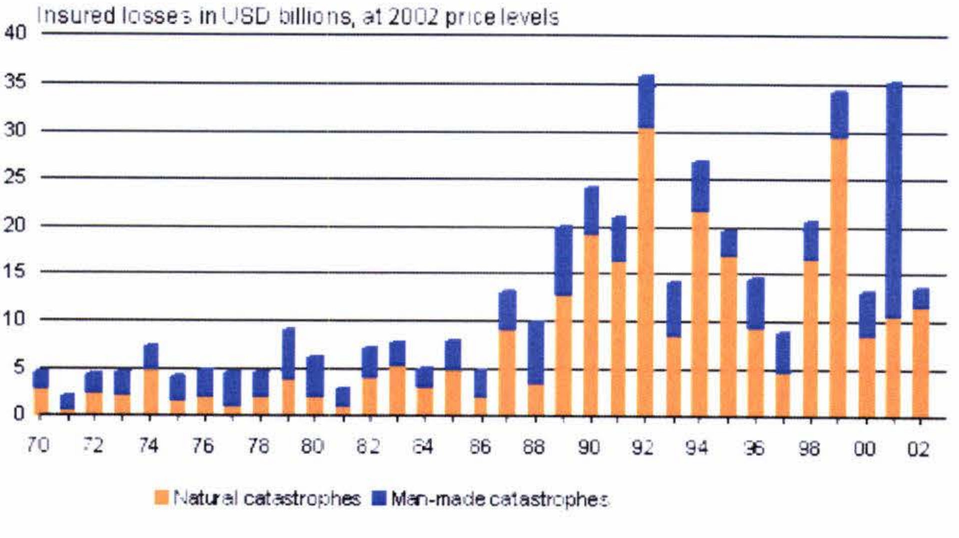


Figure 19: Insured losses in US$ billions 1970 – 2002. Source: (Swiss Re, 2003)

Insurers must expect an increasing number of extreme weather events as a result of climate change. In 2002 global losses from natural catastrophes were US$11.4 billion and more than 11,000 people died 4000 because of floods. In 1999 these losses accounted for around US$29 billion. Marginal events in 1999 were the winter storm Lothar over western Europe (80 victims[8] and insurance losses of US$ 6.2 billion), Typhoon Bart in Japan (26 victims and insurance losses of US$ 4.4 billion), winter storm Martin in France, Spain and Switzerland (45 victims and insurance losses of US$ 2.6 billion), and Hurricane Floyd with heavy downpours and floods in the US and Bahamas (70 victims and insurance losses of US$2.5 billion). Comparing to these natural catastrophes the terrorist attack on the World Trade Centre, Pentagon and other buildings caused insurance costs of US$19 billion and 3000 victims (Swiss Re, 2003).

[8] Dead and missings

Storms caused the major part of insured losses in 2002 (Fig. 20), in second place were floods. For a long time floods played a small role in the insurance industry but a new reality is dawning on insurers as floods now appear to play an increasing role. Every continent has been affected by floods over the past few years (Swiss Re, 2003).

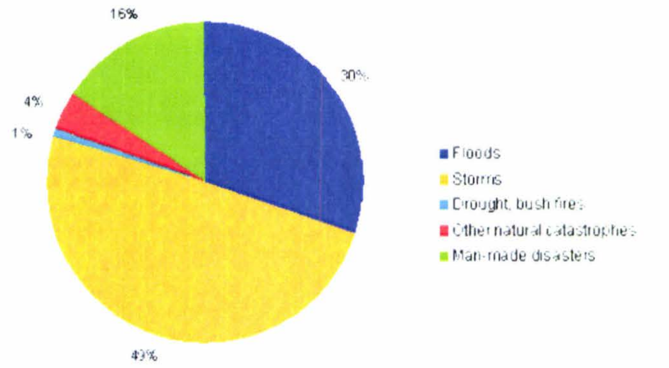


Figure 20: Natural catastrophes by category 2002. Source: (Swiss Re, 2003)

In 1995, Switzerland's National Research Programme 31 (NFP 31) estimated the economic losses due to climate change. The assumption was an increase in the temperature of 2°C during the next 50 years. The result of the study showed economic losses of US$ 1.9-2.6 billion per year (calculated at 1995 prices and 1.00 Swiss Francs = US$ 0.81) which was almost 1% of the 1995 GDP. Also losses occurred from reduced winter tourism due to snow shortages and increased flood damage. Losses of intangible assets, cultural heritage and scenery were not included in the study. Individual losses could also be high as people would lose their houses or even their lives as a result of natural disasters. Some properties can lose their value overnight when geologists find a high risk of avalanches, mudflows or floods caused by climate change (Brauner, 1998). Best guesses based on the IPCC indicate annual losses in western Europe will be 1.6% to 1.4% of the GDP (IPCC, 2003).

2.6. Household finances

Decisions on energy costs by politicians and industries influence the cost of housing and transport. All consumers are interested in saving money without decreasing the service they get. Only a few expect to pay more due to their attitudes towards environmental issues. New Zealander households paid about \$388 (BRANZ, 2002) per month for energy in houses, and \$484 for transportation (Statistics New Zealand, 2002). The housing energy and transportation cost accounted for 21% of the household income average being \$4132 per month. There are several ways of reducing this expenditure which are supported with the model developed in this study.

Household expenditure on goods and services, in which energy is included, increased between 1988 and 2001 by 50% and transport expenditure by 42% (Fig. 21). To make a sound comparison these increases would need to be assessed more specifically by taking the increasing number of households into account. The statistic shows the total expenditure of households was \$ 10 billion on transport and \$ 8.5 billion on household goods and services.

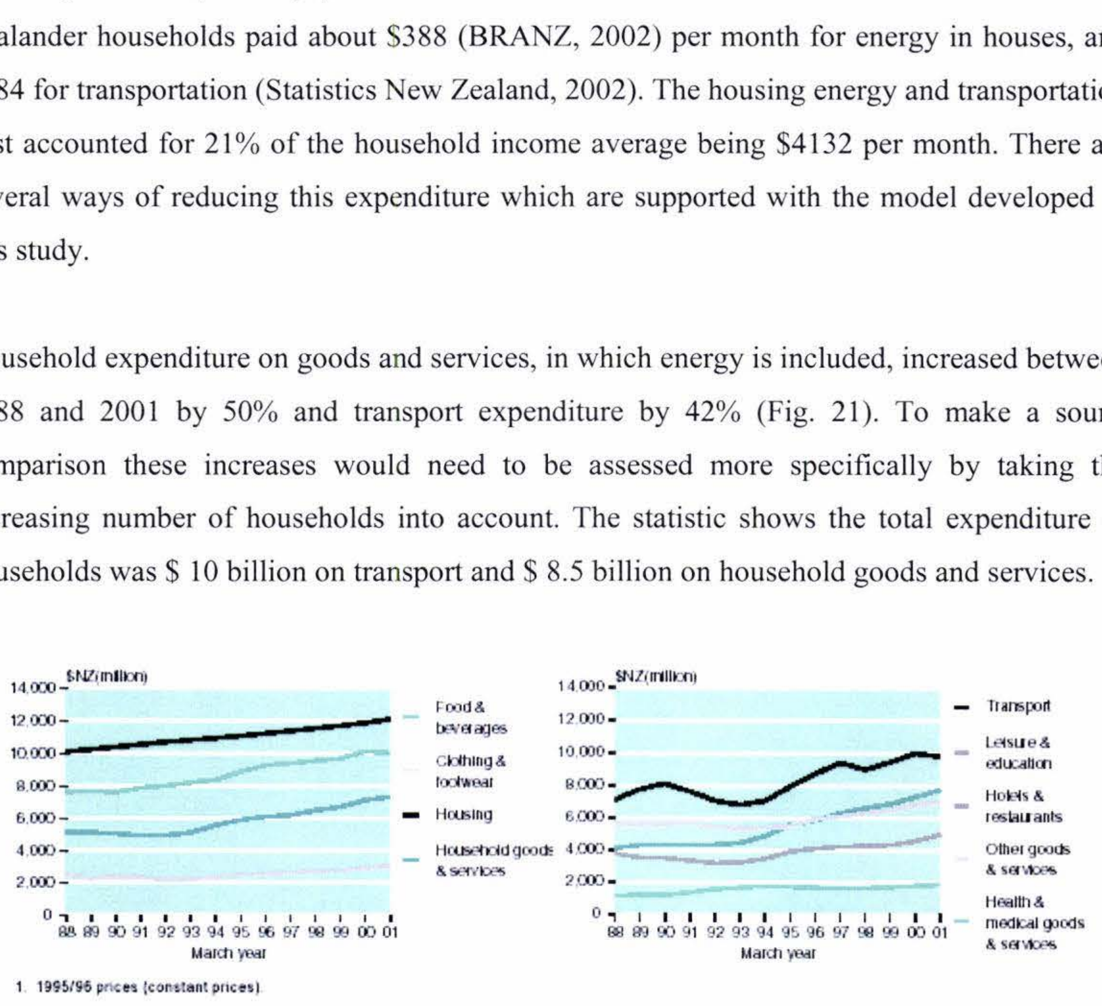


Figure 21: Real household consumption expenditure 1988-2001 in New Zealand.

Source: (Statistics New Zealand, 2002)

2.7. Environmental psychology and behavioural changes

Environmental psychology is used to get a person's attention, to evaluate their attitudes and to change their behaviour. There are possibilities of saving energy without spending money just by changing behaviour. Changes like having a shower instead of a bath, using the bike instead of the car do not cost a dollar unless you have to install a shower or buy a bike. Why and how people would change their behaviour is covered in environmental psychology. Some behavioural changes require capital investments, such as buying a solar panel or buying new energy efficient appliances. The psychological part of this study is described in detail in chapter 4.

2.8. Renewable energies and improved technologies

There are two ways of decreasing emissions without decreasing the quality of the energy service received and the resulting quality of life; substituting non-renewable (fossil) energy sources with renewable energy and using more efficient technologies. Cost effective renewable energy sources depend on the existing technology commercially available. To achieve a good result in an acceptable time frame the emission problem needs to be attacked technically from both sides. The amount of fossil energy can be decreased by replacing them gradually with renewable energies and by reducing demand with more energy efficient technologies.

2.8.1. Renewable energies

"There can be little argument that the technical potential from utilising the renewable energy sources which are abundant in New Zealand is high and could easily supply all current and anticipated future demand for heat, electricity, and transport fuels." (Sims, 2001)

Renewable energy sources are sustainable. Common renewable energy sources are biomass, wind, solar, hydro, geothermal, and marine energy (waves, tides, ocean currents). They have zero or near zero GHG emissions and are inexhaustible, not like fossil fuels. At the present renewables still tend to be more expensive than fossil fuels, although the costs are declining through rapid development (Fig. 22). This trend should increase if government policies consist of supporting research to give a greater projected learning curve (Sims, 2003).

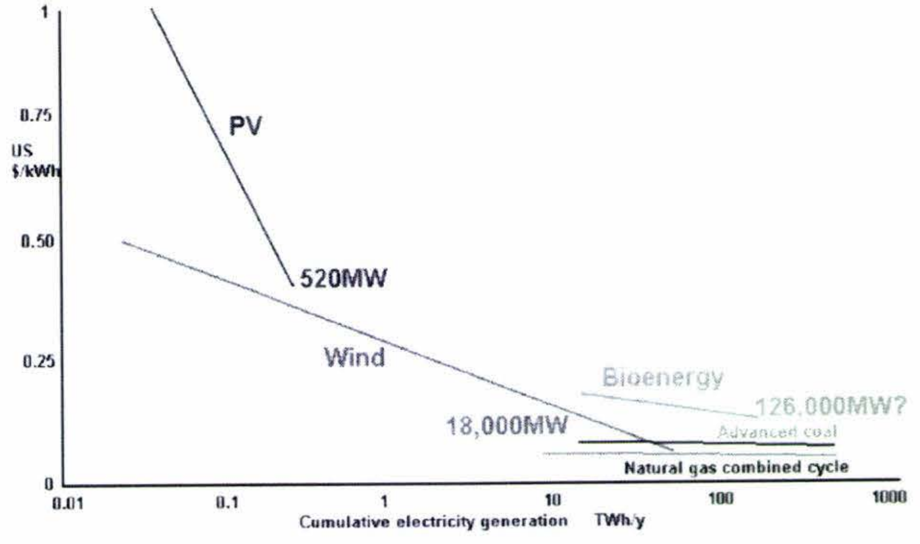


Figure 22: Generation cost reductions from wind, photovoltaic (PV) and bioenergy projects from the mid 1980s till 2000. Source: (Sims, 2003)

In 2002, New Zealand's government published its renewable energy target as a component of the National Energy Efficiency and Conservation Strategy (NEECS). In 2000, renewable energies in New Zealand produced 133.5 PJ of energy. The total primary energy consumption was around 800 PJ. The target set by the government is to increase the share of renewable energy by 30PJ between 2000 and 2012 (MfE, 2002b; MfE, 2002a). To give an idea of the target size, 1PJ is about the amount of the annual energy consumed by the city of Nelson with a population of 43,500. The target should be achieved with investments in the market place by industries. They are supported by the government Climate Change policy package and the renewable energy program. In 2003 the renewable energy program cost NZ$0.5 million (MfE, 2002b). This governmental investment will increase to NZ$4-7 million in 2006 (MfE, 2002b). The target will also be supported by an emission charge up to NZ$25/tonne CO_2 on fossil fuel consumption. This charge provides an incentive for energy efficiency and renewable energy sources. The price of using fossil fuels will rise as a result. Besides other projects the NEECS focuses on a target of 10,000 solar hot water installations in households per year (MfE, 2002b).

2.8.2. Improved technologies

The Energy Efficiency and Conservation Authority (EECA) is responsible for monitoring and supporting the energy efficiency and renewable energy targets in the National Energy Efficiency and Conservation Strategy (NEECS). The specific target in energy efficiency is an improvement of 20% by 2012. The prediction of New Zealand's energy use under business as usual is expected to increase by 20% in that period. A lot of things can be done in the residential and transport sector to achieve this target and also in the industrial and commercial sectors which are not of relevance for this study.

A way of achieving better energy efficiency is to put policies in place. For example New Zealand has Minimum Energy Performance Standards (MEPS) which must be met if a selected product is sold in the country. The coverage of products to date includes:

- domestic electric storage water heaters
- domestic refrigerators and freezers
- fluorescent lamps
- fluorescent lamp ballasts
- packaged air conditioners
- three-phase cage induction motors

The energy performance requirements for these products are incorporated into national or international standards (EECA, 2003a). Their aim is to protect consumers from the ongoing energy cost burden.

The responsibility for some appliances is by the landlord such as the hot water heater but the energy bill has to be paid by the tenants. The same problem exists with insulation of the rented houses and apartments. The landlord has the responsibility for the building such as retrofitting with better insulation but the tenants pay the heating energy bill. With this situation minimum requirements, such as the MEPS for appliances and the Building Standard for insulation during construction, are essential to protect the tenant from increasing power bills.

Another instrument are energy labels which give the consumer easy information of the appliance performance. This helps consumers to buy appliances with lower running costs. The

Energy Labels are specified by the New Zealand/Australian Standards. They need to go through a specific test procedure from which the star label can be calculated. The more stars an appliance has the better its efficiency (MED, 2003b). The range of the stars is from zero up to six. Additional to the stars, the expected annual energy consumption is also required on the label. An easy estimation of the annual running cost is calculated by multiplying the expected annual energy consumption which is given by 15cents/kWh by the consumption. For example an annual energy consumption of 600kWh costs approximately NZ$90 a year with an electricity price of 15cents/kWh (average price in 2001 was 14cent/kWh, (MED, 2003b)). So far, energy label requirements are included for the following appliances:

- fridges and freezers
- washing machines and dryers
- air conditioners and heat pumps
- dishwashers

The potential of these labels is astonishing. According to EECA, half a star of better performance of appliances nation wide would save NZ$ 9 million on annual energy bills and reduce GHG emissions by 38,000 tonne of CO_2! This is equal to taking 12,000 cars off the road. No-one would have a reduction of any service and the power bill decrease (EECA, 2003a).

The potential of road transport efficiency is considerable. The average fuel consumption of New Zealand car in 1997 was 9.65l/100km (Becken, 2002). The Energywise Rally was a race around New Zealand's North Island where the winner was the one who drove the distance with the lowest fuel consumption compared to the volume of the car. The aim of the rally was to educate the public about fuel efficiency and ecological driving styles. The winner was a standard model Peugeot 406 which was driven over 1,500 km from Auckland to Wellington and back with an average fuel consumption of 4.2 l/100km (Appendix A.27). This is less then half as the average in 1997. Cars had also been developed before 1997 which use only 1.65l/100km (Weizsäcker et al., 1997). If every New Zealander purchased one of these energy efficient cars, fuel consumption would be almost 83% lower.

New Zealand's NEECS focuses on a 2PJ reduction target for the transport sector which is highly dependent on fossil fuels (EECA, 2003a). The energy consumption of the domestic transport sector in 2001 was almost 190PJ. This number increased since 1994 by approximately 26% (Statistics New Zealand, 2002). The reduction target of the transport sector energy which only be achieved by the government setting appropriate technical standards for vehicles, fuels and distribution infrastructure; setting an appropriate fiscal regime for vehicles and fuels; promoting research and demonstration of better technology; and working proactively with the transport and energy industries (EECA, 2003a).

The potential for energy efficiency improvements is good. The government has made advances such as the MEPS and the required energy labels. Consumers often do not understand much about energy. The labels show them with little calculation the approximate cost saving potential. Cars should also such labels to make buyers more aware of the expected fuel running costs.

2.9. Energy Efficiency and Energy Conservation

"Energy efficiency is the reduction in consumption of energy for current operations (e.g., do it more efficiently). Energy conservation is the avoidance of wasteful energy use and the reduction in demand for energy related services (e.g., if you don't need it, turn it off)." (Standards Australia & New Zealand, 2000)

Energy efficiency and conservation are normally used in parallel when an energy audit is performed. The energy saving potential for the scenario "fast implementation of efficiency", in New Zealand is expected to be NZ$ 75 billion by 2020 at a cost of NZ$12 billion according to a study done by Energy Solutions (Bishop, 2001). The "fast" implementation scenario assumes that in ten years time most new infrastructure was being installed at optimally cost effective levels of energy efficiency. Additionally it is expected that in twenty years most cost-effective home retrofits will have been done. The investments are expected from government and private sector, whereby some evidence exists that private sector investments in energy efficiency closely follow government investments. The CO_2 reduction of the scenarios assessed in the study are significant and will almost allow New Zealand to meet its Kyoto Protocol target without counting any effects from forestry or renewable energy supply (Bishop, 2001). With such a saving potential the climate change problem can be lowered with money savings and economical improvements. Thus everyone can win.

The Centre for Advanced Engineering (CAE) was commissioned by EECA to examine the possible energy use trend between 2000 and 2010 (CAE, 2001). Three scenarios were presented: business as usual, "gradual" introduction and "accelerated" introduction of measures. The baseline scenario with business as usual predicts an increase of the total consumer energy usage of 15% from 460PJ to 530PJ by 2010. By applying further energy efficiency measure the total saving potential could be 64PJ. This can be achieved with normal industry initiatives and modest improvements. Three sectors were analysed: transport, communities & households and industrial & commercial. The saving potential would offset the predicted increase and would stabilise the national energy use at around 460PJ. If there were some dramatic energy efficiency measures with targeted initiatives to realise the fullest possible potential applied the energy use could even be lowered by 129PJ to a level below 400PJ. The 1990 level was at 320PJ (CAE, 2001).

The targeted actions in the transport sector were:

- traffic demand management
- replacement by advanced vehicle technology and rational downsizing
- retrofits to the present vehicle fleet, improved maintenance and driving habits
- promote public transport, cycle, walk, pooling, teleworking
- changes to urban form and transport systems

These measures can reduce the energy use of the transport sector by 6.8% to 13.7%. This would result in a reduction of 19.9PJ to 35.2PJ compared to an increase with business as usual of 25PJ. The transport sector would have considerable opportunities for improved technical efficiency where an essential role of the government is required (CAE, 2001).

The communities and household sector has a large number of small units with energy saving potential. The actions considered for this study were:

- introduction of new building design standards
- improving building services & appliances
- retrofitting and improvements to the present housing stock
- urban design from changes

With these actions savings of 17.5% to 36.5% were expected. The reduction in energy consumption would be 18.6PJ to 38.5PJ. Business as usual would result in an increase of 17PJ. The largest improvement of 10%-20% is expected by introducing new building design standards. Improved building and appliances energy efficiency standards and labelling are expected to help reduce household energy demand.

The identified potential of energy efficiency and conservation is immense. Starting with such projects as the study presented here might be a first start to gain this potential with an economic benefit.

2.10. Energy Audit

The model developed in this study (Section 3) is basically an energy audit which also shows enegy improvement possibilities. To identify energy improvement potential an energy audit has to be made as the first step. "An energy audit should answer the following four questions: How much energy of each type is being used? How much does the energy cost? What is the energy being used for? What opportunities exist for reducing energy use or cost?" (White, 2002)

An energy audit is normally the first step to an effective energy cost control plan (Turner, 1997). After a first energy audit customers are often able to save 10-20% on their utility bill with no-cost or very low cost operational changes. Investments with payback times up to two years can save another 20-30%. The audit consists of a detailed assessment of "how facilities use energy, what the facility pays for that energy, and finally, a recommended program for changes in operating practices or energy-consuming equipment that will cost-effectively save dollars on energy bills." (Turner, 1997)

The New Zealand Standard distinguishes between three levels of audits (Standards Australia & New Zealand, 2000). Level 1 is the overview, which gives rough idea of savings and costs. The accuracy is generally ±40%. A Level 2 audit identifies energy sources, supplied energy amounts and what the energy is used for. Costs and savings are also analysed with an expected accuracy of ±20%. The most detailed and precise analysis is a level 3 audit, which includes monitoring. A level 3 audit can include the entire site or a specific process. The accuracy is within +10% for costs and –10% for benefits (Standards Australia & New Zealand, 2000). This study aims at a level 2 audit.

The energy audit is the second step of an energy management program, which consists of four steps (White, 2002):

- develop an energy management policy
- undertake an energy audit and analysis
- formulating an action plan
- evaluate and maintain the energy management programme

An energy audit and analysis needs to be organised and has to follow a certain structure. The Audit is an examination which needs to be repeated periodically to see the changes made since the last audit. One possible structure is as follows (White, 2002):

Phase 1: Collection of Energy and Site Data

The first phase typically includes data gathering such as electricity and gas bill. The data should include at least 12 month record, due to the seasonal differences. It is important to identify the current contract, to understand where savings are possible. Some financial savings are possible, for example by using the cheaper night rate electricity tariffs (Turner, 1997).

To evaluate the heating and cooling options some climate information is also required. This data can be gathered from national climate institutions. In New Zealand this institution is NIWA (NIWA, 2002).

A list of the relevant equipment should be produced to prepare the on-site audit. The Building Research Association of New Zealand (BRANZ) is doing a study called the Household Energy End-use Project (HEEP) (BRANZ, 2002) to obtain more knowledge about real domestic energy use in New Zealand. A comparable model developed in the UK called BREDEM was made to analyse the impact of mandated energy efficiency appliances. Between 1970 and 1996 the model analysed energy savings close to 37%, 20% due to improved insulation and the remaining 17% by improving heating efficiency. The average indoor temperature increased by 4°C to 17°C and the amount of central space heating by 53% to 87% (BRANZ, 2002). The on-site audit in this study will be done by the user guided by PREM with the background of the HEEP study.

The HEEP-study started to monitor 100 households 6 years ago (BRANZ, 2002). It found an average energy consumption of electricity, natural gas and LPG of 875 kWh/month in measured cities (Hamilton, Wellington and Auckland). If the entire consumption was to be from electricity, which is the case in some households (72% of the privately occupied dwellings used electricity in 2001), taken an average electricity price of 11.86 cents/kWh (Ministry of Commerce, Energy Data File, January 1999), an average cost of NZ$ 103.8 per month would be the result. The New Zealand total household energy consumption is 30% lower than Australia, close to 50% of the UK and around 60% lower than the USA. This is mainly, because of the low level of space heating. New Zealand's winter evening indoor average temperature was found to be a low 17.3°C (BRANZ, 2002).

Phase 2: The on-site Energy Audit

The purpose of this phase is to identify operation and maintenance potential, and gaps in the metering and reporting. This on-site inspection for a domestic house is a so-called "walk through audit". It examines the different sectors, building, appliances, and transport and travel. The building audit analyses the heating needs for a specific building, outdoor temperature and the required indoor temperature. The efficiency of the heater itself will be covered under the appliance sector.

i: The building: This is the most challenging sector to get accurate figures. BRANZ developed a program called Annual Loss Factor (ALF3, 2000), which makes a detailed assessment of a building. The program needs inputs about the building, such as roof, wall and floor construction. It shows the user the result as, energy loss in units and percentage. The user can see where he/she is losing the biggest amount of energy due to window type, wall, ceiling and floor insulation or air leakage. It calculates the required heating energy and makes a comparison to a standard house, in the meaning of heat losses, modification costs and energy costs. ALF calculates heat losses, due to conduction and infiltration.

ii: The list of appliances prepared in step one is used. The exact model of the appliance needs to be identified and the running time has to be assessed. Verbal interviews with the user can provide more exact figures or a certain time span can be examined by monitoring the usage with power meters or just a daily report can be prepared by the user.

iii:: The assessment of the transport & travel sector is similar to the appliance sector. After knowing the model, such as car model, ferry or aeroplane, the running time or in this case the travelled kilometres need to be examined. For the car this can be done quite easily by writing down the kilometres on the odometer with the date. This will be repeated after a certain time. The difference can be taken and the user knows the driven kilometres per time.

Phase 3: Analyse Historical and Energy Audit Data

The analysis aims to show where the energy is going, how much of it and how much it costs. To do this the data need to be normalised, that means they need to be broken down to the same units. Possible time spans for example are a month or a year. It depends if the seasonal variations need to be assessed. For a comparison the energy consumption of the different services which were discussed in phase 1 and 2 needs to be transformed in a common energy unit which is usually the unit Joule. This step also includes a general analysis if optional energy sources may be an option. The analysed data need to be put into the corresponding sector in order to identify the area with the largest saving potential. In industrial applications it is also important to calculate an energy efficiecy index, to compare processes with standard values.

Phase 4: Determine and Quantify Energy and cost saving options

After the analysis the energy and cost saving options need to be identified. These options are also known as energy conservation opportunities (ECO) (Turner, 1997). The potential of the options are important. This ECO can be followed by changing the operation time (e.g., just running the washing machine at night, with the night tariff), replacing appliances with more efficient ones, retrofits of the building, changing behaviours or changing the energy supply (e.g., changing retailer, renewable energy sources). The options need to be quantified and the financial part has to be analysed. A ranking can be done to know where to start for significant energy saving and economically profitable results.

Phase 5: Detailed investigation and Analysis

If there is a large difference between the assessed power usage from bills and the power usage from the dwelling or if some other gaps are found, further investigation is required. This can be done by monitoring certain parameters.

A difference between the historical data and the used energy consumption can only be made if all entities can be assessed by monitoring the energy consumption technically or by calculating it with data which specifies the entity.

Phase 6: Report

Every inspection ends with a report. This is a crucial step, because this is the interface with the customer, in the residential sector the householders and in the industry the management. The report includes the energy usage and costs, saving options and a clear action plan.

This energy audit is the background of the model developed in this study. The final report leads to an action plan according to the four steps of the energy management program. It is also important to evaluate and maintain the energy management program in order to observe the progress. The management program is mainly developed for energy management programs of companies but the same procedure can be used for a household energy management program with some adjustments.

2.11. Energy software

A lot of computer programs exist for energy analysis of personal use. It is possible to characterise them by four categories: footprint assesment, climate change calculators (or emission calculators), domestic energy use advisors and building energy models. These different models have different purposes.

- A footprint provides information to make people aware of their impact on the environment and normally includes a lot of sectors, such as transport, housing and consumerism. They aim to find the threshold of sustainability. The result is typically shown in a special unit like numbers of earths to support the need of the specific user.
- Climate change calculators aim to show the user how much greenhouse gases somebody produces with their current lifestyle. The footprints and the climate change calculators often include estimations in order to keep it user-friendly and to overview many sectors such as the energy, waste, transport and consumerism sectors.
- Energy advisors aim to advise people on their energy use and improvements with more accurate information.
- Building models are usually very complex. They assess the energy losses and sometimes the required heating of the building. They need a good understanding of the building characteristics. The accuracy is usually very high, due to the amount of research, which is done to develop and test these models and the amount of input information required.

2.11.1. Footprints

Footprints have been developed to make people aware of their impact on the environment and to see how sustainable they can act. Most calculators provide the final report in terms of how many earths it requires to sustainably provide the needs in the case if everybody in the world would have the prompted lifestyle. The purpose of the footprint is to measure the land required to support humanity's demand on energy and resources. It is a snapshot and not a dynamic process due to the changing circumstances such as the land bio productivity (Rees & Wackernagel, 1996).

"An ecological footprint can be viewed as the bio productive area (land and sea) that would be required to sustainably maintain a region or community's current consumption, using prevailing technology." (Chambers & Simmons, 2002)

In the 1990s Rees and Wackernagel developed a technique known as the ecological footprint analysis, also termed as the "footprint" (Simmons, 2002). They developed an accounting system which includes six human activities that require "biologically productive space": 1. growing crops, 2. grazing animals which requires pasture, 3. harvesting timber which requires natural forest or plantations, 4. fishing which requires productive fishing grounds, 5. accommodating infrastructure for housing, transportation, and hydroelectric power built-up land and 6. burning fossil fuel which adds CO_2 to the atmosphere (Wackernagel & et al., 2002). They calculated the required area of forest to avoid an increase in atmospheric CO_2. Only 65% of CO_2 emissions were used in this calculation due to 35% expected to be absorbed by the ocean. The sum of the required area from the six activities gives a total amount of the "biologically productive space" needed. There is a so-called "equivalence factor" built in for each of the six activities to take the prevailing circumstances into account: effects like agriculture expanding into forest, forests shift into cropland or the decrease of biologically productive space on the planet which are changing the "equivalence factor". Multiplying the area with the "equivalence factor" results in the so-called global hectares (gha). "One global hectare (gha) is equivalent to one hectare of biologically productive space with world average productivity." (Chambers & Simmons, 2002)

By comparing with the Earth's available land area it is possible to calculate how many "Earths" are needed to maintain peoples demand. As long as this factor stays below 1 the Earth would be sustainable. This indicator has been monitored since 1961 and the point where the human demand exceeded the earth capacity was achieved in 1978, called “overshoot” (Fig. 23). After 1978 the earth was not sustainable anymore. The Brundtland report, which was commissioned by the United Nations after the Rio Earth Summit in 1992, proposed that 12% of the biosphere should be left free to retain sufficient biodiversity. Subtracting the proposed 12% in the calculation would bring the change over point from 1978 back to the early 1970s. Without the security factor of the Brundtland report we have today an overshoot of 37%, i.e. 1.37 Earths. If China and India would have the same lifestyle as the USA, there would be a massive overshoot of 250%. This would mean 3.5 Earths would be needed to support the current world populations demand (Simmons & Chambers, 2003).

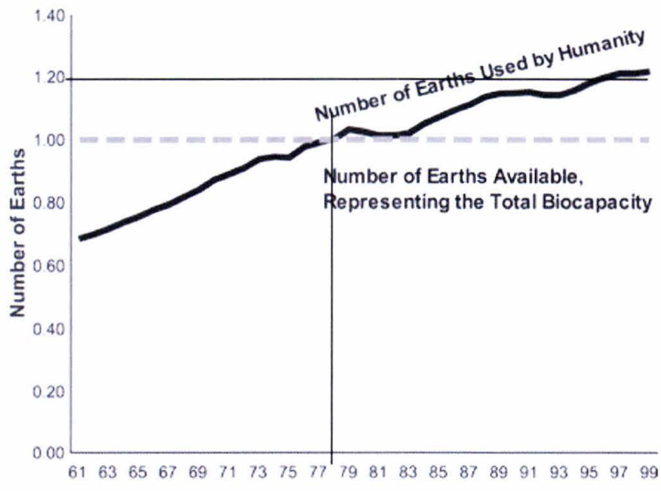


Figure 23: Number of Earths required to support the human demand for natural capital. Change over point to a non sustainable Earth 1978. Source: (Wackernagel et al., 2002)

The most significant increase of resource use during the period of 1961-1999 was in the use of fossil fuels for energy . The global hectar calculation (Fig. 24) gives the land requirement. The 35% of the CO_2 emissions which are expected to be absorbed by the ocean are not included (Wackernagel et al., 2002).

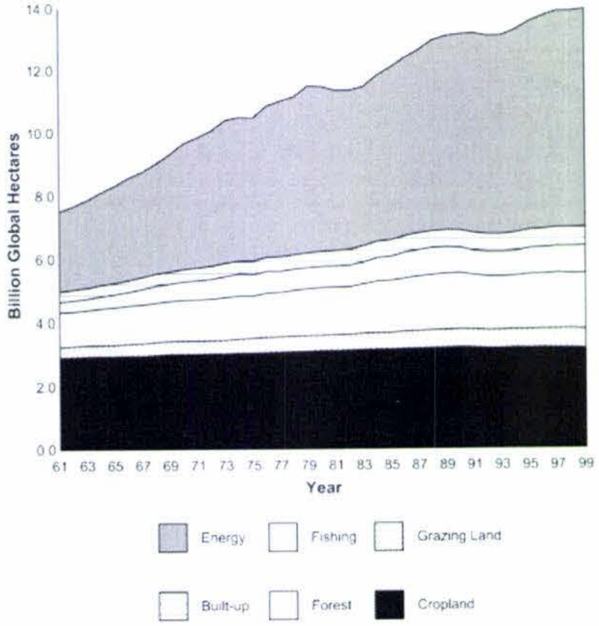


Figure 24: Increase of the global hectares needed to supply human needs between 1961 and 1999. Source: (Wackernagel et al., 2002)

The New Zealand government developed a footprinter for New Zealand's conditions as a part of its environmental reporting program (MfE, 2005) to show people how to reduce their impact on the environment. This footprinter asks the user a few questions like food consumption e.g. is the user vegetarian, mainly vegetarian, light meal or heavy meal eater? Other questions were about transport, clothing, electricity, health care, leisure, sport and income according to the six categories evaluated by Wackernagel et al. (2002). Most of these questions ask for the money investment in each category. From this information the software estimates the land requirement to supply the user's needs. The results are shown in square metres of land required and tons of CO_2 (Fig. 25). To help the user understand the amount of the CO_2 value, the software calculates the area of trees which would be needed to absorb the emitted CO_2. The program also provides some hints as to where the user could lower his/her footprint.

Your ecological footprint

Your ecological footprint is 31,589 square metres. The average New Zealand footprint is 30,800 square metres.

Your footprint consists of:

Food Footprint	**18,760 m^2**
More info on food footprints	
Transport Footprint	**2,854 m^2**
More info on transport footprints	
Household Goods Footprint	**6,215 m^2**
More info on household goods footprints	
Household Energy Footprint	**1,311 m^2**
More info on household energy footprints	
Household Services Footprint	**2,447 m^2**
More info on household services footprints	

Your ecological footprint is within the average range for New Zealanders. By New Zealand standards you live a reasonably sustainable lifestyle - although by world standards you do not. If everyone on the globe used as much land as you do, 4.3 globes would be needed to support the world's population.

Even though your meat consumption is light, it still has a considerable impact on the size of your ecological footprint. If you eliminate most of this meat from your diet, this would reduce your ecological footprint by an estimated 4,000 square metres.

Your use of airlines for international travel significantly adds to your ecological footprint. Your ecological footprint is increased by 2,161 square metres by your international air travel.

Your purchases of stationery, computers and office equipment are high. Your ecological footprint is increased to 658 square metres above the national average due to these purchases. Many of these items (eg. computers) require significant amounts of energy to produce. This in turn produces CO_2 emissions that require forested land for absorption. This increases the size of your ecological footprint.

Carbon footprint

It is estimated that your lifestyle and material consumption results in CO_2 emissions of **7 tonnes per year**.

As part of the carbon cycle, forests absorb carbon dioxide from the air. To absorb the CO_2 emissions generated by your lifestyle, it is estimated that an area equivalent to **22 tennis courts** would need to be planted in trees. But forests only absorb CO_2 when they are growing. Mature forests have little impact on atmospheric CO_2 levels. So after about 30 years (maturity of commercial forests) your carbon footprint would need to be reforested if your current lifestyle remains at a similar level.

It is assumed that the CO_2 absorbed by forests is locked up in the forests while the trees remain standing, and if they are harvested the CO_2 is locked into the resulting product, eg. building structures. Loss of forests, eg. to fire, releases the CO_2.

1 tennis court = 262 square metres (court area only).
3 tennis courts = 785 square metres (court area only) = approximate size of a residential section

More information on carbon footprints

Figure 25: Output example from the New Zealand's footprinter [m^2/year]. Source: (MfE, 2005)

Calculators are often not associated with only one of the identified categories. However a pure footprint calculator was developed by WWF (World Wide Fund) Switzerland based on the calculation method of Wackernagel showing the user's impacts and comparing the result with the numbers of a few famous people. The calculator asks the user at the end what changes as a gift to the world he/she could make to decrease his/her impact (WWF Switzerland, 2003).

2.11.2. Climate change calculators

The most comprehensive climate change calculator found was developed by the Australia's Environment Protection Authority (Victoria) (EPA, 2003) which is supported by the Commonwealth State and Territory Governments through the Energy Management Task Force, a standing committee of ANZMEC (Australian and New Zealand Mineral and Energy Council) and some governmental agencies. It provides an easy tour through the house and then into the backyard. It consists of five rooms – kitchen, bathroom, bedroom, laundry, living room - and the back yard (Fig. 26). The questions asked are mostly very simple. The house is classified as compact, small, medium and large. A further criteria is if the house has ceiling insulation installed or not.

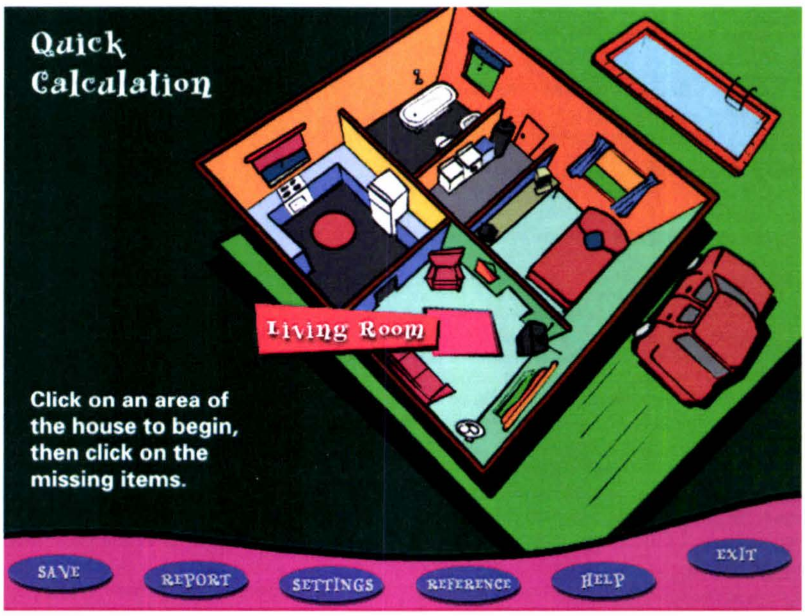


Figure 26: Overview of a household used in the climate change calculator from the Australia's Environment Protection Authority. Source: (EPA, 2003)

In every room the user has to prompt information about the main appliances. In the kitchen for example the user has to choose the hot water service, how many times they use the dishwasher and to which tap the dishwasher is connected, cold, hot, or both. The program also gives some hints how to improve the energy demand. As an example: use an energy efficient dishwasher on economic cycle or make sure that the dishwasher is fully loaded. These hints do not have any impact on the final report. The backyard contains issues such as transport, waste recycling, swimming pool heating, number of planted trees each year, and the percentage of green power[9] purchased. The final report is made of four parts. The greenhouse part gives information about the CO_2 emissions per annum by the main appliances (Fig. 27). The user's data input are compared with a "typical" individual and a "green" household.

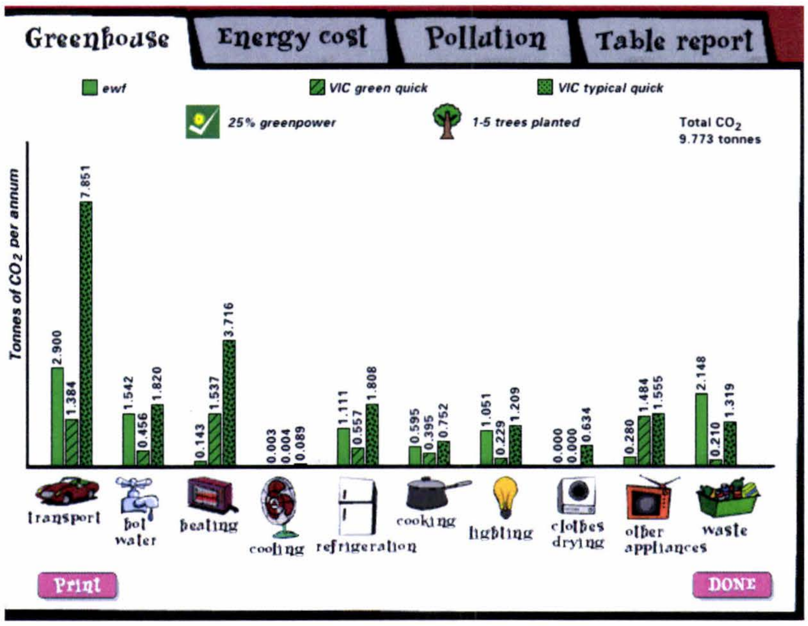


Figure 27: Greenhouse report showing the CO_2 emissions (tonne per annum) in comparison with a typical person and a green household. Source: (EPA, 2003)

The second part, energy cost, shows the energy costs per annum for each entity of the household (Fig. 28). The prices are based on the local tariffs.

9 "Green power" is electricity generated by renewable sources and is available in some regions ofAustralia for an additional price.

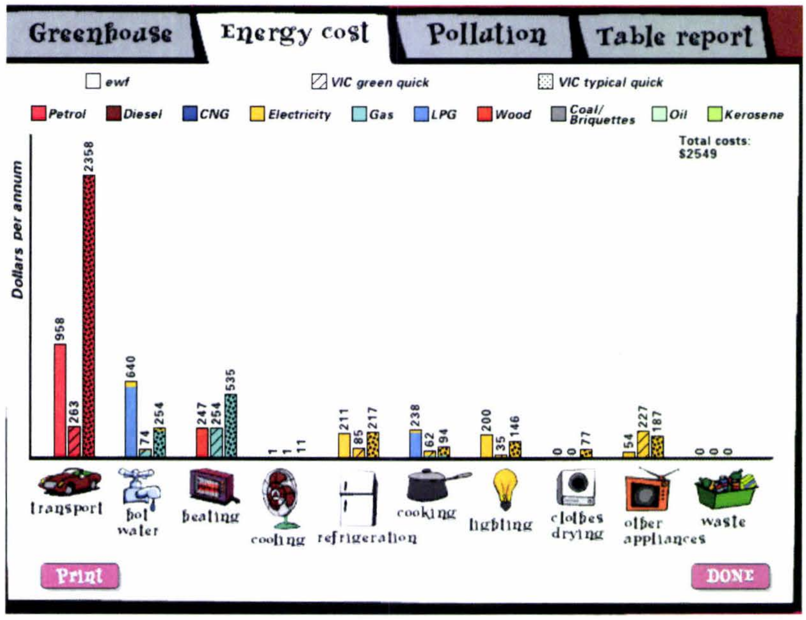


Figure 28: Energy costs ($ per annum) split into different fuels in comparison with a typical and a green household. Source: (EPA, 2003)

Additional to CO_2 other gases - NOx (nitrous oxides), CO (carbon monoxide), VOCs (volatile organic compounds), particulates and SOx (sulphurous oxides) - are shown in a separate window, split according to the entity (Fig. 29). The table report also provides all the information in a text file, including the input data.

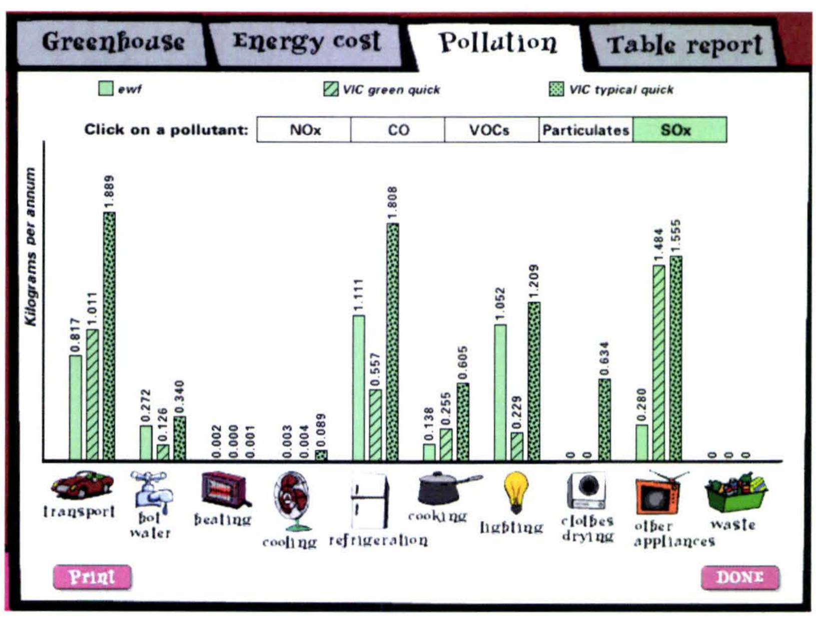


Figure 29: Pollution report, possible to see five different pollutants. The figure shows SOx (Sulphurous oxides). Source: (EPA, 2003)

This climate calculator already shows the approximate energy needed for each service. The user of this model might get aware on which service they need to make improvements to save money and greenhouse gases.

The Landcare research project EBEX21 developed a climate change calculator based on New Zealand conditions (EBEX21, 2003). EBEX's main work is advising industries on their emissions and offsetting GHG emissions by investing in land reverting to nature forest, thereby acting as a carbon sink. The service includes emission monitoring, managing and mitigating. EBEX complemented their Business and Tourism tools with a School and Household calculator. The household calculator is based on the BRANZ study who published a booklet "Being a climate friendly kiwi" (Hargreaves, 2002). The areas included in the EBEX21 household calculator are home energy use, transport and waste generation. The needed input data for this calculation can be found on recorded data such as electricity bill and car kilometres travel or litres of fuel used. The outcomes are CO_2 emissions related to home energy demand, transport and waste production. Appliances are not taken into account separately. It is not possible to identify which service produced most of the CO_2 emissions (EBEX21, 2003).

Another climate change calculator was developed by the New Zealand National Institute for Water & Atmospheric Research (NIWA). This calculator assesses CO_2 emission associated with home energy and use of the car. Data is assessed by the operation hours of household appliances. Hot water cylinder and ovens can be distinguished by electricity or gas supply. The result is shown as a total figure of the daily and annual CO_2 emissions compared to a "typical" New Zealand household (NIWA, 2002).

Only the Australian climate change calculator developed by EPA showed approximated energy costs additional to GHG emissions. The calculators from EBEX and NIWA have different approaches. EBEX includes home energy use, public and individual transport and waste whereby NIWA focuses on the home energy use with the different services.

2.11.3. Energy Advisors

One of the most extensive Energy Advisor systems was sponsored by the U.S. Department of Energy (DOE) and the U.S. Environmental Protection Agency (EPA), as part of the national Energy Star Program (DOE, 2003b). Energy Star products ensure the consumer that the products meet certain standards in energy efficiency similar to the MEPS in New Zealand (Section 2.8.2). To model the heating and cooling consumption the Energy Advisor uses the DOE-2 building simulation program. This program was developed by the U.S. Department of Energy. DOE-2 includes a weather database from 239 locations in the United States to calculate the heating/cooling energy required. Inputs required are house faces, number of stories, floor-ceiling height, house shape, the house dimensions and a few questions about insulation, windows and roof. Household appliances are assessed with simple inputs. To calculate the consumption the program uses historic sales-weighted efficiency data. The hot water heater energy consumption is based on a model developed by the Lawrence Berkeley National Laboratory. It calculates the energy due to household size, age of occupants, equipment efficiencies and water inlet temperatures. The results of the survey are shown in an annual energy bill compared to an energy efficient house in the same area (Fig. 30). The results can also be shown in CO_2 emissions of every sector.

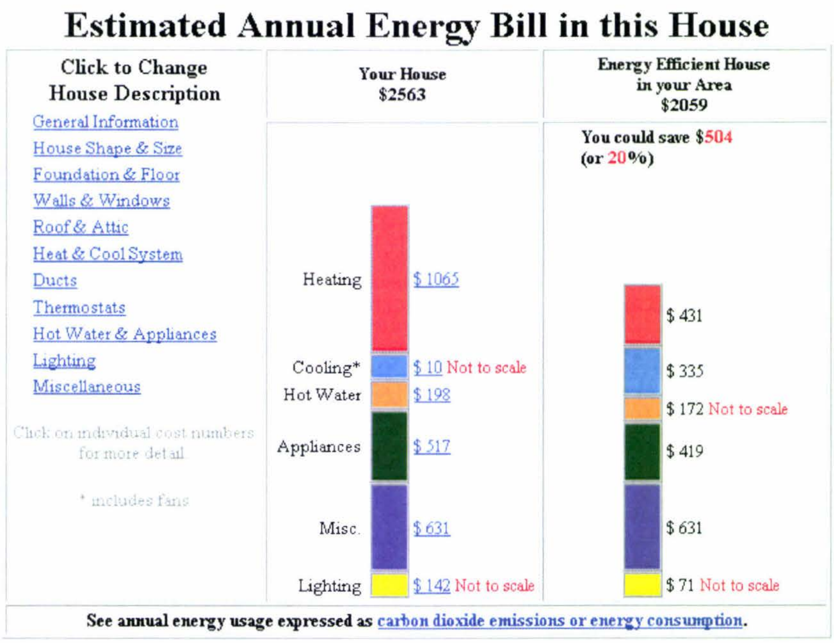


Figure 30: Energy Advisor example of a final report of a house survey. Annual energy bill subdivided into parts. Source: (DOE, 2003b)

The Energy Advisor shows the saving potential and gives suggestions of upgrading possibilities (Fig. 31). The upgrading is focused on improving the house insulation and the replacement of inefficient appliances through energy star labelled appliances.

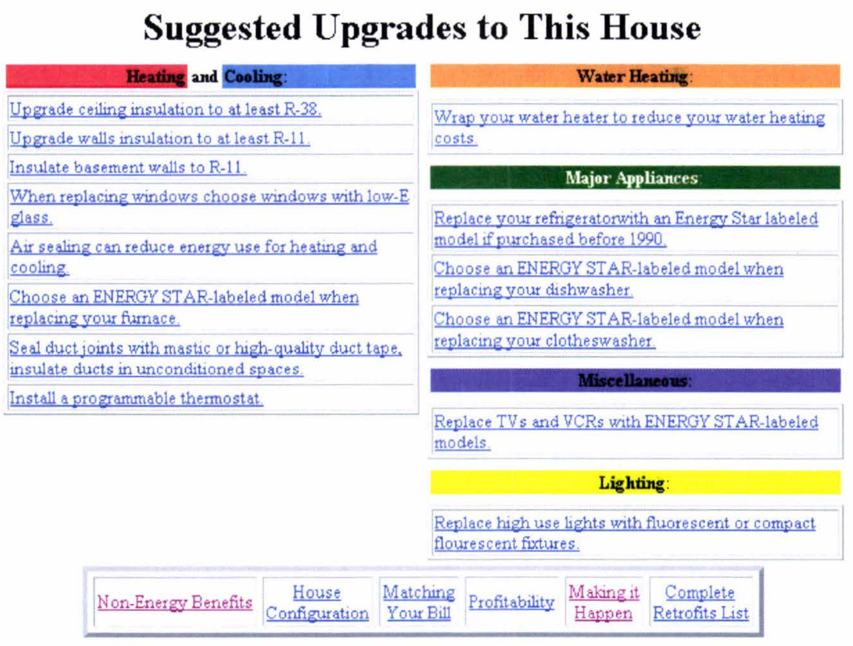


Figure 31: Energy Advisor suggestions to upgrade the house for better efficiency. Source: (DOE, 2003b)

The energy advisor has a very well studied house energy calculation. This gives a quite accurate picture of the required heating and cooling energy. The appliances are assessed with average data and the improvement is shown by purchasing energy star labelled appliances. The transport sector is not taken into account.

2.11.4. Building energy models

Thermal building simulations are well studied. Architects and engineers are using such simulations to calculate the required heating energy of their designed houses. A lot of different building simulation models are available. All of them need a good understanding of the building construction. The building models are very sophisticated due to the amount of research involved.

Simulation programs have a long history. The BLAST building simulation programme was sponsored by the US Department of Defence (DOD) and has its origin in the 1970s and was last released in spring 1998 (Crawley et al., 2001). The other simulation programme used all around the world is the DOE-2 programme which was used in the Energy Advisor model. The DOE-2 program includes a full annual simulation for a typical weather year of 239 different weather locations in the United States. This simulation program has its origin in the 1960s and was sponsored by the US Department of Energy (DOE). The last DOE-2 version was released in spring 1998. Instead of having two comprehensive building models sponsored by the US government the development of an all-new program Energy Plus was started in 1996. This development was based on the most popular features and capabilities of BLAST and DOE-2. The development team of Energy Plus includes the US Army Construction Engineering Research Laboratories (CERL), Universities such as the University of Illinois (UI), the Lawrence Berkley National Laboratory (LBNL), and the DOE. The first release of Energy Plus was 2001 (Crawley et al., 2001).

The building energy model for New Zealand conditions and constructions was developed by the Building Research Association of New Zealand (BRANZ). The developed program is called ALF (Annual Loss Factor Method) and uses climate data from NIWA. ALF has a very user-friendly interface. With some understanding of the building construction it is possible to use ALF. It calculates the annual required heating energy based on construction data e.g. floor, wall, windows and ceiling insulation. Solar gains through the windows are also part of the simulation. The result of the assessed house is compared to a standard house which was simulated using the minimum requirements of the New Zealand building standard

2.12. Summary

Anthropogenic climate change has been found to be a real threat to the world with increasing temperatures and a resulting increase in extreme weather events such as storms, floods and draughts. Scientific research shows clear evidence of the anthropogenic climate change. The solutions to this threat are various such as international frameworks and lots of good ideas to implement the technical solutions to reduce GHG.

The Kyoto Protocol was developed as a response to climate change. This international convention will commit ratified countries to reduce the GHG emissions on average at least by 5% below the emission level from 1990 during 2008-2012. The Kyoto Protocol has entered into force now that Russia has ratified it. The basic conditions with the legally binding goals and the Kyoto mechanisms would improve substantially for every project GHG-reduction project. New Zealand ratified the Protocol and started to act with national energy efficiency and renewable energy strategies.

The two largest polluters in New Zealand are the agriculture sector with 54% of New Zealand's annual GHGs mostly from methane and nitrous oxide and the energy sector (including transportation fuels) with 38% mostly from carbon dioxide. The scope of this study is the energy sector which had the largest increase in GHGs (around 27%) of all sectors during 1994 and 2000 from increasing fossil fuel use. CO_2 accounts for almost 96% of the energy sector's GHG emissions. The domestic transport and the residential sectors related to this study, together consume 53.5% of the total energy in New Zealand.

The costs to the economy and insurers due to environmental damage from extreme weather events are significant. Natural disasters, most likely as a result of climate change, have increased in the last 20 years. The households can be affected by this trend with more unemployment and higher taxes. Households in New Zealand already pay 21% of their household costs towards energy use and transport. These expenditures could be lowered with energy efficiency measures. Also renewable energies are getting cheaper and could substitute a large part of the current use of fossil fuel. Energy efficiency and renewable energy measure could bring the economy a new push by reducing energy related cost. Increasing investments in renewable energy technologies is expected to have a positive effect on the economy.

A number of software models have been developed to encourage domestic users to reduce GHG through lowering energy use. These models are footprinters which typically calculate the number of planet "Earths" needed to sustainably support the users demand in transport and household including food and waste if everyone else also had a similar lifestyle. Other software are climate change calculators which analyse different sectors and show the amount of GHG emitted. The Energy Advisor is one of the most sophisticated and specific house energy calculators based on US conditions and without the inclusion of the transport sector. Only this and the Australian Climate Change calculator show the saving potential as a monetary value which is expected to be a major point for the consumer.

None of these available in New Zealand include transport and domestic sectors or additionally, the inclusion of a psychological approach depending on the user. The next chapter describes a novel model which does include these factors by using databases to choose the exact entity with the basic structure of an energy audit.

3. Chapter Model Design

3.1. Introduction

The purpose of this chapter is to explain the design of the developed model. The aim of the model is to help people reduce their energy usage and CO_2 emission according to the national strategy and the Kyoto Protocol by suggesting specific improvements. The model is practical in that it provides appropriate information which assists the user in reducing both carbon dioxide emissions and energy costs. The model is interactive and provides simple, understandable information.

The design of the model is structured in seven parts, each described below.

1. Methodology
2. General ecological behaviour
3. Building
4. Transport
5. Appliances
6. Monthly bill
7. Improvements

The methodology explains how the model was developed. Parts 2 to 5 are specific descriptions of the data assessment. Part 6 explains how much the assessed and calculated energy costs and CO_2 emissions of the individual user appear in the monthly bill. The last part describes how the user of the model could lower the expenses of the monthly energy bills.

3.2. Methodology

The Personalised Residential Energy Model (PREM) was developed to be different to others differ from existing energy analysing software (Section 2.11). The following section shows how PREM was developed and what key points were taken into account.

An energy model including the transport and house energy sector with databases to choose the appliances was not found in New Zealand or internationally as discussed in chapter 2. The additional inclusion of environmental psychology into an energy model could not be found either, thus making PREM unique. PREM is not based on footprint calculations which are not very accurate in CO_2 calculation. PREM can be placed somewhere between climate change calculators and energy advisors. The climate change calculators in New Zealand that are already developed do not include the financial side. These calculators also have included different sectors but none include house energy and transport as PREM does. PREM shows the user where money, energy and GHG emissions can be saved most effectively by evaluating cause of emissions and costs by each service.

PREM is closest to the Australian climate change calculator where house energy and transport sectors are also included. The Australian calculator has an additional sector of waste treatment. Normally energy costs are shown as an annual total bill. In contrast PREM displays the energy costs on a monthly bill. This was found to be easier for the user to compare the costs with the income and monthly expenditures such as rent. PREM includes a lot of databases where the exact appliance type can be chosen. The model is more practical in that it can assist the user with the purchasing of new appliances. PREM also adds a psychometric scale to assess where the user could change his/her energy behaviour. The improvements found as a result of these behavioural changes are shown in the monthly bill along with the money and CO_2 emission savings.

Additionally to the US Energy Advisor, PREM includes the domestic transport sector which was found to be a large CO_2 emitter. The Energy Advisor focuses on energy consumption of buildings that use a sophisticated building and hot water simulation. PREM does not include an individual building simulation, but gives the choice to calculate the required heating energy using ALF. The hot water heating energy is calculated differently than the method used in the Energy Advisor which was developed by the Lawrence Berkley Labratory and could not be applied because it is based on data from US household averages.

The actual development of this model will be reviewed. To provide all the data needed for the monthly bill PREM assesses the energy use according to the energy audit which was outlined in chapter 2:

- collection of energy and site data;
- the on-site energy audit;
- analysis of historical and energy audit data;
- determination and quantification of energy and cost saving options;
- detailed investigation and analysis and
- reporting

The collection of energy and site data is done by assessing the client's energy bills. In a household these bills normally consist of electricity and gas bills. The second step of PREM, the General Ecological Behaviour (GEB) assessment is an additional assessment to the conventional energy audit (Section 4.4). An on-site energy audit need to be conducted by the model user supported with large databases of appliances (Chapter 5). The user can choose his/her energy using appliances and their time of usage. With this input the model then calculates the monthly used energy with related costs and CO_2 emissions. The calculations are discussed in section 2.10 "Analyse historical and energy audit data". The cost and emission saving options are explained in section 3.8. "Detailed investigation and analysis" is not yet written into the model as not enough databases exist to compare the on-site audit with the historical data. The model uses databases for most of the entities and subtracts the accumulated usage from the electricity and gas bill. Any "left over" energy is split into the other entities according to the percentage of the energy-usage based on the HEEP study (Section 5.7). The end result is shown in a monthly bill with the costs and CO_2 emissions for each service. This calculation is required because in this study not all appliances could be produced as databases. In addition a way to calculate an appliance's energy consumption with specific data was not possible as it would have required a considerable understanding of the technology which cannot be assumed for the majority of users of the model.

The domestic transport and residential sector accounted for 53.5% of the national CO_2 emissions in New Zealand in 2002. This demonstrates the importance of the assessed sectors (MED, 2003b). The model calculates the CO_2 emissions of the reported production emissions and the combustion of fossil fuels. This applies partly to the sectors "other transformation", "fugitive" and "thermal electricity generation" (Section 2.4). A reduction in energy usage results in a reduction of cost and CO_2 emissions. This reduction can often be done without restricting lifestyle. Energy conservation and energy efficiency are the first and often the easiest applicable steps to reduce greenhouse gasses. The next step would be to install renewable energy sources. PREM will not support the use of renewable energy systems but this could be a further upgrading of the model (Chapter 7). Upon seeing the results, the user can start to change appliances and their usage hours interactively or use the improvement suggestions from the model to evaluate the potential which is shown in the adjusted monthly bill.

In order to reach a large number of people the model aims to be an internet program. For this purpose the model was first developed as an Excel model to verify the calculations (CD-Appendix A.27). The Excel model includes all the calculation and the inputs. The advantages of an internet program is that it can be reached from everywhere and the interface handling will be more user-friendly.

The model flow of PREM includes the data saving and the improvement reports (which are not applied in the Excel version) (Fig. 32). The welcoming and introduction page provides some information as to how the model can help to save money and emission. This first page also provides a manual with a list of input information for the model user to prepare themselves in advance. The manual for the excel version is shown in Appendix A.4. After the welcoming and introduction page, the model asks if the user already has a profile (personal data) stored. If not, the model will assess the person's general ecological behaviour and energy demand such as from household appliances and car usage. This data will then be stored as the personal profile along with the monthly bill showing expenditure per service and the related CO_2 emissions. The monthly bill is the report of the model where the information on energy saving is provided in dollar value. If the person already has a profile, the monthly bill is shown directly after the welcoming page and the user can make specific changes to the inputs manually or by the model automatically to improve his/her usage. The interactive changes allow the user to analyse the results of changes they are interested in. Any improvements assessed by the model are an outcome of the GEB scale and the energy calculation. The behaviours with the largest probability to be performed are shown first and the improvement potential is shown as a dollar and emission value. Every change in the input data is stored so that the user is able to gradually improve his/her energy use over time.

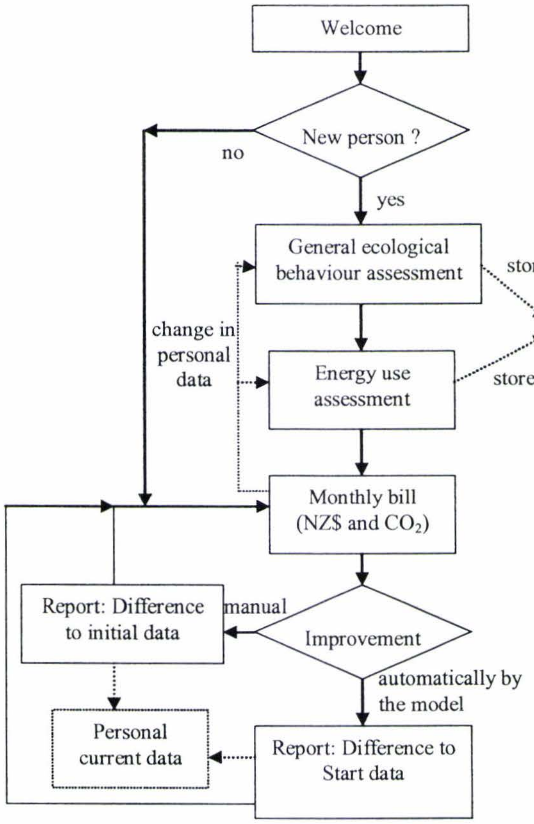


Figure 32: Personalised Residential Energy Model flow

The major advantages of the model are that it is service specific, easy to understand and simple to handle. The handling is done by using general findings of the environmental psychology and by including databases with choices of appliances. Due to the fact that the model also aims for accuracy, a conflict arose when aiming for simplicity. In other words the more input information the model requires the more accurate it is, and thus the more complicated and time intensive for the model user. With the databases embedded in the model it is still easy to handle and the user does not need to know the technical specification in order to make an accurate calculation. Unfortunately not all appliances are gathered in databases. The calculation of the other appliances are done with average data which can be changed if the user has the technical knowledge and the time. If more databases exist the model could do all calculations with this data and could compare the calculated consumption with the energy bill as suggested in the energy audit.

3.3. General Ecological Behaviour

The first step consists of the General Ecological Behaviour (GEB) assessment. This is a special psychometric scale developed by Kaiser (1998), an environmental psychologist, which assesses an individual's ability to behave environmentally friendly (Chapter 4).

The model poses 23 questions, most of which are answered with "yes" or "no"(Appendix A.7). The GEB scale tells the user how good or bad their behaviour is towards the environment. Feedback from the person's specific GEB-score also allows their score to be compared within others. This value can also be used to calculate probabilities in developing certain energy conservation and environmentally friendlier transport behaviours.

3.4. House construction

The house construction plays an important part in the conservation of energy use. Around one third of the household energy use in New Zealand is due to heating (Section 3.6). The amount of heating required varies with insulation, orientation and passive solar design. The most accurate way to assess the energy required for heating would be the utilisation of ALF (Section 2.11.4). The simplicity in using the model is that it leaves the possibility to assess the required heating energy with ALF, but will also provide the user with three different house constructions: lightweight construction, heavy construction and super insulated construction, as an approximation.

A house insulation and energy-efficiency program in the Eastern Bay of Plenty retrofitted more then 3000 houses with several projects underwritten by the Eastern Bay of Plenty Trust (EBET) and the Energy Efficiency and Conservation Authority's (EECA) Energy Saver Fund (Hunt, 2003a). The target group of these projects were low-income households. After the assessment of the house and organising the materials the actual retrofit job took the team between 2-4 person hours. The average retrofitted house saved NZ$ 313 and 13.4 tonnes of CO_2 emissions per year as a result of energy savings (Hunt, 2003a).

3.5. Transport

The transport section assesses different travel modes. By calculating cost and CO_2 emissions the user will be able to compare the breakdown of costs for each service and CO_2 emissions. Figure 33 displays the modes of transportation used in New Zealand.

An EECA study found that the energy used for transportation is increasing by 3.8% per year. That same study expects that the transport energy will make up to approximately 52% of the total consumer energy by 2020. The main passenger transportation modes in New Zealand are car 89%, domestic travel 7.4%, buses 2.9%, and rail transport 0.3% (Fig. 33) (Becken, 2002).

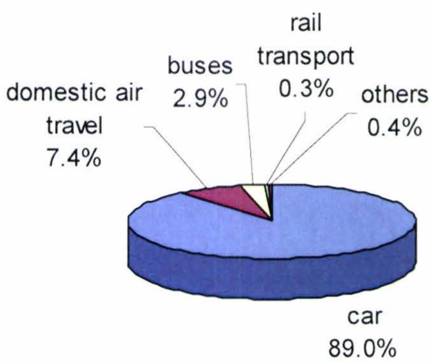


Figure 33: Passenger transport energy use in New Zealand (excluding walking and cycling). Source: (Becken, 2002)

All modes of transportation reach different distances, have different comfort levels, availabilities, costs and emissions. The model assesses the cost and emissions of these transport modes. Other factors such as comfort level and availability cannot be included with these results and are given by the infrastructure and the current state of the used technology.

The most used transport mode is by car which is also the largest GHG emitter of the domestic transport sector in New Zealand. The car ownership in New Zealand is the second highest in the world with 69 vehicles per 100 people (Becken, 2002). Cars in New Zealand are characterised as an "inefficient and ageing fleet of cars that is not subjected to any emission controls" (Becken, 2002). The major factors in the running costs and emissions are fuel consumption and driven kilometres. To make it convenient for the user to input the personal data into PREM, they have the choice of different car models when assessing the transport energy use. The database provides fuel consumption for the specific car. With the distance travelled PREM is able to calculate the total amount of fuel used. From these results fuel costs and CO_2 emissions can be calculated. These calculations are done by using emission factors which are explained in chapter 5.

The calculation of the public transport is less intensive as emission factors for New Zealand exist to calculate emissions from the distance travelled. The input the user needs to know is how many kilometres he/she travelled using each transport service. A kilometre table to support the user with the input is provided in the manual.

The transport section emissions were found to account for a large part of the individual total emission. In a nation wide study transport modes were assessed and are included in the model. For an example the user will be able to compare the costs and CO_2 emissions between taking a train or a plane from Wellington to Auckland.

3.6. Appliances

The Building Research Association of New Zealand (BRANZ) has been undertaking a study called HEEP (House Energy End-use Project) to assess the energy consumption of household appliances for over the past six years. From this study it was found that the largest energy consumers were: hot water heaters, heater/air conditioners, lighting, refrigeration, cooking, TVs, computers, dryers, dishwasher and washing machines. The rest of the appliances use 6.7% of the appliance energy demand (Fig. 34). The energy used and emissions of the production are not included, as each manufacturer would need to do an LCA in order to determine this data.

Data from the three cities; Hamilton, Wellington and Auckland were analysed in the early part of the HEEP study (BRANZ, 2002). The study is currently extending to other cities such as Christchurch, Nelson and Taupo. The Hamilton and Wellington data have 19% to 28% energy usage that is unassigned. The Auckland data were more specific with 3.9% miscellaneous appliances (Fig. 34). To find the major end-use appliances for PREM, the Auckland data was taken. However the three cities do not have a statistically significant different energy use patterns (BRANZ, 2002).

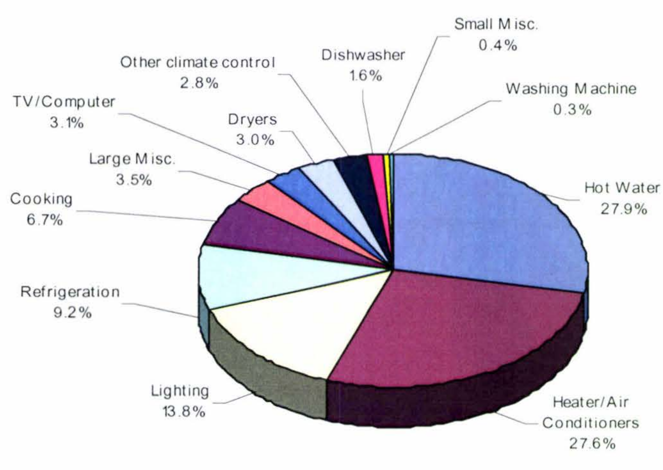


Figure 34: Auckland domestic sector mean annual electricity and gas-use breakdown. Source data: (BRANZ, 2002)

The major energy users were hot water heating and space heating with a consumption of approximately 28% each. These are followed by lighting (13.8%), refrigerating (9.2%) and cooking stoves (6.7%). TV/computer, dryer, diverse climate control, dishwasher, washing machine and other miscellaneous appliances were responsible for the remaining 14.7%. Some appliances are interconnected, for example the washing machine settings (hot, warm or cold) affects the hot water consumption as well as the electricity demand (BRANZ, 2002). The study identified the important appliances that need to be included in the audit for New Zealand households. It also demonstrated the importance of space heating, and thus the need for a building construction assessment. With a better insulated building the occupant would not need to turn the heater on so often or perhaps could leave it run on a lower setting. This particular calculation is shown in chapter 5.

3.7. Monthly bill

The general aim of PREM was: "...to determine the extent to which individual decisions and behaviour contribute to energy consumption, greenhouse gas emissions and cost savings. The thesis aimed to include environmental psychology into a technical based energy model to make it more individualised. Subsequently, with the aid of psychological instruments, determine where a specific person is most likely to change their behaviour" (Section 1.1). From the psychological view, a way to help people change their behaviour is by providing proper information and showing the saving potential (Stern, 1992). This can be done using the monthly bill. The bill in the model displays both CO_2 emissions and costs for each service. People generally are not able to judge physieal values, sueh as kg CO_2 emitted (Stern, 1992). Therefore, emissions are given in money value in the bill as well as kilograms CO_2. A virtual CO_2 tax, which very possibly, will be in place in 2007, gives the conversion factor from kilograms to dollars. The energy use is not shown in kWh either. The price of each energy source, such as electricity, fuel and gas, is taken to convert the energy use into a dollar value. This information is personal, specific and can be compared to the average New Zealand household energy and domestic transport costs of NZ$ 872 per month (Section 2.6).

3.8. Improvements

The improvement of a person's behaviour is based on the reduction of costs and CO_2 emission in their energy bill. Emission savings can be achieved by using less energy or using less GHG emitting sources of energy. These emission and cost saving options can be evaluated in two ways. First the user can interactively change his/her input data and view the savings of such changes in their monthly bill. A second option is viewing the cost and CO_2 emission difference with the suggested behaviour changes which are listed according to the calculated probability of performance. These two options should give every person the possibility of finding the individual way to save money and CO_2 emissions.

With the monthly savings the calculation of the basic simple pay backtime of an investment can be calculated by dividing the investment by the monthly savings. For example an energy efficient fridge would cost NZ$ 800.00 and the cost savings by replacing the old fridge through the energy efficient calculation of PREM accounts for NZ$ 8 per month. The pay back time would be 8.3 years (Equ. 1).

$$\frac{Investment}{savings / month} = \frac{NZ\$800}{NZ\$8 / month} = 100 month = 8.3 years$$

Equation 1: Pay back time example for a fridge replacement

The lifetime expectancy of the appliance needs to be considered as well. If the fridge in this example has a life time expectancy of 15 years the investor would save money for a period of 6.7 years. When the investor multiplies the 6.7 years times the monthly cost savings the result is a plus of NZ$ 643 at present day prices and without discounting the dollar value (Equ. 2).

$$\begin{aligned}&(lifetime - pay\ back\ time) \cdot saving / month = \\ &6.7 years \cdot 12 month / year \cdot NZ\$8 / month = NZ\$643\end{aligned}$$

Equation 2: Total savings of the investment

This single calculation can be done for every new investment such as buying a new car, new appliances or using public transport and will indicate in very broad terms if a change to a new option would be economically profitable.

3.9. Summary

A model such as PREM has yet to be found in New Zealand or anywhere in the world. It can be placed between a climate change calculator and an energy advisor software. The main purpose is to help people in reducing their energy usage and CO_2 emissions. PREM is economically and ecologically based as it supports CO_2 and cost savings to be implemented by a majority. To increase the success of PREM, environmental psychology was included to reduce the barriers and to present the information in an understandable way.

Household and domestic transport emissions assessed to be large emitters in New Zealand. Nationwide these two sectors are responsible for over 50% of CO_2 emissions. The household section can be split into two parts: building construction (which covers calculation of the required heating energy) and appliances (which cover heating, hot water and other appliances used in a household). The transport section assesses the most popular modes of transport in New Zealand which are car, air travel, bus and train.

As a result of using the model, the monthly bill will show how much each service costs the user per month including the CO_2 emissions. Behavioural change suggestions will help the user understand how to reduce costs and emissions.

The developed model shows the saving potential of households. Since 21% of the household income is used for domestic energy and transport costs, saving opportunities should be welcomed (Statistics New Zealand, 2002). In the model the total energy and transportation costs will be broken down by service (such as car travel, cooling food or space heating). Hence the user will have the possibility to identify individual saving opportunities. The model will show the costs in a monthly bill which will then enable the user to compare these to the average New Zealand household energy and domestic transport costs.

4. Chapter Psychometric Scales

4.1. Introduction

"Global environmental problems are caused by human activity" (Stern, 2000).

Behavioural research that addresses energy issues starts with the principle that wherever people travel, work or live, they use energy and resources, which in turn cause emissions and wastes. In other words, the energy problem is to a large part a behavioural problem. An important step towards solving this problem is to assess how people use energy and produce greenhouse gases. The next step is to show people how they can change their energy usage.

The first part of this chapter will describe environmental psychology research in order to give an overview of what is done in this field and provide some general findings and definitions. The second part describes the background theory which is used in this study. This leads to the development of a specific scale used to assess a person's general ecological behaviour. This scale in turn can be used to evaluate specific potential areas in which a person can change specific behaviours.

The model developed in this study has the following general objective: " to determine the extent to which individual decisions and behaviour contribute to energy consumption, greenhouse gas emissions and cost savings. The thesis aims to include environmental psychology into a technical based energy model to make it more individualised. Subsequently, with the aid of psychological instruments, it will determine where a specific person is most likely to change their behaviour" (Section 1.1).

4.2. Psychology and energy conservation

In the 1970s and early 1980s, psychological research focused on understanding energy use and energy conservation particularly in households (Stern, 1992). Research in the environmental psychology area mainly started during the oil embargo of 1973 and diminished with the loss of U.S. federal interests and the consequential lack of money in the early 1980s. In the late 1980s concern about the environment started to rise, with issues of acid rain, urban air pollution and the threat of global climate change, gaining widespread public attention. For this reason, environmental psychology research began to become more prominent again (Stern, 1992).

When people drive their car to the kindergarten or grocery store they do not intend to produce negative consequences for the environment. The intention is to make life easier and more comfortable. The air pollution is an undesirable and often unforeseen side effect (Kaiser & Wilson, 2004). Generally stated: "Through human history, environmental impact has largely been a by-product of human desires for physical comfort, mobility, relief from labour, enjoyment, power, status, personal security, maintenance of tradition and family, and so forth, and of the organisations and technologies humanity has created to meet these desires" (Stern, 2000). Environmental psychology needs to understand how people are becoming more environmentally aware and how they might start to think how their by-products affect the climate.

Environmentally significant behaviours were previously defined from an impact view, which indicates that behaviours with large environmental impacts were identified and targeted (Stern, 2000). People's concerns and understanding of environmental problems were minimal and behaviour changes could not be expected due to beliefs and attitudes. Relatively recently, environmental protection became more important in human decision making. People started to choose certain products or changed some behaviour to achieve a reduced impact on the environment. This new aspect added the intention-oriented definition to the existing impact-orientated definition. The intention orientation indicates that some people actively intend to save the environment and are willing to change. Hence, psychological research could be made more usefully applied to environmental issues by focusing on peoples' beliefs and intentions in order to understand and change target behaviours (Stern, 2000).

Environmentally friendly behaviours need to be communicated with information about the effects on the climate and the resulting personal advantages. After all, money and information are the major classes of policy instruments available to change residential energy use (Stern, 1992). Money incentives work better if the people are informed about the personal advantages. The availability of information is not the most important factor. How information is conveyed also plays a major role. For instance, research has shown that behaviour change is much more likely if information is personalised, vivid and specific. In 1992, a study showed that households receiving daily reports on their energy consumption were reducing energy use between 10% and 15% (Stern, 1992). It has also been shown that in order for the information to be effective, it is important that the feedback be given within a short time after any behaviour change.

A major incentive regards subsequent financial benefits (Stern, 1992). These benefits need to be shown in a way that people can see. This is as important as the amount which can be saved. For example, different ways of presenting cost savings tend to generate different responses. Researchers have found that homeowners often think of their utility bill per month, rather then science oriented units, such as cents/kWh (Stern, 1992). It also makes a difference if financial savings are shown as the payback period[10], net present value[11] or internal rate of return[12]. The pay back period is much easier to understand compared with the internal rate of return. How the savings are worded also makes a difference. For example, investment in a hot water cylinder wrap is more likely if couched as a way of not losing money instead of a means of saving money (Stern, 1992). The optimal money information occurs when it is shown how much money would be lost every month if the investment were not done.

There are also non-financial motives which influence energy conservation (Stern, 1992). Consumers have preferences that are affected by a wide range of factors. One study demonstrated that people in the USA prefer to install storm windows to save energy, rather then insulating walls, which would have the greater effect. The main reason was that storm windows are more attractive and reduce home upkeep. The preference for storm windows could result from group memberships. The opinions and actions of friends and peers often influence people more than expert advice (Stern, 1992). Another problem which cannot be

[10] Payback period: The length of time required to recover the cost of an investment.
[11] NPV compares the value of a dollar today versus the value of that same dollar in the future, after taking inflation and return into account.
[12] IRR is the return that a company would earn if they expanded or invested in themselves, rather than investing that money abroad

solved with financial incentives is that people tend to avoid problems until a crisis point is reached. A problem which is expected to come up in the future mostly does not worry people for a longer time. Experts can often calculate long term affects but people need to feel the affects of the crisis themselves. When they can see the disadvantages caused people like to follow rules of thumbs which can also be communicated more easily by friends and peers. "Simplification has been a key to success for energy incentive programs." (Stern, 1992) Therefore the PREM model gives simple answer which change in energy use behaviour makes the largest difference in the monthly bill.

The key question which needs to be asked to find the most effective energy use behaviours are: Which are the most important actors and which would have the largest impact on energy conservation for each actor? (Stern, 1992) The major actors in energy conservation are consumers of goods and services; intermediaries who can affect decisions with regard to what will be produced or consumed; and policymakers as can be seen in figure 35. These three actors influence each other (Fig. 35). If consumers demand energy efficiency goods, the market in this sector increases and the industry will produce more of these goods and services in order to make more money. The industry can also play an environmentally responsible role by increasing their marketing strategies to increase the demand in the energy efficient sector to build a strong market.

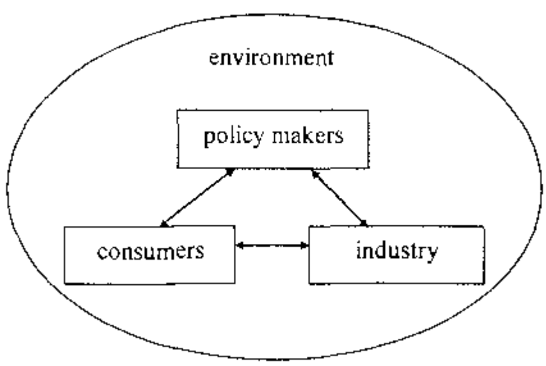


Figure 35: Actors in energy conservation

Politicians in a democratic nation are elected directly or indirectly by the people. If they notice that environmental issues would help them to be elected they would likely focus more on this issue. On the other hand, they are responsible for the sustainable development of the nation and can influence the awareness of the people with specific programme. A connection between industries and politics also exists. Some parties receive large amounts of money from industry which might also influence their politics. Also, for sustainable development, industries also need to be involved because the welfare of a state is helped by a functional industry. "Psychology research should focus on the largest energy users, the actions with the greatest potential for change, and the subset of those actions that are potentially changeable by psychological intervention" (Stern, 1992).

As residents are responsible for a large part of the emissions and are the scope of this thesis the following section looks at the different types of behaviour. Recent research found that people have four distinguishable environmentally significant behaviours which influence the different sectors; politics, industry and consumerism (Stern, 2000):

Environmental activism manifests in active involvement in environmental organisations and demonstration.

Nonactivist behaviours in the public sphere can be split into two types:

- environmental citizenship (e.g. petitioning on environmental issues) and
- support or acceptance of public policies (e.g. willingness to pay higher taxes for environmental protection).

These behaviours affect the environment indirectly, but the effect may still be significant. Public policies are able to change behaviours of many individuals and organisations in this regard.

Private-sphere environmentalism tends to attract the largest numbers of consumer researchers and psychologists. This behaviour can be further defined in four main parts.

- the purchase of major household goods and services that can be environmentally significant in their impact (e.g. cars, energy for home, recreational travel),
- the use and maintenance of environmentally important goods (e.g. a home heating and cooling system),
- household waste disposal, and
- "green" consumerism (purchasing practices that consider the environmental impact of production processes, for example, purchasing recycled products and organically grown foods) (Stern, 2000).

Private sphere environmentalism has the potential to create large impact on environmental factor. For example, since 1970, United States households have been directly responsible for almost half of all national carbon dioxide emissions (Stern, 2000). 1994 carbon dioxide emissions caused by households (including corresponding transport) in the USA were 47.2% of the entire emissions for that country (Stern, 2000).

Other environmentally significant behaviour includes individual behaviour within organisations, such as engineers designing energy efficient products and bankers and managers using environmental criteria in their decision making processes. These behaviours have significant environmental impacts, "because organisational actions are the largest direct sources of many environmental problems" (Stern, 2000).

Industry and politics are partly influenced by the residential and private transport sectors, which are the basis of both. The focus of this project will be on the individual person who is both a consumer and voter. The PREM model developed supports the private sphere environmentalism but based on the general finding of the environmental psychology explained above, the model should also influence non environmentalists who want to save money on their energy bill.

4.3. Theory of Planned Behaviour

The Theory of Planned Behaviour (TPB) is a theoretical framework which explains and predicts human behaviours in specific contexts. It serves as the background theory for this study and will be used to facilitate possible environmental behaviour change. TPB combines three psychological categories, the attitude towards the behaviour, the subjective norm and the perceived behaviour control. These combine to create an intention to perform a behaviour. Research has shown that the intention to do something predicts up to 80% of the actual performing of a specific behaviour (Ajzen, 1991). The General Ecological Behaviour (GEB) scale (Section 4.4) assesses the intention of a person to perform ecological behaviours.

A great deal of research was done in order to predict behaviours relating to a person's general attitude. Studies were conducted involving people belonging to a specific organisation or institution (the church, public housing, an employer) or minority groups (Blacks, Jews, Catholics) (Ajzen & Fishbein, 1977). These studies tried to explain behaviour according to the attitude by analysing the different groups. It was assumed that a specific group also has a specific attitude. This concept failed and there were calls for abandoning the pure attitude approach (Wicker, 1969). There were also attempts to predict behaviour based upon persons' traits, which also failed (Mischel, 1968).

One of the most famous studies in the environmental attitude research is the 1978 study by Dunlap and Van Liere (cited in La Trobe & Acott, 2000) where they developed the New Environmental Paradigm (NEP) derived from the Dominant Social Paradigm (DSP). The DSP includes the dominant western mode of thinking: "Resource exploitative, growth oriented, consumptive, and materialistic with little concern for the nature" (La Trobe & Acott, 2000). In contrast, "The NEP focused on beliefs about humanity's ability to upset the balance of nature, the existence of limits to growth for human societies, and humanity's right to rule over the rest of nature" (Dunlap et al 2000). The NEP measures the environmental attitude (Kaiser, Woelfling, & Fuehrer, 1999). This research also failed as a predictor of environmental behaviour. As found by other researchers, attitude and the trait of a person cannot be used to predict behaviour. "In short, the strength of the relationship between the NEP and ecological behaviour ranges from non-existent to weak" (Kaiser & Wilson, 2000).

Learning from previous studies, the approach of subsequent research was to aggregate specific behaviours across occasions, situations and forms of action studies (Epstein, 1983; Fishbein & Ajzen, 1974). The idea of this approach was that a specific behaviour is not just influenced by a relevant general disposition. It is also influenced by several other factors related to the particular occasion, situation and action (Ajzen, 1991). This lead to Theory of Reasoned Action (TRA) (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 1975). The TRA has two components, the attitude toward the behaviour and the subjective norm, which leads to the intention to perform the behaviour (Fig. 36).

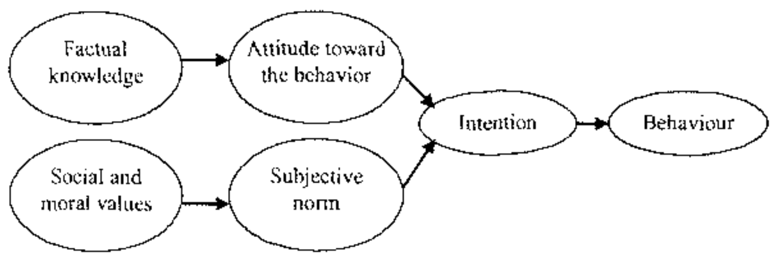


Figure 36: The theory of reasoned action (TRA) (Fishbein & Ajzen, 1975)

From factual knowledge about the behaviour a person builds his/her *attitude toward the behaviour* (Stutzman & Green, 1982). For example, if a person only knows negative facts about an issue, the behavioural attitude toward the issue will also be negative. When this person learns more about the behaviour and also sees the positive facts, the attitude can change. The more a person knows about specific behaviour, the better he/she can build an attitude toward the behaviour.

The *subjective norm* is an approximation of what one should do from a normative stance and is related to social expectations and moral principles (Kaiser et al., 1999). It is basically formed by social and moral values. However, this model is limited when people don't have complete control over their behaviour due to resources and opportunities, e.g. not enough money, skills, time or cooperation of others (Ajzen, 1991).

Ajzen (1991) found that the TRA was not complete. A component to explain and better predict the behaviour is needed. The additional component, *perceived behaviour control (PBC)* made the TRA evolve to the TPB (Fig. 37). The PBC is a combination of non-motivational factors and the expectancy of success. The non-motivational factors are resources and opportunities which represents the situational ease or difficulty of performing the behaviour of interest. These resources and opportunities are, for example; money, skills, time or cooperation of others. The second factor, the expectancy to succeed with a behaviour, depends on the belief that a person can actually perform the behaviour. For example if a person strongly believes that he/she is able to become an aeroplane pilot, the chances to succeed are much higher than if he/she doubts it (Ajzen, 1991).

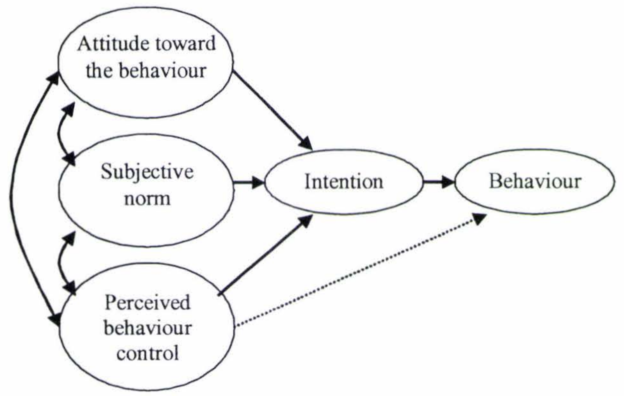


Figure 37: The theory of planned behaviour (TPB) (Ajzen, 1991).

The *intention* functions as the proximal determinant of the resulting *behaviour* (Hardeman et al., 2002). The intention is an indicator of how hard people are willing to try and how much effort they are planning to apply to perform a certain behaviour. The stronger the intention to engage in a behaviour, the more likely its performance if the behaviour is under volitional control. The usual assumption from earlier studies is that motivation (intention) and ability (behavioural control) interact in their effects on behavioural achievement. The immediate antecedent of a behaviour is the intention (Ajzen, 1991).

"Attitudes toward the behaviour, subjective norms with respect to the behaviour, and perceived control over the behaviour are usually found to predict behavioural intentions with a high degree of accuracy. In turn, these intentions, in combination with perceived behavioural control, can account for a considerable proportion of variance in behaviour" (Ajzen, 1991).

The TPB is often used to predict behaviours in health related studies. Some examples are: "condom use with main partner" (Bowen, 1996), "participation in a stepped programme of smoking cessation" (Black & Babrow, 1991), "weight loss" (Schifter & Ajzen, 1985)or "taking vitamin C tablets every day for three weeks" (Sheeran & Orbell, 1999). It is also used to predict behaviour like drink driving or being a passenger of a driver who has been drinking (Sheehan et al., 1996) or working in projects (Den Ouden, 1995). The TPB is supported by great deal of research and a complete literature review for the application of the Theory of Planed Behaviour was recently published (Hardeman et al., 2002).

The TPB was also applied to environmental issues. Bamberg (2003) did a study to answer the question: "How does environmental concern influence specifie environmentally related behaviours?" This study tests the hypothesis of the influence of environmental concerns to specific behaviours, specifically the decision to acquire information about green electricity and local providers. It was found that social psychological research, especially the work from Ajzen and Fishbein provided strong theoretical and empirical evidence that only situation-specific cognition is a direct determinant of a specific behaviour. (Bamberg, 2003)

The study "The proposition of a General Version of the Theory of Planned Behaviour: Predicting Ecological Behaviour" from Kaiser and Gutscher provides evidence for the TPB's validity to predict behaviour (Kaiser & Gutscher, 2004). "The three predictor – attitude, subjective norms, and PBC – accounted for 81% of behaviour intention's variance, within the ecological conservation domain. Intention, in turn, determined 51% of people's ecological behaviour when situational influences were controlled rigorously by means of aggregation." (Kaiser & Gutscher, in press) The ecological behaviour was assessed using the General Ecological Behaviour scale (GEB) which was used in this study to assess the intention of a person to behave in an environmentally friendly manner.

The TPB is a well-studied theory which has been already applied successfully to environmental issues. In this field, the three predictors, attitude, subjective norm and PBC, become environmental attitude, environmental values and PBC which is in every field the same because the infrastructure and resource constraints do not have a specific environmental application. The intention predicted by these three factors is measured in this study with the GEB which predicts the actual behaviour.

4.4. General Ecological Behaviour

General Ecological Behaviour (GEB) was used in this study to assess the actual state of the ecological behaviour of a person. The model PREM attempted to show the improvement potential of a person if her/she behaves in more environmentally friendly ways regarding use of energy. The GEB does not only assess the actual state of the behaviour. It can also calculate the probability for the assessed person to perform certain behaviours. The GEB is the first step of the model PREM. The results from this instrument were shown as a magnitude of the personal intention to behave in environmentally friendly ways. PREM also generated a list of behaviours which an individual will be most likely to perform and are then evaluated with regards to the potential to save money and emissions.

The current GEB version consists of 50 behaviours divided into six domains: energy conservation; mobility & transport waste avoidance; consumerism; recycling; and vicarious social behaviour toward conservation (Appendix A.6) (Kaiser & Wilson, 2004). The GEB measure works but with difficulties in its abilities to calculate the probability of a person to perform certain behaviours (Kaiser & Wilson, 2000).

Difficulties are estimations of the situational constraint beyond people's control. It can be assessed by considering how many people behave in a certain way. For example, the number of people riding a bike to work instead of driving a car. The GEB scale used in this study was based on the difficulties generated from a Swiss study with 445 participants (Appendix A.6) (Kaiser, 1998). Which difficulty a person is able to overcome depends on the general ecological behaviour of that person. This is called the "ability of a person".

The ability of a person is assessed by asking the model user if he/she already performs certain ecological behaviour (Appendix A.6). The calculation process uses the maximum likelihood method. This takes the answers from the questionnaire, and with a special search process, the ability can be calculated (Appendix A.9). In the GEB scale it is important to assess the person's ability in each domain separately. The performance probabilities are often too heterogeneous, with people behaving differently in different domains. As such person's ecological behaviour cannot be generalised across domains (Kaiser et al. 2003). Previous studies have also highlighted that people answer "never", "seldom", "occasionally", "often" and "always" very differently and unsystematically (Kaiser, 2003c). This led to the categorisation of response format, "never", "seldom", and "occasionally" which are negative and "often" and "always" which are positive (Kaiser & Wilson, 2004). This fact led to an appropriate use of the "maximum likelihood method" which works with a yes/no format (Embretson, 2000).

To calculate the probability of a person to perform a certain behaviour, the ability of that person needs to be known in the specific domain. With the use of the Rasch model (Kaiser & Wilson, 2000) the probability of a person to perform a certain behaviour can be calculated (Section 4.5). The Rasch model is a probabilistic measure whereby people can behave inconsistently. This is important due to the heterogeneous nature of ecological behaviour (Kaiser & Wilson, 2000).

With the comparison of the GEB-scale to other ecological scales, Kaiser (1998) confirmed that the dimension measured was the general ecological behaviour. "The higher the GEB-measure the lower the estimated mileage one drives or flies per year, the higher the readiness to contribute financially to ecological organisation, the greater the readiness to adopt behaviours easy and difficult to perform, which have a positive impact on the environment, and the greater the willingness to accept governmental prohibitions" (Kaiser, 1998).

The cross-cultural applicability was tested between Switzerland and the USA (California). Swiss adults were more ecologically minded than California students. The results cannot be taken to compare just the country specific differences, because the Swiss study group were adults (median age 45.5 years), compared with USA-students (median age 21 years). The difficulties of the behaviour differed due to sociocultural differences and other circumstances. For example, the climate in California means it is easier to reduce heating use in winter and in Switzerland it is easier not to drive a car into town since Swiss cities are not easily accessible by car and it is hard to find a parking space. From the 38 original items, 15 had comparable difficulties in Switzerland and California, 13 were easier to perform in California and 10 were easier in Switzerland. Because of the use of the Rasch model, the GEB scale situational influences on the behaviour are acknowledged which makes the GEB cross-culturally applicable (i.e. a culturally independent measure)" (Kaiser & Wilson, 2000). This means that the GEB scale can be used also in New Zealand where the model PREM will be applied. Furthermore, the GEB scale is a dynamic measure (Kaiser & Wilson, 2000), which means that it is possible to add desired items to the scale. But to do this an additional psychological survey would need to be performed.

The GEB measures ecological behaviour reasonably reliably where energy conservation and transport behaviour are involved (Kaiser & Wilson, 2004). This model employs feedback information about emissions and cost savings as a motivating factor for ecological behaviour, which is a person's ability to behave environmentally friendly in the two measured domains of, energy conservation and mobility and transport. Previous studies indicated that providing feedback improved energy conservation by up to 15% illustrating the importance of this type of information (Stern, 1992). Feedback also makes the model more personalised and vivid.

4.5. Rasch model

The Rasch-model, developed by George Rasch in 1960, is used in this study to calculate the probabilities of performing a certain behaviour (Bond & Fox, 2001). He developed this mathematical model for constructing measures based on a probabilistic relation between an item's difficulty and a person's ability. With a mathematical based procedure the Rasch model compares the ability of a person with the difficulty of a behaviour. The result of this calculation is the probability of the person to perform the behaviour.

This model helps to transform raw data into an abstract interval scale. The basic concept of the Rasch model compares the ability of a person to the difficulty of a behaviour, by predicting the probability of performance. Each behaviour has a measurable degree of difficulty, for example behaviour B, (e.g. I wash dirty clothes without pre-washing), has a difficulty of –1 (Fig. 38). The difficulties can be assessed with a psychological survey. Accordingly, each person has an ability. For example Bill's ability is –1, which stands for the ecological behaviour of that person. The ability in this case is assessed with the GEB-scale (Section 4.4).

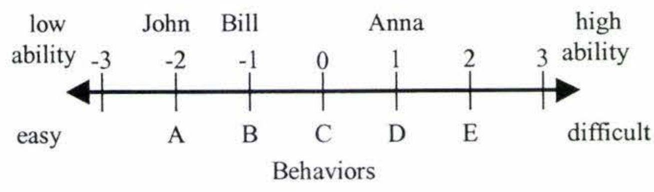


Figure 38: Person-Item logit scale for the basic Rasch model concept

If the difficulty of a behaviour and ability have the same value on the scale, then the probability of that person to perform the specific behaviour is 50%. For example, the probability that Bill is able to perform behaviour B is 50%. This means, the chance that Bill washes his clothes without pre-washing is 50:50. The scale works as a logit scale. For every, so-called logit step (one step on the scale), the probability changes by one logarithmic interval. For example Bill's probability to perform behaviour A, (e.g. I prefer to shower rather than to take a bath), which is easier than B, increases to 75%, decreases for behaviour C (e.g.

For longer journeys (more than 6 hours), I take an airplane) to 25% and for D (e.g. In the winter, I turn down the heater when I leave my apartment for more than 4 hours) to 12.5% (Bond & Fox, 2001). These probabilities can be calculated with the Rasch formula (Appendix A.8).

A desirable feature of the Rasch model is, that both item property and person's ability are linked to the behaviour. The item difficulty and the person's ability are independent variables, which have to be estimated separately (Embretson, 2000).

4.6. Summary

This study utilises some general findings from general environmental psychology such as providing feedback and presenting the information in personalised and specific ways. It also integrates the research finding that the unit for the services which people understand the best are money values per month. The model PREM will show the money spent for each service per month.

The TPB is the basic theory of this study which is used to conceptualise and facilitate behaviour change. The three factors, attitude, subjective norm and PCB prediction of the intention, which is measured with the GEB. By knowing the intention to perform the behaviour the probability of a person to perform a specific behaviour can be calculated. This information is needed in this study in order to show the user where he/she can most likely change their environmentally related behaviour. This component of the project helps to make the information specific and personalised for each user.

The user of the model PREM will be provided with the behaviour in a list due to the probability of performing them. This list shows the user where he/she is most likely able to change the behaviour. The technical assessment and calculation will add a dollar and emission value to the behaviour which shows the user the expenditures and improvements based on a monthly period. This is where psychological approaches are combined with technical information.

5. Chapter Model Data Input

5.1. Introduction

This chapter takes the model and fills the gaps with data. In the next few pages is written where the data comes from, who provided the information and the data calculations. The model uses many databases to allow the user the easiest possible input. By showing a list of several cars for example, the user just needs to know the brand and model name. The database then provides the relevant data like fuel consumption to calculate the energy use. This approach aims for easy data input with accurate output.

Section 5.2 explains how house construction is considered in the model. Household features influence the energy usage significantly. The average house in Auckland needs approximately a third of the entire household appliance energy consumption to heat it. The distribution of the household energy is similar overall New Zealand.

Section 5.3 provides information about the electricity and fuel cost and how they are included in the model. The data is from the Ministry of Economic Development (MED). One of the main aims of the MED is to promote sustainable economic development based on economic, social and environmental ideas (MED, 2003a). This made the Ministry to monitor relevant data as indicators and benchmarks.

Section 5.4 shows how the CO_2 emissions can be shown as a monetary value with the inclusion of a carbon tax which will be in place by late 2007.

Section 5.5 covers the generation of electricity and the production of fuels which emits CO_2. The model calculates the monthly energy cost and the CO_2 emissions. Electricity generation is not exclusively from renewable sources but also from thermal generation using coal and gas powered stations which emit CO_2. Producing petrol or diesel is a process which includes drilling at the platforms, transportation and refining. Although a LCA[13] could not be applied, in the scope of this study.

Section 5.6 covers the transport part which is partly private transport (car and bike) and public transport (bus, train, air travel and ferry).

Section 5.7 assesses the appliance energy usage. A mix between databases and figures from the HEEP (Household Energy End-use project) study was used.

[13] In the case of producing diesel a LCA should take the energy used for the oil platforms, transportation, refining, etc into account.

5.2. House construction

The house construction is an important part of energy usage in a dwelling. The insulation, size and draughts significantly influence the required heating energy. A BRANZ study showed that around a third of the household and appliance energy consumption is used to heat the house (BRANZ, 2002).

To accurately assess the required heating energy an elaborate building simulation program needs to be implemented which requires a lot of knowledge of the house design and construction. However this model provides a simpler input. If the user likes to have a more accurate input than the averages provided, which will be discussed later, he/she can do the detailed calculation using the building simulation program ALF3 (2000). This simulation program was developed by BRANZ and is a very sound method to assess the design of the house and the climate including floors, walls and windows, roofs and skylight, air leakage and thermal mass (ability of materials to store heat). The ALF program also includes solar gains, with window size, orientation and shading used for calculation. Solar gain can help the heating significantly. For example the Rocky Mountain Institute in the mountains of Colorado uses solar energy for 99% of the heat demand of the building. The other 1% is covered with a wood stove (Weizsäcker et al., 1997).

In this model the main building energy input takes average values for three different house designs, which is easy to handle and does not require much knowledge. The most common houses in New Zealand are constructed with lightweight prefabricated timber frame assembled and fitted outside (Vale & Vale, 2001). The two most common floor constructions are suspended particleboard floor on a tanalised timber pile foundation or slab on ground. The most common wall construction used is a timber frame with 94mm of glass fibre insulation. The windows are often large and single glazed with aluminium frames (Vale & Vale, 2001).

The basis of the simulation are the three construction types evaluated by the Building Industry Advisory Council's (BIAC) in New Zealand with the following specifications (Vale & Vale, 2001):

Level site; floor area 94m2 (14m x 6.7m); 3 bedrooms with open plan living, dining and kitchen; separate bath/WC/laundry, sloping ceiling with exposed rafters in living and dining areas and flat ceiling in other areas. For this standard house design three different constructions (further specified in Appendix A.10) show how much the required heating energy can vary (Vale & Vale, 2001). These three constructions were simulated with the building simulation program ALF (Section 2.11.4). The required heating energy for the constructions differs (Vale & Vale, 2001):

1. Lightweight construction: 3116 kWh/annum
2. Heavy construction: 2672 kWh/annum
3. Super insulated construction: 709 kWh/annum

Assuming the entire house is heated exclusively with electric heaters and the electricity price is 14 cents/kWh, the heating energy for the lightweight construction would cost NZ$ 436.24 per year, the heavy construction NZ$ 374.08 per year and the super insulated NZ$ 99.26 per year. The difference of the energy cost per year between the light weight and the super insulated construction would be NZ$ 336.98 .

5.3. Electricity and fuel costs

Gas and electricity bills provide easily accessible data to assess the overall energy consumption and energy costs for the entire household. Additional energy costs appear from wood and LPG.

A single bill does not exist for transport. This calculation is done using data of vehicle fuel consumption, distance and fuel prices. Public transport costs require input from the user due to the complexity of the pricing system and various special offers available.

5.3.1. Electricity

Electricity prices in New Zealand vary depending on how many meters the house has, which retailer and the tariff chosen. The New Zealand Consumer Association has a web page to find the cheapest contract due to the location and electricity use (Consumers' Institute of New Zealand, 2001). This takes the location, the amount of power used per year and the different offers into account and finds out the best match. The electricity market in New Zealand was liberalised in 1998 in order to lower the electricity costs with active competition. The average retail price for electricity domestic tariff did fall a while after the liberalisation in 1998, but has increased since (Fig. 39).

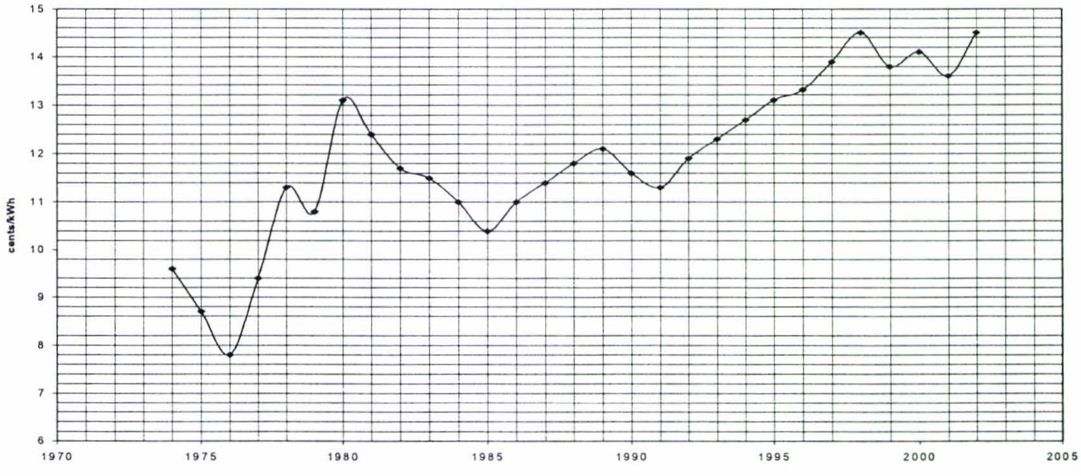


Figure 39: Average domestic retail electricity price in New Zealand from 1974 to 2002.

Source: (MED, 2003b)

The average retail price for 2002 was 14.5 cents/kWh (including GST) (MED, 2003b). This was a similar price to 1998 at the time of liberalisation. Figure 39 shows that the electricity price in the model needs to be updated at least once a year as it can change significantly. This average price is used only if the user does not know the price paid for the electricity. Accordingly the electricity price would allow a plausibility check of the inputted data by the software.

The model will need to know how much electricity is used during a certain period and how much the consumer paid for it. This will be assessed when the model user is asked for some figures from his/her electricity bill.

5.3.2. Natural gas

The primary New Zealand gas products are mains supplied natural gas and liquefied petroleum gas (LPG). Mains gas is distributed in the North Island by some power companies or specialised gas companies but not in the South Island.

The average price in 2002 for mains gas was NZ$ 17.65/GJ (including GST) (6.35 cents/kWh, Appendix A.11) (MED, 2003b). This gas price 2002 was lower than in the early 1980's (Fig. 40). The price for gas in the model needs to be adapted according to the price trends that the model stays accurate.

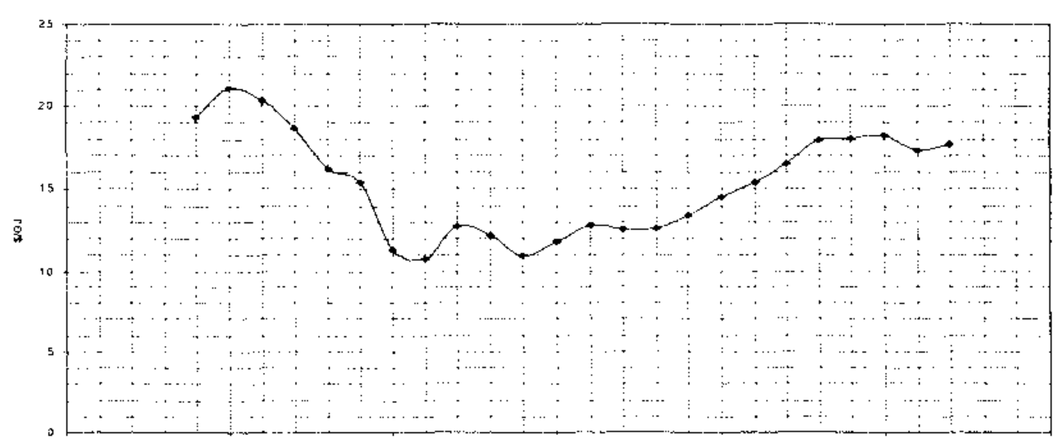


Figure 40: Mains natural gas residential average prices in $/GJ from 1974 to 2002. Source: (MED, 2003b)

The model requires inputs of the amount of gas consumed during a certain period and how much the consumer paid for it. The model will provide a similar format to the gas bill to allow simple input of data directly from the bill.

5.3.3. Liquefied petroleum gas

LPG is used for portable heaters and car fuel. It is available at gas stations and is filled in bottles. The price changes over time and is currently fairly low compared to 1991 (Fig. 41)

Figure 41: LPG prices in cents/litre from 1991 to 2002. Source: (MED, 2003b)

The price differs between the gas stations and consumers are not expected to have an overview of the exact figures for filling up their bottle at different stations. The price used in the model is the last available average price using the same approach as for petrol which is described below. In 2002 the average price for LPG incl. GST was 65cent/litre (MED, 2003b)

5.3.4. Car fuel costs

The main car fuels are petrol, diesel and LPG. The prices for petrol and diesel change, mostly due to the oil price (Fig. 42). The model takes the latest available average for 2002, being 102.1 cents per litre for premium petrol, 97.0 cents per litre for regular and 63.9 cents per litre for diesel (MED, 2002a). These prices are used to calculate the vehicle fuel costs per year of the model user. The large price changes show the importance of updating the model with current fuel prices.

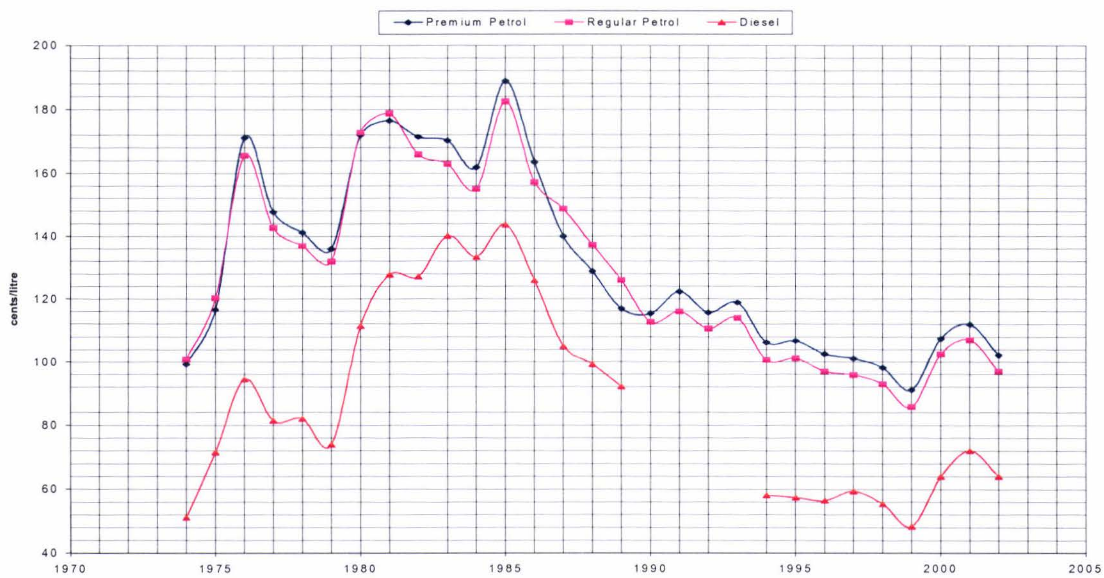


Figure 42: Premium petrol (96 RON), regular petrol (91 RON) and diesel prices incl. GST in New Zealand between 1974 - 2002. Source: (MED, 2002a)

Diesel prices are quite low compared to the petrol price because of the tax system with petrol taxes being included in the price at the gas station, while diesel has a separate road user charge for road vehicles. With this approach the government is able to tax cars differently than trucks or buses. The diesel car user has to pay an additional tax for the driven kilometres. For a vehicle with two axis, single tyres and under 2 tonnes which characterise a standard car, the tax is NZ$ 24.74 per 1,000km (LTSA, 2002).

5.3.5. Solid fuel costs

Wood prices cannot easily be taken as an average value. Some people cut their own wood for the winter, some own forests and others need to buy it from one of the many wood retailers. Wood is often sold in "trailer loads", which is a fairly weak unit. By law everybody has to give a price in "stacked cubic metres" which is when the cut wood is thrown on a trailer for example. The model asks the user about the price paid per stacked cubic metre and will then calculate the costs of the supplied heating energy.

The wood price calculation needs some assumptions as the model should not get too complicated for the user although the assumptions can be changed if the user has the required knowledge. The assumptions are based on figures of typical fuel wood (moisture content 20%, bulk density 170 kg/m^3, lower heat value 16 MJ/kg, typical wood heater efficiency 65% (Sims, 2002). Using these figures and the wood price, which need to be prompted by the user, the model calculates the annual fire wood bill to provide the required heating energy (Table 2).

Input: Required heating energy			**1336**	**kWh**
Required heating energy with typical heater efficiency of 65%			2055.38	kWh
Solid mass of wood (calculated with conversion factor)			462.42	kg
Conversion factors (Fuelwood 20% m.c.)	16	MJ/kg =	4.4448	kWh/kg
	1	MJ =	0.2778	kWh
		density	170	kg/m3
Wood loose			2.72	m3
Loose wood price (input from the user)			10.45	NZ$/m3
Output: Wood bill			**28.40**	**NZ$/year**

Table 2: Example of a wood price calculation based on the required heating energy for a house. Source: (Sims, 2002)

5.4. Carbon - Tax

The Ministry for the Environment (MfE) established the New Zealand Climate Change Programme and published the climate change confirmed policy package which was announced by the government in October 2002 (New Zealand Climate Change Programme, 2002). One of the key policies which should take place after 2007 will apply an emission charge on fossil fuel and industrial process emissions. This charge will approximate the international carbon price, but will be capped at NZ$ 25 per tonne of carbon dioxide equivalents[14]. The revenue from this charge will be used to support climate change projects and programs. A charge of NZ$ 25 per tonne of carbon dioxide equivalents is expected to increase the petrol price by 6c/l, diesel 7c/l, electricity 9%, gas 8% and coal 19% (New Zealand Climate Change Project, 2002).

The model uses the charge of NZ$ 25 per tonne of carbon dioxide equivalents in the monthly bill. The charges will not be applied until late 2007 but the model shows how much the model user will pay once it comes into force. It is also important that the user has a value in dollars per month for the CO_2 emissions as people are not often able to judge physical values (section 3.7).

[14] Carbon dioxide equivalents are GHG compared to the climate change impact of carbon dioxide; One tonne CO_2 is one tonne CO_2 equivalents; one tonne of methane is equivalent to 23 tonne of CO_2 equivalents, (IPCC, 2003)

5.5. Electricity and fuel production

The CO_2 emissions from electricity generation and fuel production are calculated with data from the MED (MED, 2002b). The use of electricity does not emit CO_2 directly, rather the emissions come from coal or natural gas used for generation. The use of fossil fuel emits CO_2 and in addition CO_2 is emitted in the production of the fuel.

The model does not calculate a complete life cycle analysis (LCA) of electricity and fuel production. Rather it includes closely related CO_2 emissions in order to show the difference of the energy sources. An LCA would additionally include the building of the production infrastructure and the transport of the fuel.

5.5.1. Electricity

May consumers have a choice of retailer in the New Zealand electricity system. The retailer buys electricity from the spot market and may also be a generator, meaning the consumer does not have a complete choice of how their electricity is produced. In a very few cases the consumer has the choice of generator as some generators supply a certain area with their electricity, and are not connected to the national grid. These embedded generators are connected to local distribution lines. No special offers for the consumer exist in New Zealand to buy sustainably produced "green" electricity. Therefore the model calculates the GHG emissions as a percentage of the national generation which came in the year 2001 to a total generation of 38,305 GWh (MED, 2003b), mostly from natural gas and hydro generation (Fig. 43).

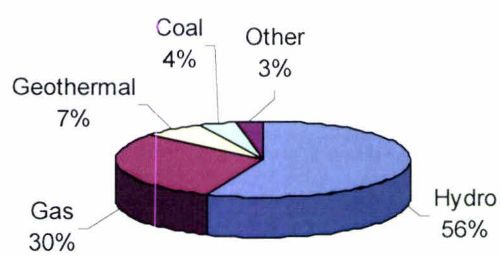


Figure 43: New Zealand's Electricity Generation in percentage by fuel 2001. Source: (MED, 2003b)

The MED provided a report called "Energy Greenhouse Gas Emissions" which keeps track of the greenhouse gas emissions from the industrial processes sector, such as the energy industry (MED, 2002b). CO_2 emissions from the electricity generation were 6,800,567 tonnes in 2001 from the actual generation and not a life cycle assessment. Thus emissions due to maintaining the generation or building the power stations were not included. The report provides emission values for each fuel type (Fig. 44).

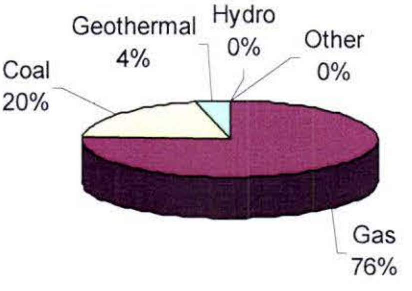


Figure 44: New Zealand's electricity generation CO_2 emissions in percentage by fuel 2001. Source: (MED, 2002b)

With this information an average emission factor[15] for New Zealand's generation was calculated (Table 3) for 2001 to be 0.17754 kg CO_2 per kWh. The emission factor is not the same every year as circumstances vary. 2001 was a fairly dry year, so hydro generation was lower due to dry periods and consequently the CO_2 emission factor was higher.

[15] Emission factors are conversion factors used to calculate the equivalent CO2 emission from a quantity of fuel of a certain activity.

	Generation [2]	Emission [3]	Emission factor
	GWh	t CO_2	t CO_2/GWh
Hydro	21392	0.00	0.00
Gas	11623	5198000.00	447.22
Geothermal	2700	268000.00	99.26
Coal	1385	1334000.00	963.18
Oil	0		
Biogas	100		
Steam	637		
Wood	332		
Wind	136		
Other	1205	567.00	0.47
Total	**38305.2**	**6532567.00**	**170.54**
Uncertainty:		+-3%	
			0.00017754 CO_2 t/kWh

Table 3: Electricity production CO_2 emission calculation for New Zealand generation in 2001.

Sources: 1: (Boyle, 1996); using integrated gas turbine cycle. 2: (MED, 2003b). 3: (MED, 2002b)

By taking the LCA emission factors from a US study (Boyle, 1996) to compare, it is possible to see that hydro power has some CO_2 emissions. These emissions are from concrete manufactured dam building, and maintaining the power station and distribution lines. Still 56.4% of the electricity in New Zealand was generated by hydropower and caused just 1.3% of the CO_2 emissions (Fig. 45). Electricity generated by gas was 29.9% and produced 84% of the CO_2 emissions.

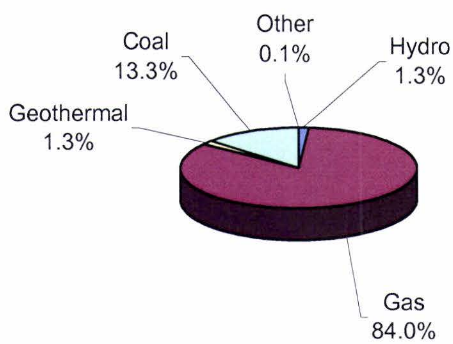


Figure 45: New Zealand's electricity generation CO_2 emissions in percentage by fuel for March year 2002 using LCA international emission factors

5.5.2. Oil and gas products

Oil and gas products do not just emit CO_2 during combustion, as it is also emitted before the fuel goes into the fuel tank or the gas bottle. Hence transportation, building of the refinery, and the maintenance are not included in the calculation but the extraction and processing emissions.

77% of New Zealand's oil products were imported in 2002 and 23% were from domestic oil fields (MED, 2003b). New Zealand also exported 78% of the locally produced crude oil, condensate and naphtha[16]. To calculate the CO_2 emissions of the production of the imported products would need a larger study. The CO_2 emissions of New Zealand produced products can be partly assessed using figures from MED. The gas sector is without exports or imports.

[16] Various volatile, often flammable, liquid hydrocarbon mixtures used chiefly as solvents and diluents

Factors for gas products are not similar because the composition of the gas varies. Mains gas in New Zealand is natural gas (MED, 2003b) and is entirely produced in the Taranaki region. This region has eleven gas and oil fields of which the Maui field dominates gas production. The entire gas production in 2002 was 238.8PJ (MED, 2003b). The emission factors for the different forms of gas sold are very close: treated gas 52.7 t CO_2/TJ, Maui sales gas 52.8 t CO_2/TJ and mixed gas 52.8 t CO_2/TJ (Baines, 1993). The error from taking the emission factor of 52.8 t CO_2/TJ for treated gas would be 0.19%, including CO_2 from combustion. LPG is also mainly from the Maui field (Baines, 1993). The gas compositions may have changed slightly during the last ten years but no newer data exists.

The GHG (MED, 2002b) does not list emissions from oil and gas products separately with the exception of refining. The combined emissions are fugitive, and extraction and processing. Using these data and the total produced oil and gas an approximation can be calculated showing the production related emission factor (Table 4).

	All oil product	
Fugitive CO_2 emissions	306	kt CO_2
Refining	375.79	kt CO_2
Extraction & processing	294	kt CO_2
total	975.79	kt CO_2
Oil production	215.66	PJ
Gas production	265.25	PJ
Production PJ	480.91	PJ
Emission factor	2.029057358	kt CO_2/PJ
	2.029057358	kg CO_2/GJ
	0.00000202906	t CO_2/MJ

Maui GCV	101.325	kPa	0.0390	MJ/l
CNG GCV	24800	kPa	9.5455	MJ/l
Maui NCV	101.325	kPa	0.0352	MJ/l
CNG NCV	24800	kPa	8.6154	MJ/l

	GCV		t CO_2/Unit	Unit
CNG [3]	9.5455	MJ/l	0.0000193684	l
Mixed gas [3]	35.4	MJ/m3	0.0000718286	m3
			0.0000005637	kWh
LPG [1]	49.51	MJ/kg	0.0001004586	kg
	26.44	MJ/l	0.0000536483	l
Premium Gasoline [1]	35.4	MJ/l	0.0000718286	l
Regular Gasoline [1]	34.7	MJ/l	0.0000704083	l
Diesel AGO [1]	37.8	MJ/l	0.0000766984	l

1MJ=	0.2778	kWh	[3]
	7.345032	kWh/litre	

	Furuholt LCA [4]	Calc above	Units
Diesel	120	76.70	kg CO_2/1000l
Regular Gasoline	200	70.41	kg CO_2/1000l

Table 4: Emission factor calculation for fuels in New Zealand.

Sources: 1: (MED, 2003b). 2: (MED, 2002b). 3: (Baines, 1993). 4: (Furuholt, 1995).

The reticulated natural gas sales streams serving the North Island are treated gas (mixture of processed Kapuni Gas and Maui Gas), Maui sales gas and mixed gas (Maui and treated) (Baines, 1993). The price differs between gas retailer and region and consumers are charged by the unit (GJ). The meter in the house measures the volume of gas used in cubic metres. They use then the calorific value to convert the volume into an energy figure, due to the supplied gas type.

Fuel production consumes energy and causes emissions. A Norwegian study assessed fuel production in a LCA (Furuholt, 1995). It analysed the entire production chain from the oilfield to the petrol station, using the example of an offshore oilfield in Norway. The circumstances of New Zealand fuel production are not the same thus the factors can only be used to compare the results. The Norwegian study found CO_2 emissions of 200kg CO_2 per 1000 litres of regular gasoline produced and 120kg CO_2 per 1000 litres of diesel produced (Furuholt, 1995). Higher emissions for regular gasoline production than diesel production by the Norwegian study compare to the calculation used in this study (70.4kg CO_2 per 1000 litre regular gasoline and 76.7kg CO_2 per 1000 litre diesel). The MED which provided the data for the calculation in this study does not report separate figures for diesel and petrol (Table 4). The differences between the different fuels are only according to the calorific value. A more detailed study would need to be done to compare the fuel production emissions more accurately.

Another comparison can be done with emission factors from the Landcare Research New Zealand[17] and the World Business Council for Sustainable Development (WBCSD). For fuels the emissions were calculated only for the combustion of the fuel (Appendix A.12). Landcare Research manages a carbon emission calculation project EBEX21 (2003). This project started with an emission calculation and reduction program for small and middle sized businesses which calculated emission factors for a variety of fuels and transportation modes.

[17] New Zealand's environmental research organisation specialised on sustainable management of land resources, (Landcare Research, 2003)

The EBEX21 emission factors are based on IPCC (2001) and adjusted for New Zealand conditions. To validate and compare the EBEX21 factors the emission factors of the WBCSD were used (Appendix A.12) (WBCSD, 2003). These factors are the international IPCC emission factors and are international averages mainly for Europe and the United States. The comparison between EBEX21 and WBCSD factors shows that diesel and gasoline fuels are very similar.

5.6. Transport

Domestic land transportation in New Zealand was responsible for 42% of energy related CO_2-emissions in 2001 and likely to increase (MED, 2002b). Car use, bikes and public transport are compared in this model. The calculation for the car emissions are the most complicated because the model assesses the car model, fuel type and driven kilometres to show the user the differences.

The transport section of the model uses emission factor for the car fuels according to section 5.6.2 and for the other transport modes from EBEX21 which are calculated per passenger kilometre (Appendix A.12). The emission factors for international and domestic flights do not differ between the WBCSD and the EBEX publications, while for other transport modes WBCSD emission factors were used to compare the accuracy. Train emission factor in the EBEX21 database is an average value for the New Zealand train network, based on partly diesel and partly electric locomotives. The EBEX21 factors are lower than the diesel and electric locomotive factors of the WBCSD most likely due to the fairly high percentage of hydro electric generation, which does not emit CO_2.

5.6.1. Car

The main factors of a car which needs to be assessed to calculate the energy cost and CO_2 emissions are the fuel consumption, fuel type and the driven kilometres. The user is not likely to know the fuel consumption of his/her car, therefore a database such as provided by the AGO is used. This "fuel consumption guide" - database includes the major brands and types sold in Australia and New Zealand respectively. With this approach the model user just needs to know brand and type of his/her vehicle.

The choice of fuel is another important factor, with diesel cars more efficient than petrol cars. For instance the Peugeot 406 petrol model has an average fuel consumption of 9litres/100km city use and 6litres/100km highway use. The exact same model with a comparable diesel engine has an average fuel consumption of 6.8litres/100km city use and 4litres/100km highway use (AGO, 2003b), which equates to almost 25% and 34% respectively lower fuel consumption than the petrol car. The problem with diesel at the moment is the sulphur portion in the diesel and the emitted particulates which causes respiratory health problems. Both problems are possible to solve, as retailer Gull sells a 99% sulphur free diesel and some cars are ready to be purchased with a particle filter. Another fuel option is biodiesel[18] which is considered carbon neutral. The standard model Volkswagen Golf used in the Energywise Rally 2002 was driven 1500km from Auckland to Wellington and back by a Massey University team with 100% biodiesel at 4.7l/100km at an average speed of 75km/h (Appendix A.27).

The Department for Transport (DfT) in England has a Vehicle Certification Agency (VCA, 2000) providing a database of car emissions and noises. The emission tests are conducted by independent organisations, manufacturers or importers and officially recognised by the DfT after its credibility is evaluated by inspecting the laboratories and witnessing some tests or by checking certification of other governments. The database provides a figure for CO_2-emissons per km for a wide range of cars, dating back to 2000. The US Department of Energy (DOE) provides fuel consumption data of 1978 until 2004 models (DOE, 2003a), however this database does not provide emission figures such as the VCA database.

The database chosen for the PREM model is from the Australian Greenhouse Office (CD-Appendix A.29 & A.30) (AGO, 2003b). The reason for this choice is its similarity to the New Zealand car market. The European and the US markets are slightly different although most of the models are international and differ mostly in the names. Vauxhall Astra for example is the model sold in Britain, Opel Astra in Europe and Holden Astra in Australia and New Zealand. Some standards differ as well, for example in Europe the emission limits are prescribed in the Euro IV rule which does not exist in New Zealand or Australia.

For cars which are too old or too exotic to be included in the database, an alternative input is provided where the user needs to know the fuel consumption in l/100km. This figure can be obtained from the retailer. Another possibility is to set the trip meter to zero with a full tank. When the car is filled up again the volume of tanked fuel can be divided by the distance on the trip meter and multiplied by hundred. The result will be the fuel consumption in litres per 100 kilometres. This is the most accurate method to find out the fuel consumption if this is not done under special circumstances such as holidays. The advantage of this self assessment is that the specific model and the personal driving style are included. During the Energywise Rally 2002 in New Zealand the participating cars tried to drive from Auckland to Wellington

[18] Biodiesel: Diesel produced with natural oils such as canola oil or oil from tallow can be used in new diesel engines without modification for the most part.

and back with the lowest possible fuel consumption. The driving style was an important factor in fuel consumption. For instance the Volkswagen Passat driven by a Massey University team completed the distance with an average fuel consumption of 6.1litres/100km (Appendix A.27). This compares to the figure in the VCA (2000) databases of 8.4litres/100km and in the AGO (2003b) database of 11litres/100km for city use and 6.4litres/100km for highway use. This example shows the potential fuel saving effect of fuel efficient driving habits.

Once the fuel consumption is known total monthly fuel consumption requires assessing the driven kilometres. The user will be provided at the start of the program with a few tips on how to prepare the information to being using the model. Writing down the odometer number and the date at two different times can determine the driven kilometres. The longer the time between the two reading, the more representative the result of the calculation. An easy approach to this would be to take the first reading from a registration date or warrant of fitness (WOF) document and the second reading then can be the current one assuming it is several month later. With this figure it is possible to calculate approximately the average litres used per month. Emission factors for combustion, published by EBEX21 (Appendix A.12), and the emissions caused by the production of the fuel (Section 5.5.2), provide the needed information to calculate a figure for the CO_2 emissions.

The fuel costs can be calculated from the used litres and the average fuel price (Section 5.3). Fuel costs are not the only costs associated with private transport. To compare these with public transport running costs need to be taken into account. The New Zealand Automobile Association publishes example car running costs (NZAA, 2002), as averages for four different categories. If the model user knows his personal running costs, an alternative input is available.

5.6.2. Bike and walk

Cycling and walking are considered to have no CO_2 emissions as they do not produce a significant amount of CO_2 and since it is from digestion of food from crops, the carbon is recycled. To take the entire life cycle into account CO_2 emissions associated with producing the bike would need to be calculated as well, which is outside the scope of this study but expected to be a negligible part.

5.6.3. Ferry

The main ferry in New Zealand is the connection between the North and the South Island over the Cook Strait between Wellington and Picton, 83 km (Vanisha, 2003). Three different services are available, the Interislander, the Lynx and the Bluebridge. Prices for the ferry ticket can vary significantly, with a one-way ticket using the Interislander service varying between NZ$ 25 and NZ$ 52 (Supersaver and standard fare at peak times) (Interislander, 2003). The prices differ mainly due to the time when the passenger likes to travel (high/low season), the ferry service chosen and the refund insurance. The model user needs to know the money spent on ferry travel in the last year.

The emission factor 0.45kg of CO_2 per passenger is based on a non-conditioned monohull ferry with 20% occupancy (Hargreaves, in press) (Appendix A.12). This figure will not lead to an exact result, but it will give a good assumption without requiring too much input from the model user. To have an exact emission figure for ferry usage an emission factor for the different services and occupancies would need to be assessed. This would give the user a choice of the more environmental friendly service. Ferry emissions are not expected to be a major part, but still need to be included to compare air travel and ferry travel combined with car or train.

5.6.4. Aeroplane

The prices for plane tickets vary a lot due to many reasons, such as popularity of the destination, season, airline, number of stopovers, travelling class and special offers. These reasons would make it very difficult and inaccurate to find an average price in dollars per kilometre. To have an acceptable figure, the model users will need to know how much they paid for the plane tickets.

The other numbers the model needs to know are the travelled kilometres and the emission factors which are published by EBEX21 as CO_2 emissions per passenger kilometre (Appendix A.12). The emission factor distinguishes between international and domestic flights. International flights have a lower emissions factor per passenger kilometre, because long flights spend proportionally less time taking off and landing, and so have a lower climb power per kilometre. Emission factors are calculated for an average occupancy of the plane. To help determine the distances travelled a few distances to popular destinations are provided (Hargreaves, 2002):

Auckland to Wellington	480km
Auckland to Christchurch	740km
Wellington to Christchurch	300km
Auckland to Sydney	2170km
Auckland to London	19000km

With the ticket costs and the travelled kilometres the model is able to calculate the monthly costs and the monthly CO_2 emissions.

5.6.5. Train

The rail network is reasonably small in New Zealand with the main connections being between Auckland and Wellington, Picton and Christchurch, and Christchurch and Greymouth. Tranzscenic offers most services while in Wellington and Auckland, Transmetro offers some train services in and around the cities.

The prices differ mostly due to availability, night/day train and special offers. For example the day train between Auckland and Wellington can cost between $73 up to $145 (Tranzscenic phone enquiry, 16. June 2003). For this reason the costs need to be entered by the user in the same way as air travel tickets. Tranzscenic and Tranzmetro provide fare finders to find out the cheapest way of using the train (Tranzscenic, 2003; Tranzmetro, 2003).

The emission factor per passenger kilometre provided by EBEX21 is an average factor between diesel and electric locomotives and also for an average occupancy (Appendix A.12). To use this factor the kilometres travelled need to be known. To assess the travelled kilometres some distances are provided as help (Chapman, 2003):

Auckland to Wellington	680.7kms
Auckland to Rotorua	139.0kms
Palmerston North to Wellington	136.2kms
Picton to Christchurch	347.3kms
Greymouth to Christchurch	223.8kms

With this information the model will calculate the monthly cost and the monthly CO_2 emissions.

5.6.6. Bus

The New Zealand inter city bus network is very comprehensive and it is possible to reach most destinations . Two main services are available. InterCity Coachlines is a regular bus service with a frequent timetable (InterCity Coachlines, 2002) and connects all the major cities and a few rural towns (Fig. 46).

Figure 46: New Zealand's bus connections by InterCity Coachlines. Source: (InterCity Coachlines, 2002)

The prices vary a lot with different offers. Passes are available to tour around New Zealand (InterCity Coachlines, 2002) and cost between $480 and $636 for an adult, depending on the number of destinations. Regular tickets between towns vary due to special fares with students having 20% discount on standard fares, Backpackers 15% and persons older than 60 years 20%. The saver fares are just available on selected services and can give a discount of 25% or 50% (InterCity Coachlines, 2002).

The second type of bus service is a Magicbus or Kiwi Experience (Magicbus, 2003; Kiwi Experience, 2003). These services are specially made for backpackers and travellers, and sell mainly passes for required areas such as only North Island, only South Island or both. The shortest distances on highways between cities are provided in a table to determine the travelled distance by the model user (Appendix A.13)

The emission factor used was 0.02 kg CO_2 per passenger kilometre. This is the recommended factor for individual bus transport in New Zealand (Hargreaves, in press) (Appendix A.12).

5.7. Appliances

The main aim of the model is to identify which services the model user is paying money for and producing CO_2 emissions. To achieve this, an assessment of their household appliance consumption was done. The approach used to solve this is to implement databases with the consumption data for a variety of appliances where the consumer can choose his/her appliance, as well as usage time. The implemented databases come mainly from the Australian Greenhouse Office (AGO) and were chosen because appliances used in Australia and New Zealand are quite similar. The Australian and New Zealand Government also work on the same standards so most appliance energy standards are the same. For example the star rating system used in New Zealand is taken from commonly used standards. Unfortunately rating systems for gas appliances are not common in New Zealand yet and a rating system for cooking stoves and hot water heaters does not exist at the date of writing.

The largest energy using appliances are hot water heaters, heater/air conditioners, lightning, refrigeration, cooking, TVs, computers, dryers, dishwasher and washing machines which is explained in chapter 3. This study does not take standby energy into account as this would make the model too complicated and confusing.

The calculation of the costs and emissions of the used energy are calculated according to the fuel type. Most of the household appliances run with electricity. The electricity costs are described in section 5.3.1 and the electricity emission factor in section 5.5.1. With the electricity consumption and the factor the costs and emissions can be calculated.

5.7.1. Heaters & air conditioners

Due to the climate, very few houses in New Zealand have air conditioners. The HEEP study from BRANZ is currently monitoring (July 2003) 286 random selected houses, and only 6 have air conditioners, giving a rate of 2% of the analysed houses (Camilleri, 2003). Therefore this study will exclude air conditioners.

Due to a lack of a database and the high number of different heater models the percentage of the fuel used for the heating system is assessed with the required heating energy known from the house specification, as discussed above. In New Zealand gas heaters are very common with 71% of all houses using portable LPG heaters in 2001 (BRANZ, 2002). Other common forms of heating are electric heaters, wood fired stoves and open fireplaces. Electricity, LPG, natural gas and wood are the heating fuels used by this model, and each has different specifications. An electric heater is 100% efficient, every kWh of electricity being converted into a kWh of radiated heat (Consumers' Institute of New Zealand, 2001). But the way of producing the electricity is not so efficient. The efficiency of gas and wood heaters depends on the type of heater used. The average efficiency of flue less gas heaters is 95% (Rinnai NZ Ltd, 2003) and an average efficiency for wood stoves is 65%. If the user knows the efficiency of his/her heater this can be entered into the model. The user can also tell the model what percent of each fuel type is used to heat his/her house. For each fuel type the required fuel amount is calculated from the heater efficiency and the required heating energy.

The electricity and gas costs are known from the bill data input at the start of the model (Section 5.3). The wood costs need a separate calculation described above (Section 5.3.5).

Again the emission factors from EBEX21 were used to calculate the CO_2 emissions from the required fuel energy calculated by the model (Section 5.5.1 & Appendix A.12). The emissions of the production of the fuels are included (Section 5.5.2), with wood considered carbon neutral, as the CO_2 intake of the trees during growth being equal to the CO_2 emitted by their combustion.

5.7.2. Lights

Lighting is responsible for 13.8% of total household energy consumption (BRANZ, 2002). There are several different kinds of light bulbs on the market, with the main types being incandescent and compact fluorescent (CFL) bulbs. Incandescent bulbs are historically and currently the major light source. An incandescent light bulb emits just 3% of the original energy used for generation in light (Weizsäcker et al, 1997). CFLs are more efficient with a 14W CFL bulb emitting the same amount of light as a 75W incandescent bulb. As well as an efficiency increase, CFLs also have a 6 times greater life expectancy (Philips New Zealand, 2003).

A comparison of incandescent and CFL light bulbs shows the purchasing cost and the electricity cost of usage compared to running time (Fig. 47). The example was calculated for a 60W incandescent light bulb manufactured by Philips purchased for $1 and compared with an 11W CFL (same light output as a 60W incandescent) also manufactured by Philips purchased for $8.50 (Warehouse, 2003).

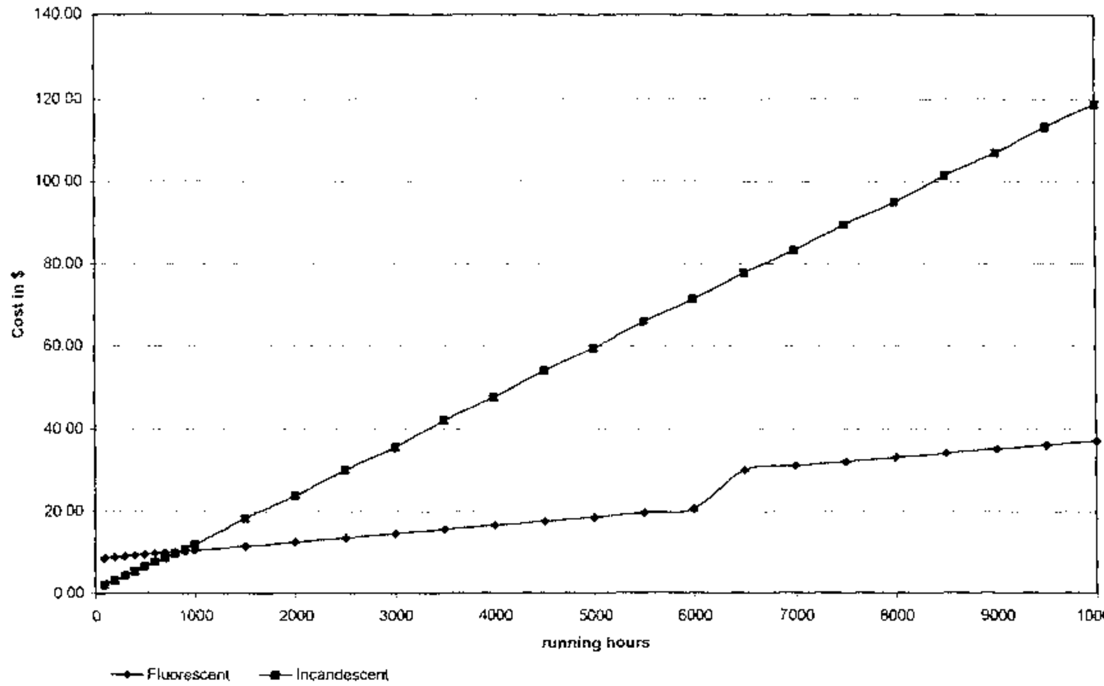


Figure 47: Incandescent vs CFL lightbulbs running costs

The comparison shows after 800 running hours the two light bulb had used the same amount of money and after this point money would be saved with the CFL light bulb due to the lower electricity consumption and the 6 to 7 times longer lifetime. The CFL cost starts at $8.50 with the purchasing cost and increases slowly due to the low energy consumption. The cost increase at 6000 hours shows the first replacement of the bulb. The incandescent bulb cost starts at $1 and increases much faster. The replacement costs every 1000 hours are not visible because of the low purchasing cost of one dollar.

The database for light bulbs comes from a survey of the available bulbs in a large store (Appendix A.15) (Warehouse, 2003). With the time the light bulbs were switched on and the energy usage of the chosen bulbs, the energy consumption was calculated. The CO_2 emissions and the costs are then calculated with the electricity cost (Section 5.3.1) and the electricity emission factor (Section 5.5.1).

5.7.3. Refrigeration

Refrigerators and freezers are tested under the Australian and New Zealand standard (AS/NZS 4474, 2001) specified test conditions. Two of the outcomes of the test are the star rating, which visualise the consumption and the comparative energy consumption (CEC), which is the annual consumption under the specified test conditions. The model needs to know the monthly consumption, which is calculated from the CEC. The Australian Greenhouse Office offers a database with 662 fridges, freezers and combined models which are tested under the standard (CD-Appendix A.31) (AGO, 2003a). This data also applies to New Zealand due to the same standards. The database includes standard international models and also Fisher & Paykel, a New Zealand brand.

The electricity consumption of all refrigeration models tend to increase with volume (Fig. 48 and Appendix A.14). The two extreme examples of comparable fridges both made in Germany are Liebherr, with a volume of 405 litres and a energy consumption per month of around 17 kWh, and Gaggenau with a volume of 409 litres and a energy consumption of 77 kWh. They differ by more then a factor of four in energy consumption (Fig. 48) and this difference is shown in their star ratings. The fridge from Liebherr has 6 stars, which is the maximum, while that from Gaggenau was only 1.5. Similarly Vestafost a freezer model made in Denmark with a volume of 78 litres uses 25 kWh per month, while a comparable model made in the USA called Amada, with a volume of 79 litres, uses 85 kWh per month, more then three times as much (Appendix A.14). The number of stars again shows the difference, with the Vestafrost freezer having 4.5 stars and the model from Amada only 2.

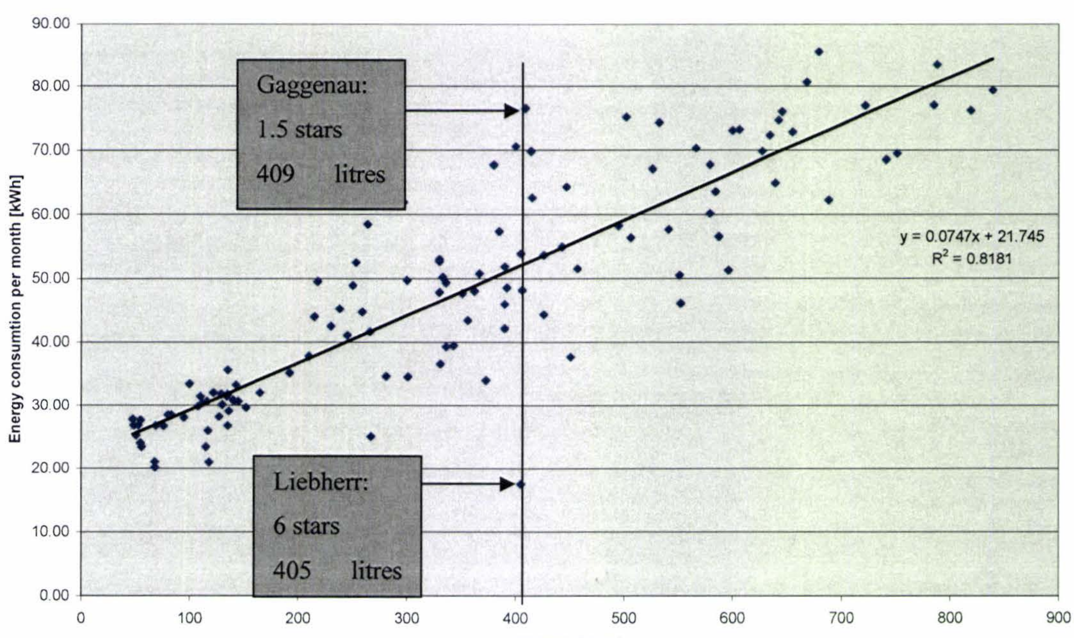


Figure 48: Fridges: Volume to energy consumption. Source data: (AGO, 2003a)

5.7.4. Television

The most common type of television (TV) is the cathode ray tube (CRT) although flat screens (LCD liquid crystal display) are rapidly entering the market. Electricity consumption is higher for larger TVs and differs between different brands. The AGO commissioned a study of the operating energy of home entertainment system (Appendix A.16) (Sustainable Solutions Pty Ltd, 2003). Over the last year energy efficiency improved for CRT televisions but screen size and frequencies also increased. The average consumption of the new TVs in stores was found to have an operating energy of 100W, while the existing stock of TVs was under 70W. The existing stock value was used in the model. A 17inch (43cm) LCD screen has an operation energy of 30-34W. Savings up to 85% are possible with LCD compared to CRT televisions (Sustainable Solutions Pty Ltd, 2003).

The PREM model user can select either CRT or LCD TV, and the model then selects the operating energy. To calculate the electricity consumption per month the operating time needs to be entered by the model user whereby stand-by power is not included.

5.7.5. Computers and Monitors

The Lawrence Berkley National Laboratory did a study in support of the Environmental Protection Agency (EPA) ENERGY STAR Office Equipment program to assess office equipment energy consumption. The Energy Star label was established in the USA to reduce the amount of electricity used in appliances, and rates appliances by different criteria such as operating and standby power levels, PCs and monitors were the first products labelled by the ENERGY STAR Office Equipment program (Robertson et al, 2002).

The operating energy of desktop computers ranged from 28 to 117W (Appendix A.17) and was mostly a function of the CPU (Central Process Unit) make and model. It does not correlate closely to the CPU speed, although the slowest PC examined had the lowest operating power energy use but the fastest PC did not have the highest (Robertson et al, 2002).

Laptop computers use significantly less energy, ranging from 14-25W with an average of 19W (Robertson et al, 2002). The highest operating power of a laptop compared to a desktop is more then 78% lower even without taking into account the monitor for desktops. The lowest operating power of the laptop is still 50% lower then the lowest of a desktop. Laptops are designed to run on low power as they are manufactured to run at times by battery.

Computers have built in energy saver features which can put the computer and the screen in a standby mode after a certain time. These energy savers are able to shut down parts of the system which are not in use without shutting the system down. This enables the system to restart after an absence in a short time. Such energy saver features are not included in this calculation as the user would need to know the exact times of the saver mode, standby and working times. Consumption figures are averages. A computer needs different amounts of electricity for the different operations according to the modules used such as when running hard drive or CD-drive.

Desktop computers require a monitor and the average monitor operating power measured in a survey of monitors' sales in 2001 was 65W. The average power of an Intel Pentium 4 with an average monitor adds up to 132W, which is almost seven times greater than an average laptop. The energy use of a monitor is primarily a function of its type, screen size and displayed image. CRT monitors have higher energy consumption than LCDs (Robertson et al, 2002), and for both types the larger the screen size the greater the energy consumption. The difficulty in comparing CRT and LCD monitors is the declared screen size which does not directly correspond to the actual screen size. A declared 19" diagonal size in a CRT is closer to 18" than to 19", and the difference between nominal and actual screen size is not consistent. In the Lawrence Berkley study the CRT monitors were assumed to have one inch less than the nominal size, and the measured monitors were sorted by the screen size 15" to 21" for CRTs and 15" and 18" for LCDs (Appendix A.18). A 15" LCD monitor has an average operating power of 25W while a 15" CRT monitor has an average power of 59.5W when turned on. This is more than twice as much as the comparable LCD monitor (Robertson et al, 2002).

5.7.6. Dryers

Rotary clothes dryer test conditions are regulated with an Australian and New Zealand standard (AS/NZS 2442, 1996-2000). The AGO provides a database with 71 rotary dryer models tested using this standard (CD-Appendix A.32) (AGO, 2003a) providing the electricity consumption provided per year. For the energy star calculation the dryer was assumed to be used 52 times per year, however this model calculates the energy consumption per use to provide a more flexible calculation.

Dryers tend to increase their energy consumption with increasing rated capacity (Fig. 49), the rated capacity being the maximum mass of standard cotton test load in multiples of 0.5kg declared by the manufacturers (AS/NZS 2442, 1996-2000), but some models use less energy for the same capacity. Two dryers manufactured by AEG in Germany have significantly different energy consumptions, the WP model with a capacity of 5.5 kg has an energy consumption per use of 2.3 kWh and the model 57700 with the same capacity uses 5.4kWh (Fig. 49). The star ratings are 6 stars for the WP model and 1.5 stars for the model 57700. Dryers could be replaced by a simple clothes line.

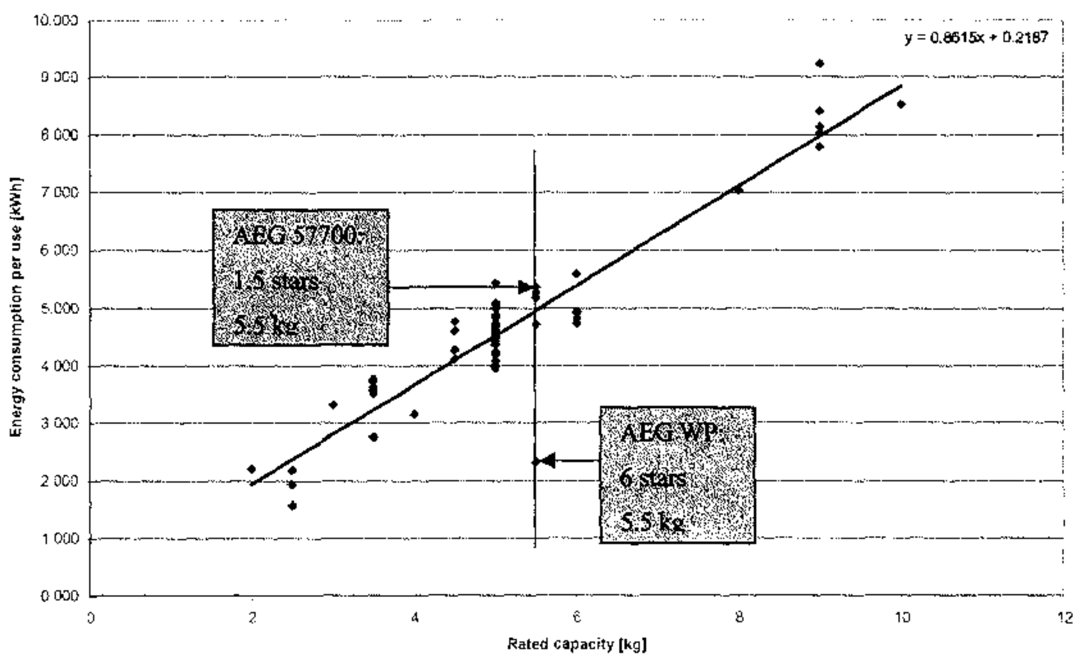


Figure 49: Rotary cloth dryer: Rated capacity to energy consumption per use. Source data: (AGO, 2003a)

5.7.7. Dishwashers

The dishwasher test procedure is regulated by Australian and New Zealand standards (AS/NZS 2007, 2003). The AGO provides a database with 224 different models tested under the standard conditions, and indicates star ratings (CD-Appendix A.33). The model calculates energy consumption per usage and the total energy consumption is the sum of the electricity used by the dishwasher and the externally supplied hot water (AS/NZS 2007, 2003). Some dishwashers have a hot water connection to supply the dishwasher, but the AGO does not provide data to distinguish between the electric energy consumption and the external supplied hot water energy.

The energy consumption does not increase with the rated capacity (Fig. 50). The rated capacity being the number for the place settings washed. Interestingly place settings of 12 and 14 are often used in the dishwasher design. The energy consumption per use for dishwashers with a rated capacity of 12, ranges from 0.7 kWh per use for the brands Dishlex and Kelvinator both made in Australia with a star rating of 3 kWh up to 1.6 kWh per use for the brand Haier made in China with a star rating of 1 which has more than twice the energy consumption.

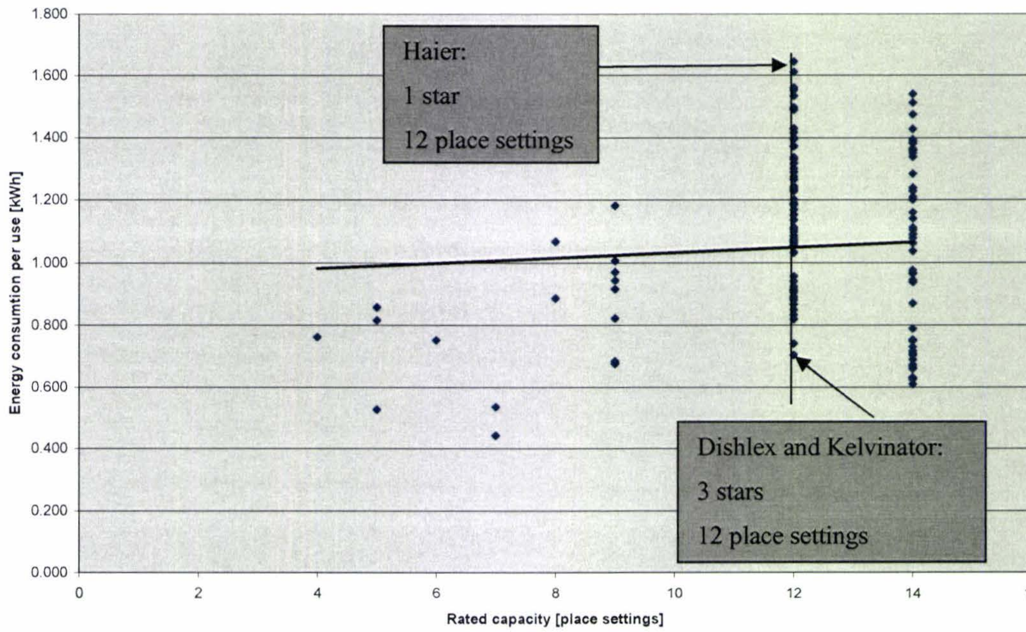


Figure 50: Dishwasher energy consumption to the rated capacity. Source data: (AGO, 2003a)

Energy consumption increases with increasing water consumption although there exist a wide distribution (Fig. 51). A Miele model made in Germany with a water consumption of 19 litres has an energy usage of 0.6 kWh with a star rating of 4. By comparison three Italian brands D Amani, Baumatic and Franke with similar water consumption and a star rating of 1 need almost 2.5 times as much energy input.

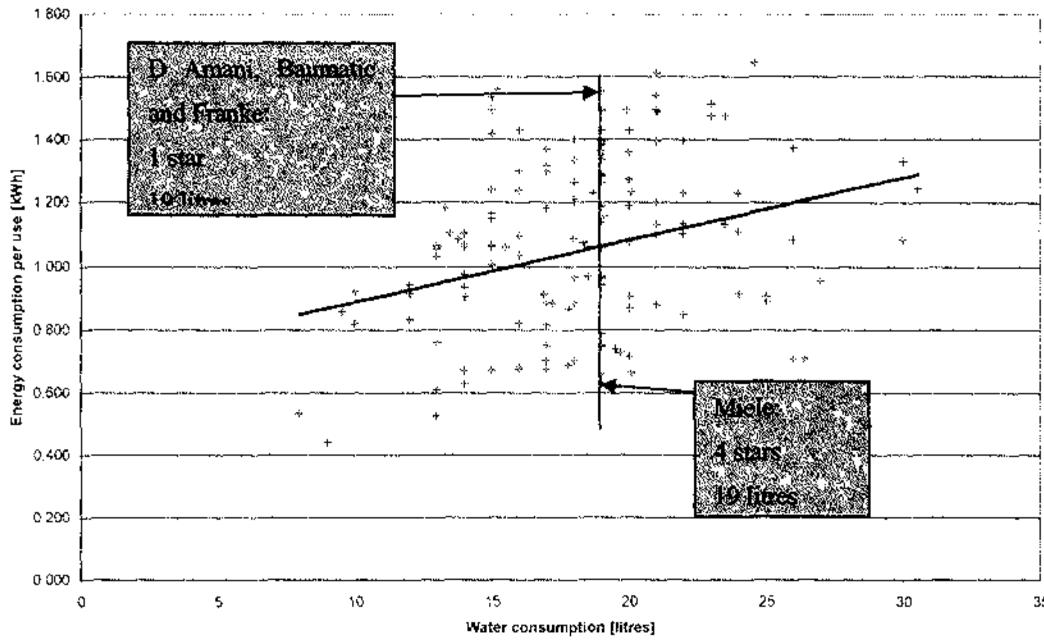


Figure 51: Dishwasher energy consumption to the water consumption. Source data: (AGO, 2003a)

The user must choose his/her model from the database and enter the number of uses per week, and from this information the model calculates the monthly energy use. The energy consumption is the sum of the electric energy used by the dishwasher and the externally supplied hot water. The monthly cost and CO_2 emissions are calculated with the assumption of an electric hot water heater because of the lack of data to distinguish between electrical energy used of the dishwasher and the externally supplied hot water. This could lead to a small error if circumstances differ.

5.7.8. Clothes washing machines

The washing machine tests are described in the Australian and New Zealand standard (AS/NZS 2040, 1998-2000). The tested clothes washing machines are published by the AGO in a extensive database of 322 different models (CD-Appendix A.34) (AGO, 2003a), and are similar to the dishwashers in two ways. Firstly some clothes washers have a hot water connection supplied from the hot water cylinder. This external energy is added to the electric energy used from the cloth washer. Secondly the energy consumption correlates better with the total water consumption than to the rated capacity (Fig. 52 & 53). The rated capacity is the maximum textile material for a load stated by the manufacturer in kilograms (AS/NZS 2040, 1998-2000).

The energy consumption tends to increase with increasing capacity, although the distribution is large (Fig. 52). Comparing clothes washing machines with the same rated capacity shows significant differences, as a model from Miele, made in Germany with 4.5 stars, has an energy consumption per usage of 0.5 kWh whereas models from Simpson and Samsung, made in Brazil and Korea respectively, have an energy consumption of 1.6 kWh (Fig. 52). The models from Simpson and Samsung have a star rating of 1 star and use almost five times as much electricity than the model from Miele.

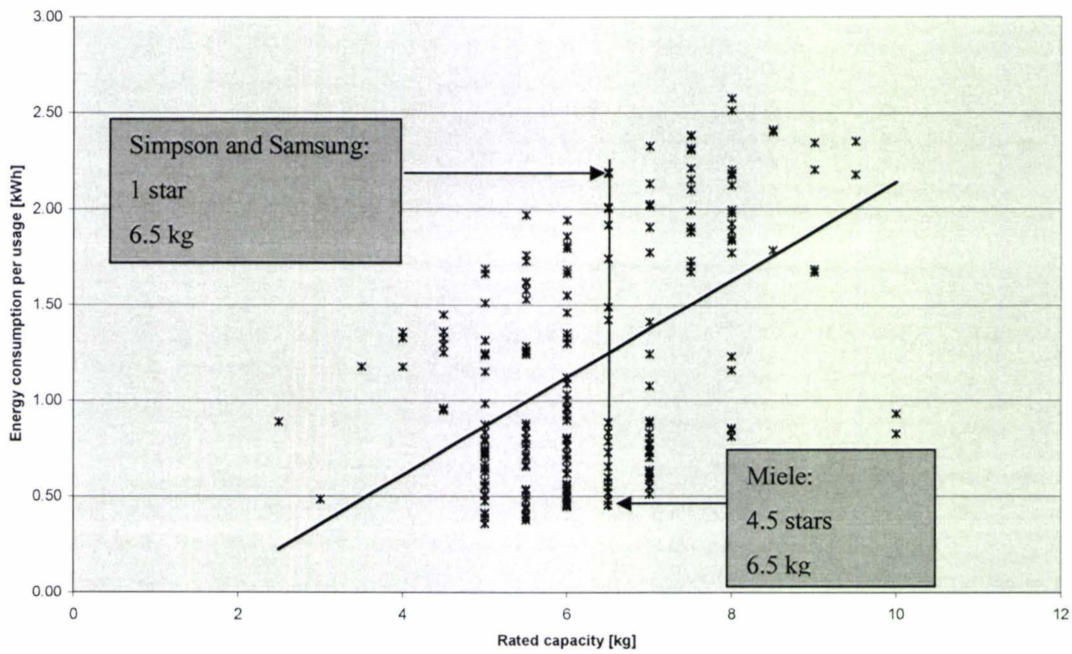


Figure 52: Cloth washing machine energy consumption to the rated capacity. Source data: (AGO, 2003a)

Figure 53 shows the tested clothes washing machines in a graph of energy consumption to total water consumption. The distribution is lower than in figure 52 energy consumption due to the rated capacity. A comparison of two models with similar water consumption shows a difference of a factor of three in energy consumption. The model from LG made in China with one star used 1.6 kWh per load, while the model from Bosch with a similar water consumption used 0.5 kWh and earned four stars.

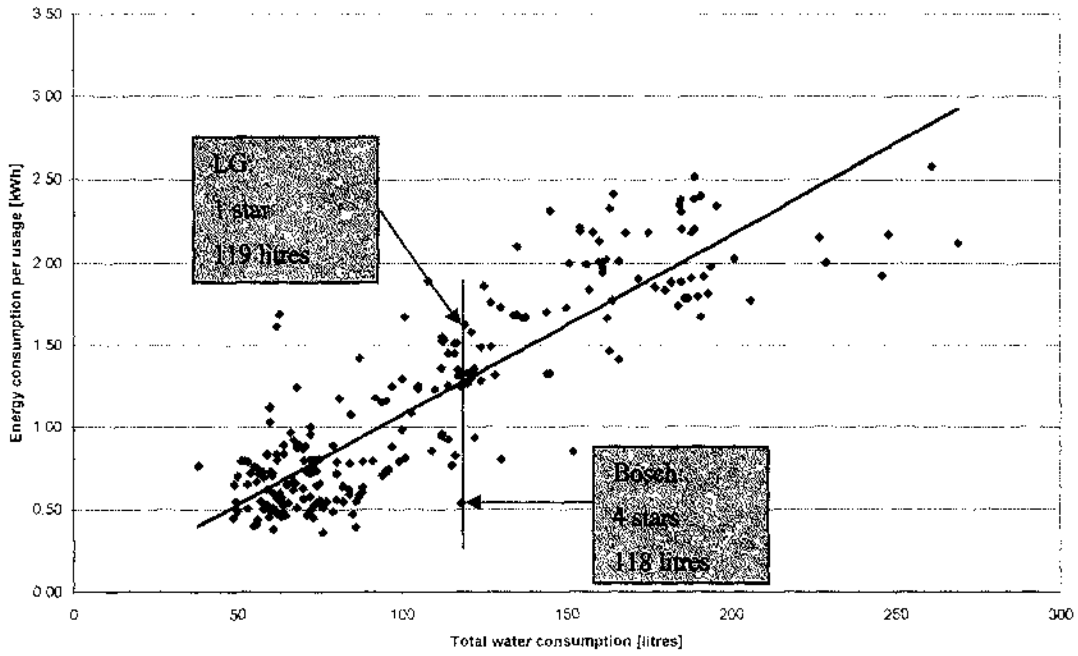


Figure 53: Clothes washing machine energy consumption to the total water consumption. Source data: (AGO, 2003a)

All clothes washing machines in the database were tested using the hot wash program, and only some additionally with the cold wash program. The difference between the hot and cold wash program energy consumption ranged from 0.03 kWh to 2.3 kWh per load, with the average difference amounting to 1.4 kWh per load. Assuming an electricity price of 0.14$/kWh the average difference amounted to NZ$ 0.19 per load. The star label calculates the yearly consumption using seven loads per week. The average difference would then cost almost NZ$ 70 a year. Due to the fact that the cold wash program is not tested for all the washing machines and a calculation for the remaining figures with an acceptable accuracy could not be found PREM only includes the hot water wash program.

5.7.9. Hot water heater and cooking

Hot water heaters and cooking equipment do not require an energy label and therefore a database from the AGO does not exist. Hot water heaters and cooking stoves are along with heaters, the only appliances using different fuel types, such as electricity or gas.

The HEEP study (Section 3.6) shows what percentage each appliances uses in an average household. Except hot water heaters, cooking equipment and miscellaneous, all analysed appliances are assessed in PREM using databases and with time of use input by the user. At the beginning the model total consumption was assessed from gas and electricity bills. From these the model knows the total electricity and gas consumption, and subtracting the assessed appliances the remaining energy must be that consumed by the hot water heater, cooking equipment and miscellaneous. The model divides the remaining energy according to the percentages in the HEEP study and the prompted fuel type. Hot water heaters use 27.9% of the total gas and electricity consumption of the entire household, cooking equipment 6.7% and miscellaneous 6.7%. Consequently the model user only needs to know which fuel his/her hot water heater and cooking equipment uses. The energy consumption will be calculated by the model including costs and CO_2 emissions according to the factors of each fuel type (Sections 5.3 & 5.5).

5.8. Summary

In PREM energy consumption in buildings was assessed by using average data of the required heating energy for three different house construction types which can be done based on the minimal influence of the house size. For a more individual input the building simulation program ALF could be used.

Transport energy was done with a database of car fuel consumption assessment and secondly with an emission factor based on public transport assessments. Car emissions were calculated due to the combustion and some production based emissions of the fuel type used.

By assessing electricity and gas bills the total household energy consumption was analysed. The total energy consumption of the chosen appliances from various databases was subtracted from the household energy use and the remaining energy was split up by percentage between hot water heaters, cooking and miscellaneous for which no databases exist. Emissions were calculated from the appliance energy use due to the energy source type by using calculated emission factors.

The data for the different appliances and cars, the related costs and their emissions came from various sources. Some raw data required calculations to be useful for the model. The model user can also enter his/her specific data if preferred. Some data were entered from databases which exist for car models and for many household appliances.

6. Chapter Model Verification

6.1. Introduction

PREM is verified in this chapter in three different ways. Two fictional people were used to analyse the saving potential of two different lifestyles. It was assumed both virtual characters drove and flew the same distance each year, and required the same energy services, such as the same time of usage and amount of light from light bulbs in their homes. Demand was based mostly on the "average" New Zealand consumption. The effect of an energy prices increase was added. These three different verifications were made to give a good overview of the model as they show which questions from interested people can best be answered in order to reduce energy costs and emissions. The accuracy of the model could not be checked against other models as no similar product exists. A survey using real people could not be done for reasons further discussed in chapter 7.

6.2. Case studies

To verify the model two cases were invented, Mr. Greeny and Mr. Careless, who have total different lifestyles when they enter their data into PREM. Mr. Greeny tries to be environmentally friendly but he could not afford a solar hot water heater. Mr. Careless drives a large car but he would not turn the home heater very high. Rather he would wear more clothes as Mr. Greeny does. Mr. Greeny also drives a small car and he went for an overseas travel last year whereas Mr. Careless flew the same distance domestically. Mr. Careless did not care much about energy consumption and his chosen appliances have larger consumption than Mr. Greeny's who chose them by watching the energy labels on the appliances carefully. Both of them live in a similar house size with their partners, demand the same energy services but with different appliances used. They travel the same distance and do not know particularly where to save energy costs and CO_2 emissions. The result of using PREM will help them to optimise their energy budget and might change some of their ecological behaviour.

The inputs for both case studies were chosen to be close to the New Zealand average. For example the average cooking energy was 58.6 kWh/month (BRANZ, 2002) and the driven distance per car was 1411km per month (licensed private cars in 1999: 1.8million (MfE, 2002a) and the total car kilometres travelled in 1999 was 30,500 million km (Statistics New Zealand, 2002)). The other factor included was the use of a range of energy sources for specific home heating applications. For example Mr. Greeny heats 50% with wood and 50% with mains gas whereby Mr. Careless heats 50% with electric heaters and 50% with LPG.

The difference in the monthly energy bill between the two characters was significant. Mr. Greeny's energy bill and total CO_2 generated were only half that of Mr. Careless being a total of NZ$ 801.42 and emitting 435kg CO_2 (Appendix A.20). Mr. Careless additional monthly energy costs was NZ$ 734.40 and 371kg CO_2 per month (Appendix A.21). The largest difference of NZ$ 694.44 and 303kg CO_2 came about in the transport figures, NZ$ 465.10 and 231kg CO_2 of which was from car usage (Fig. 54). Mr. Greeny drove a smaller car with a fuel consumption of 4-6l/100km and Mr. Careless a large car with a fuel consumption of 10.5-16l/100km.

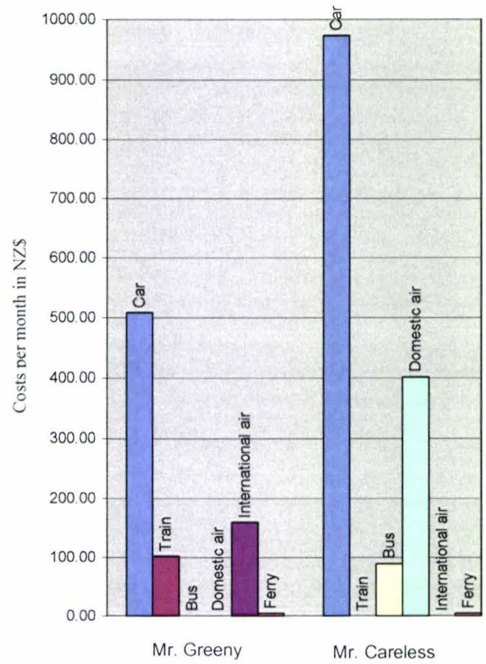


Figure 54: Monthly transport energy costs.
A comparison between Mr. Greeny and Mr. Careless.

The proposed CO_2 tax of NZ$ 25 per tonne which is to be introduced in 2007 would not make a significant difference to the calculated figures. If it was NZ$ 25/t CO_2 Mr. Greeny would pay NZ$ 10.90 per month which is only 1.4% of his total monthly energy cost and Mr. Careless would pay NZ$ 20.20 per month or 1.3% of his total monthly energy cost. The CO_2 tax for household energy use was only NZ$ 0.55 and NZ$ 2.25 per month respectively. The largest CO_2 tax occurred by Mr. Careless was for car usage at NZ$ 10.15 per month, which, at only 1% of the total monthly car usage cost, is relatively small (Fig. 55).

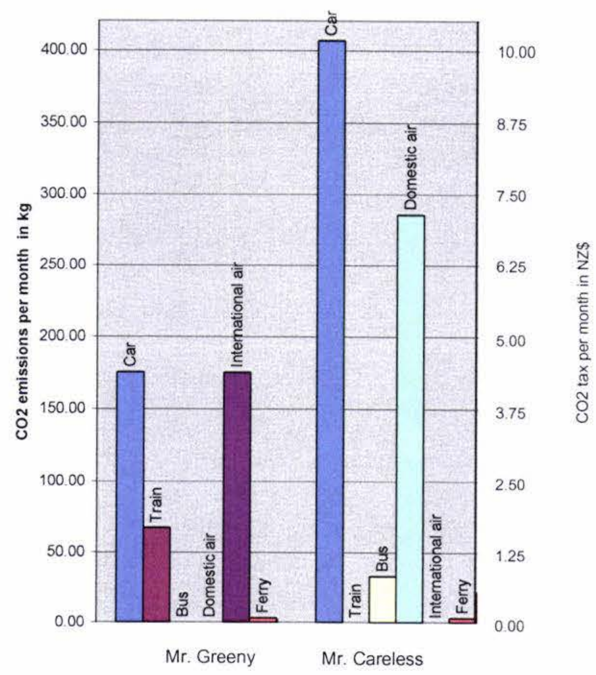


Figure 55: Monthly transport and household energy CO_2 emissions and carbon charge; a comparison between Mr. Greeny and Mr. Careless, assuming a carbon tax of NZ\$ 25/tonne CO_2.

In this example, the transport costs were high due to the air travel and the car usage. Mr. Greeny went on one long distance air trip return to Hong Kong. In the same period, Mr. Careless flew the same distance domestically 12 times between Auckland and Christchurch which costs and emits much more CO_2 per kilometre than an international flight. This is due to the larger number of take offs and landings which are needed for the domestic flights. As a result Mr. Careless paid an extra NZ\$ 242.35 and also emitted around 100kg CO_2 more per month. An interesting comparison was the public transport from Auckland to Wellington. Mr. Careless took the bus and Mr. Greeny did the same trip by train but emitted more then twice as much CO_2 with 15% higher expenses than Mr. Careless. This calculation was made with the average utilisation ration of both bus and train (Section 3.5).

Household energy costs and emissions depend to a large part on the house construction, heating fuel used and hot water cylinder design (Fig. 56). Mr. Greeny lives in a better insulated house than Mr. Careless, and his current heating costs are NZ\$ 4.90 a month all year round. If he were to upgrade to a super insulated house, he could save another 73% of the heating energy cost which would be around NZ\$ 3.60 per month all year round. Mr. Careless paid NZ\$ 15.50 per month for his heating requirement by using electricity and gas in equal parts, and emitted 30 times more CO_2 than Mr. Greeny who used gas and wood in equal parts.

Mr. Careless retro-fitted his house with super insulation so would save almost 80% in costs and CO_2 emissions. Mr. Greeny was supplying half of his house heating with wood the other half with gas. If Mr. Greeny heated the entire house with wood which is considered carbon neutral the costs would only be NZ$ 2.40 per month all year round without any CO_2 emissions.

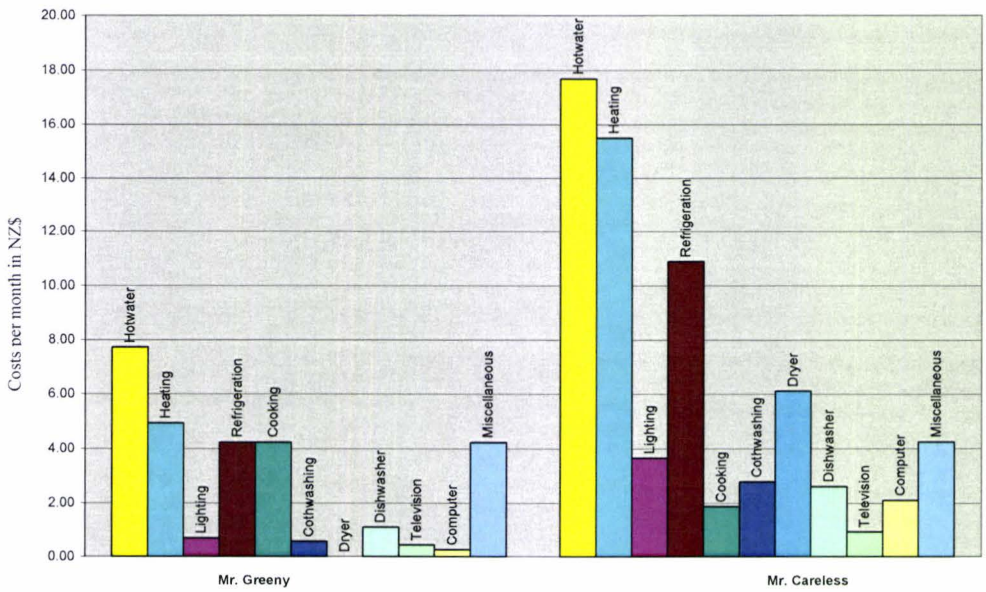


Figure 56: Monthly household energy costs for a range of appliances; a comparison between Mr. Greeny and Mr. Careless.

The costs of the energy for appliances is much lower than that for transport costs for both Mr. Greeny and Mr. Careless. The total costs to run Mr. Greeny's appliances are NZ$ 28.35 per month and the transport costs NZ$ 773.10. Mr. Carless has larger appliance costs of NZ$ 68.30 and larger transport costs of NZ$ 1467.50.

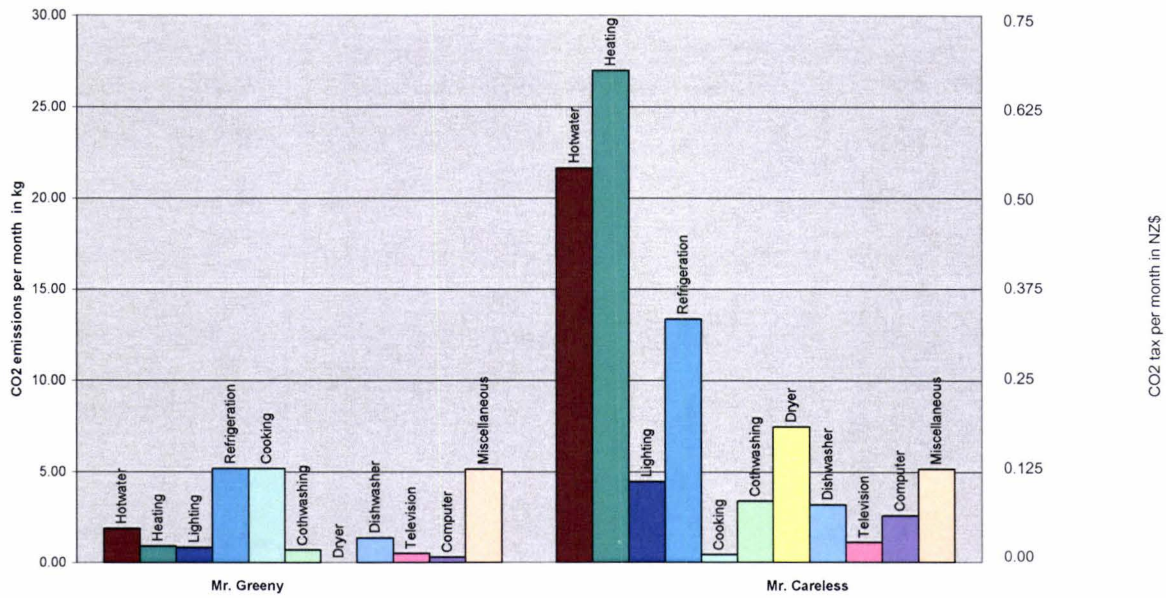


Figure 57: Monthly household energy CO_2 emissions and taxes; a comparison between Mr. Greeny and Mr. Careless, assuming a CO_2 tax of NZ$ 25/tonne CO_2.

Although Mr. Greeny and Mr. Careless used the same amount of energy for their hot water heater. Mr. Greeny used mains natural gas and Mr. Careless electricity which resulted in a difference per month of almost NZ$ 10 and 19.8 kg CO_2 in favour of Mr. Greeny (Figs. 57 & 58). The efficiency of the two types of hot water heater would need to be analysed further to know the real difference in the amount of hot water produced for a set amount of energy. It can be said that electricity is more expensive and emits more CO_2 than mains natural gas for the same amount of energy. Cooking was a similar issue; Mr. Careless used gas and saved NZ$ 2.40 and 4.7 kg CO_2 per month compared to Mr. Greeny who used electricity.

The lighting compared 12 traditional incandescent light bulbs with 12 compact fluorescent light bulbs, all used for 1.8 hours per day an average throughout the year. The difference was the second largest factor in the entire household, the CFL light bulbs being 5.3 times lower in energy usage. However the monthly cost saving were only NZ$ 3 and the CO_2 emission saving 3.6 kg per month. With the bulbs running 1.8 hours a day it takes 14.5 months of use until the CFLs would become cheaper including their purchasing costs, at NZ$ 8.50 per CFL light bulb and NZ$ 1 per incandescent bulb, and the lifetime expectancy of 6000 hours of the CFL bulb and 1000 hours of the incandescent bulb.

The electric appliances including fridge and freezer combination, freezer, clothes washing machine, dishwasher, television and computer resulted in a saving of NZ$ 12.30 and 15.5kg CO_2 per month by Mr. Greeny chosing efficient appliances to obtain similar services. The largest relative difference with a factor of 8.3 was due to the use of a laptop computer instead of a desktop by Mr. Greeny but this only accounted for a cost difference of NZ$ 1.80 per month. Mr. Careless also used a dryer when Mr. Greeny used the clothes line to dry his clothes which resulted in an additional difference of NZ$ 6.10 and 7.5 kg CO_2. The absolute differences of individual appliances occurred in a range between NZ$ 0.50 (television) and NZ$ 6.70 (refrigeration), 0.6kg CO_2 and 8.2kg CO_2 respectively.

The assessed General Ecological Behaviour (GEB) for Mr. Greeny was 2 for his energy conservation behaviour and 2.5 for his mobility and transport behaviour. Mr. Careless achieved only -1.5 and -3.5 respectively on a scale which ranged between -3.5 and 7. The probabilities of performing ecologically sensible behaviours are totally different for the two imaginary persons (Appendix A.23). The behaviour "Buy energy efficient appliances" had the highest probability for Mr. Greeny and the lowest for Mr. Careless. According to the GEB result Mr. Careless would be most likely to change his car for a fuel efficient one which could save him a further NZ$ 177.40 and 272.50kg CO_2. The ten assessed behaviours show the improvement possibilities which for Mr. Greeny total NZ$ 222.95/186.76 kg CO_2 per month and for Mr. Careless NZ$ 364.30/479.70 kg CO_2 per month. These figures do not take into account the possible carbon charge which would be an additional NZ$ 4.70 and NZ$ 12.00 respectively within certain specifications (Appendix A.22).

If an energy price increase happened it is interesting to know how much it would affect each household's energy bills, which in the transport sector also includes some fix costs. To simulate such a price increase the prices of each energy source were first increased separately and then all together by 10% (Table 5). The increase was analysed for the two sectors transportation and household energy, for both Mr. Greeny and Mr. Careless.

		Electricity cost +10%	Mains gas +10%	LPG +10%	Wood +10%	Car fuels +10%	All fuels +10%
Mr. Greeny	Transp.	n.a.	n.a.	n.a.	n.a.	1%	1%
	Appl.	5.5%	4%	n.a.	0.4%	n.a.	10%
	Total	0.2%	0.14%	n.a.	0.03%	1%	1.3%
Mr. Careless	Transp.	n.a.	n.a.	n.a.	n.a.	1.2%	1%
	Appl.	8.8%	0.28%	0.88%	n.a.	n.a.	10%
	Total	0.39%	0.01%	0.038%	n.a.	1.1%	1.3%

Table 5: Monthly total bill increase, separately assessed assuming an increase of each fuel price by 10%

If all fuel prices increased by 10% including electricity, mains gas, LPG, wood and all car fuels, the total monthly energy cost would only increase by 1.3% (Table 5) for both examples Mr. Greeny and Mr. Careless. The appliance energy cost would increase by 10%. The transport sector has large fixed costs such as car maintenance and depreciation so the fuel price does not change the monthly transport costs significantly. An increase in fuel prices would quite possibly also increase the ticket costs on public transport, which cannot be calculated. The prices would hardly increase by 10% due to the different price politics and the fixed costs for these services neither of which depend on fuel prices.

The separately increased fuel costs have different effects depending on the amount of each fuel used and the total energy costs. As an example an increase in the electricity price of 10% would cause an increase in Mr. Greeny's and Mr. Careless' appliance energy costs of 5.5% and 8.8% and raise their total energy costs by 0.2% and 0.39% respectively (Table 5).

Generally the model shows the energy costs and CO_2 emissions in an easy understandable way that allows the user to see their savings potential. Questions which the model can answer are:

- How much would a fuel price increase affect total costs?
- Which form of travel would be the cheapest and emits the lowest amount of CO_2 for a certain distance?
- Which energy service provider would cost the largest amount and emit the largest amount of CO_2?
- Which behaviour (from a selection of 11 behaviours) would be the easiest to perform and how much could it save?

These are the questions that need be answered in order that people have enough information to change to a less polluting lifestyle. As shown above PREM can answer these questions in a clear and easy to understand way.

6.3. Summary

The case study of the two virtual people Mr. Greeny and Mr. Careless showed extreme examples of the potential for improvement which is possible to analyse with PREM. Mr. Greeny paid only half the energy costs per month and produced only half the carbon dioxide when compared to Mr. Careless. The proposed behaviour changes without the replacement of appliances would save Mr. Greeny NZ$ 223.93 and 186.75 kg CO_2 which would result in an increase of the carbon charge by NZ$ 4.65. Mr. Careless' behaviour changes would save him NZ$ 364.30 and 479.70kg CO_2 and would result in a CO_2 tax of NZ$ 12.00. The model showed the costs of the energy services, including CO_2 emissions, could have some concrete improvements with the proposed behaviour changes.

7. Chapter Further Research & Conclusion

7.1. Introduction

This final chapter describes where further research could follow this study and the conclusion. Although the developed model meets the objective targets, it can always be improved by adding certain sectors and taking more details into account or improving the interface.

The sectors influencing the household and transport energy were pointed out in the literature review (Fig. 4). Climate change science is supported by the UN which is needed to advise organisations and governments for international conventions. Many governments such as New Zealand who ratified the Kyoto Protocol can profit from such scientific background. The countries themselves are forced according to the UNFCCC to continue research in writing the demanded "National Communication" reports. Another factor that forced climate change research (e.g. energy efficiency, energy conservation and renewable energy) was the ratification of the Kyoto Protocol by the Russians.

Research on the environmental costs and their influence on household finances were difficult to find due to the limited number of research done in this area as well as the complexity of this issue. Judging present and future environmental damage using monetary value is extremely challenging.

New technologies and improving renewable energy systems are on their way. This will further support the trend for energy efficiency and sustainable energy production. Research in this area is in part up to the companies to make the new technologies economically valid. Also, governmental incentives are required to encourage such developments. For example the requirement for energy labels on some appliances gives the consumer information about their energy consumption. These labels could also be on other appliances such as hot water cylinders and cooking equipment. A label requirement could be implemented for cars as has been recently done in Switzerland. An analysis of the current situation is the first step in solving the problem.

Research on the environmental behaviour seems to have grown as governmental institutions have noticed that their programs need to be psychologically based to achieve the largest possible success.

The influences of further research in the different fields would lead to an improvement of PREM as more information would exist. The increasing awareness of the climate change issue would make the demand for such models greater and therefore its marketing potential higher. As the pressure increases to save natural resources, a factor that is closely related with the emissions and the costs of energy, the larger the requirements for improvements in efficiency and conservation. The PREM model could be important to a majority of the New Zealand's population in order to lower the energy costs and reduce the emissions. Interest could come from schools, governments and electricity companies in order to educate people on the benefits.

7.2. Further Research

The broad objective of the study (Section 1.1) combines various fields such as climate change research, environmental psychology and technical development. Further research and changing policies will influence the improvement of the model. The basic model flow of PREM allows for further research at different stages (Fig. 1).

7.2.1. Environmental Psychology

New findings in Environmental Psychology could help in making behavioural changes more likely. An added psychological field would be the learning effects of software programs. Such studies could have didactical improvements of the interface between the user and computer.

A cross-cultural study (Kaiser & Wilson, 2000) showed that the GEB scale can be applied in different cultures and environments. Nonetheless difficulties might differ slightly. In this model it was assumed that the difficulties demonstrated by the Swiss and New Zealand population are not too far apart. To assess these differences a survey would need to be done in New Zealand. "We need to know more about the applicability of ecological behaviour measure across different groups of people, countries, communities, and so forth." (Kaiser & Wilson, 2000)

The GEB scale has assessed the difficulty of many different behaviours, but still has the potential to grow. If more behaviour difficulties were assessed, the model could implement them in the "improvements possibility list". This list would then become larger, more detailed and would inform the user of the associated monetary and emission savings.

Kaiser's research will further develop the GEB-Scale. The aim is to improve the answer possibilities. At the present time the answer can only be assessed with "yes" or "no". The frequency such as "often", "seldom" or "never" do not have separate values. The response for the calculation is always "1" or "0". There is no difference between "seldom" or "never"; both would be a "0". "It is one of my research aims to develop a response format which is able to give reliable frequency indication" (Kaiser, 2003a)

The potential in Environmental Psychology is large as the human mind is complex and the field fairly young. A lot of additional studies will follow and some will also show improvement possibilities for the PREM.

7.2.2. Entity assessment

A general improvement of the CO_2 emission factors and the assessment of the appliances and transport modes can be executed with the use of LCA. An LCA would make the model more accurate and would take the building of the dam and the maintenance energy for the entire hydro generation into account. These calculations are very comprehensive, time intensive and vary between different sites.

Further investigation would also be needed with the public transport mostly by train and bus. In the model calculation it can be demonstrated that the train emits more CO_2 than the bus per passenger kilometre. The calculation is based on the emission factors from EBEX which are sound data. A reason for this unexpected difference is that the train in New Zealand uses a mainly diesel locomotives. An increasing infrastructure for electric locomotives would diminish the CO_2 emissions caused with these train rides.

Future technologies could be added to the model to show their improvement possibilities. For example biodiesel and hydrogen could be included as additional transport fuels. The problem by implementing such fuels would be the price, which can only be an estimation due to the fact that the quantity of the production cannot be determined yet which has a great influence on the price.

The "Detailed investigation and analysis", which is a step in the energy audit, is not done by the model as not enough databases exist to compare the on-site audit with the historical data. If, for all large entities, databases could be used, the entire energy calculation could be based on them. The resulting energy usage could be compared with the energy bills and further investigation could be done in order to see how much the two differ. This comparison would be an excellent instrument in verifying the inputs. If databases cannot be found a theoretical approach could be used, as done in the "Energy Advisor" model for hot water consumption (Section 2.11.3). Such studies could not be found for New Zealand conditions.

Appliances often have a small energy consumption when they are turned off. This energy is called "standby-power" and was not included in PREM. However with such an inclusion, the model user could compare the loss of energy through "standby-power" with the total energy consumed. This might give the individual the needed information to save money by switching off the appliances at the wall.

The inclusion of small renewable energy systems would also show the user the saving potential on energy costs and emissions. Two systems are common: the independent renewable energy production, which demands batteries or net metering, which uses the grid instead of batteries. Both of these systems can power the entire household without emitting as many GHGs.

To calculate the amount of energy required for heating, the data from three average houses are available in the current model. By including the building simulation program ALF, PREM could be as accurate as "Energy Advisor" which uses the DOE software. ALF makes a sophisticated calculation and takes the climatic differences in New Zealand into account. Nonetheless it does not go as far as taking embodied energy into account. This would show the real energy usage of building a house such as a LCA for the appliances.

At the moment the user must first investigate how much, for example, a new fridge would cost. Knowing the retail price, the investment calculations can then be done. If some energy efficient appliances were already included in the databases with the purchasing prices, the model could calculate the profitability of such an investment.

7.2.3. Monthly bill

When people save electricity the total coal or gas power station outputs are generally lower. This emission factor is taken for the consumption. When someone is saving electricity in New Zealand it is assumed to be first saved in the gas generation meaning savings in CO_2 emissions are larger than they appear now. This theory would need to be further analysed in order to determine which types of power stations will produce less electricity when the consumption is lowered (Bishop, 2003)

7.2.4. Behaviour change

According to the TCB, people change their behaviour based on three factors: attitude, subjective norm and perceived behaviour control. Attitude can be slightly changed by giving factual knowledge like that described in the Theory of Reasoned Action. The developed model displays to the user where CO_2 is emitted using unneeded energy and lowering costs. Further investigation could focus on changing behaviour by changing the subjective norm and the perceived behaviour control.

The GEB scale is a dynamic scale which allows it to include additional behaviour. A large variety of behaviours increase the possibility that the user finds the best way in reducing energy. It also helps to compare the behaviour based on their saving potential in emissions and money. A selection of behaviours which could be included are shown in Appendix A.24, 9.25 and 9.26.

7.3. Conclusion

As stated in chapter one, the general objective of this study was to determine the extent to which individual decisions and behaviour contribute to energy consumption, greenhouse gas emissions and cost savings. The thesis aimed to include environmental psychology into a technical based energy model to make it more individualised. Subsequently, with the aid of psychological instruments, to determine where a specific person is most likely to change their behaviour. This objective was achieved in two ways. Firstly the user of the PREM model would have the chance to change the inputs to test a range of options as buying another fridge model or driving less kilometres and taking the bus instead. The achieved savings are shown in a monthly energy bill. With this approach the user can check how much he/she could save per month by modifying their current behaviour and technology choice.

Secondly the user will be provided with potential improvement across eleven different behaviours listed in order of probability that the user will perform them, to obtain cost and CO_2 emission savings. Some items do not need financial investment, only a behaviour change to save money and GHG emission. Behaviours which require monetary investment such as "buying a more fuel efficient car" can be assessed on their economical profitability with the same procedure as described above.

The first specific objective of the study was to develop a model implemented as a computer program to assess the person's household and transport energy usage, which will be shown in a monthly bill. The model was developed as an Excel program and the results are shown as a monthly total energy bill.

The second specific objective was to use a psychological approach to make behavioural changes more likely. This objective was achieved but well need to be assessed on its success by a separate study. What can be said to date is that general findings of environment psychological research were implemented by giving the user of the PREM model feedback on energy consumption using the GEB-scale and a background theory of planned behaviour. The GEB scale analyses where the user has the largest probability of changing his or her behaviour.

Adding CO_2-emissions and \$-values to certain behaviours was the third specific objective and this was achieved by showing the monthly bill with information for each service used and by adding the information to selected behaviours to improve the current lifestyle and change it to a less polluting and expensive one.

The verification of the model was primarily done by two fictional individuals with lifestyles based on typical New Zealanders. They were using different entities and transport fuels so it was not surprising that a large difference occurred of NZ\$ 734.40 and 371kg CO_2 per month equivalent to a carbon charge of NZ\$ 9.30. The larger energy user had a bill 50% higher. The monthly bill showed the largest saving potential was by reducing car use, heating, hot water, refrigeration, lighting and drying. There are various improvement options, such as, driving a more efficient car, installing better insulation, insulating the hot water cylinder, useing more efficient appliances, and not using a clothes dryer. The improvement behaviours suggested by the GEB evaluation show a saving potential of NZ\$ 222.95/186.76kg CO_2 equivalent to a carbon charge of NZ\$ 4.70 per month and NZ\$ 364.30/479.70kg CO_2 equivalent to a carbon charge of NZ\$ 12 per month respectively.

The second verification was to answer the question of how much energy costs will rise with an increase in the energy prices. It is important for the consumer to see what will happen if fossil fuel prices increase and renewable prices decrease. Such a change in prices could help to meet the Kyoto protocol target. The different energy sources were increased separately and then all together. An increase of 10% in all energy prices resulted in a rise of the monthly bill for both types of 1.3%. This small increase is a result of the large maintenance and desperation costs of the car, as well as ticket costs for air travel and public transport, neither of which increased. The objective of giving an accurate summary of monthly energy costs and CO_2 emissions was achieved.

Further development on the model should focus on the programming of an internet application to give public access to the PREM, and the implementation of databases of larger appliances and renewable energy systems. Another important development would be the inclusion of an investment calculation that shows the user the payback time of an investment. In order to calculate this figure the actual purchase prices of the appliances would need to be known and updated in the model. Difficulties of the inclusion of purchasing prices appear from the large variation of entity prices due to purchasing place and price changes over time.

In summary, PREM shows the energy consumption in a dollar value and quantity of CO_2 emissions for the majority of all appliances and modes of transport. The model aids the user in making decisions in order to reduce household and transport costs, as well as their related CO_2 emissions.

Reference list

AGO (Australian Greenhouse Office). (2003a) *Appliances databases* [Web Page]. URL http://www.greenhouse.gov.au/ [2003a, September 25].

AGO (Australian Greenhouse Office). (2003b) *Sustainable Transport* [Web Page]. URL http://www.greenhouse.gov.au/transport/index.html [2003b, September 25].

Air New Zealand. (*Air New Zealand* [Web Page]. URL http://www.airnewzealand.co.nz/ [2003, November 11].

Ajzen, I., & Fishbein, M. (1977). Attitude-behavior relations: A theoretical analysis and review of empirical research. *Psychology Bulletin, 84*, 888-918.

Ajzen, I., & Fishbein, M. (1980). Understanding attitudes and predicting social behavior. *Engelwood Cliffs, NJ: Prentice-Hall.*

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes, 50*, 179-211.

AS/NZS 2007. (2003). Dishwashers. *Standards Australia/Standards New Zealand.*

AS/NZS 2040. (1998-2000). Cloth washing machines. *Standards Australia/Standards New Zealand.*

AS/NZS 2442. (1996-2000). Rotary clothes dryers. *Standards Australia/Standards New Zealand.*

AS/NZS 4474. (2001). Refrigeration Appliances . *Standards Australia/Standards New Zealand.*

Baines, J. T. (1993). *New Zealand Energy Information Handbook*. Christchurch: Tayler Bains and Associates.

Bamberg, S. (2003). How does environmental concern influence specific environmentally related behaviors. *Journal of Environmental Psychology, 23*, 21-32.

Becken, S. (2002). Tourism and Transport in New Zealand - Implications for Energy use. *TRREC Discussion Paper.*

Berndt, S. (2003, July 9). MSc Chemist, Massey University, Centre for Energy Research. Personal communication.

Bishop, R. (2001). New Zealand's Energy Efficiency Potential - A "Top Down" Analysis. *Energy Solutions Ltd.*.

Bishop, R. (2003, July). Technical director, Energy Solutions Ltd., Wellington, NZ. Personal communication.

Black, R. M., & Babrow, A. S. (1991). Identification of campaign recruitment strategies for a stepped smoking cessation intervention for a college campus. *Health Education Quarterly, 18*, 235-247.

Bond, T. G., & Fox, C. M. (2001). *Applying the Rasch scale*. Mahwah, N.J.: Lawrence Erlbaum Associates.

Bowen, A. M. (1996). Predicting increased condom use with main partners: Potential approaches to intervention. *Drugs and Society, 9*, 57-74.

Boyle, G. (1996). *Renewable Energy, Power for a Sustainable Future*. Oxford: Oxford University Press.

BRANZ. (2002). Energy use in New Zealand Households: Report on the year 6 analysis for the Household Energy End-use Project (HEEP) (Report No. ISSN: 0113-3675). Wellington: BRANZ.

Brauner, C. (1998). Climate change does not remove the uncertainty - Coping with the risks of climate change. *Swiss Re*.

CAE. (2001). Possible Energy Use Trends for New Zealand. *Centre for Advanced Engineering* .

Camilleri, M. (2003, July 22). BRANZ LTD. Personal communication.

Chambers, N., & Simmons, C. (2002). Environmental Report 2001/02 Best Foot Forward Ltd.

Chapman, B. (2003, June 17). Tranz Scenic Contact Centre. Personal communication.

Consumers' Institute of New Zealand. (2001) *Powerswitch* [Web Page]. URL http://www.consumer.org.nz/powerswitch/default.asp [2003, June 18].

Crawley, D. B., et al. (2001). Energy Plus: creating a new-generation building energy simulation program. *Energy and Buildings, 33*, 319-331.

Den Ouden, M. D. (1995). Intentions are not enough: The role of intentions in behavioural change. In: Peiro, J.M and Orieto, F. (Eds.). *Work and Organizational Psychology: European Contributions of the Nineties, Erlbaum (UK) Taylor & Francis, Hove, England*, 23-32.

Dlugolecki, A. (2003). Climate change and the financial service - Threats and opportunities. *UNEP Finance Initiatives Climate Change Working Group*.

DOE (US Department of Energy). (2003a) *Fuel economy* [Web Page]. URL http://www.fueleconomy.gov/ [2003a, September 25].

DOE (US Department of Energy).(2003b) (*Energy Advisor* [Web Page]. URL hes.lbl.gov/hes/ [2003b, October 29].

Dunlap, R. E., Van Lieren, K. D., Merting, A. G., & Jones, R. E. (2000). Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. *Journal of Social Issues, 56*(3), 425-442.

EBEX21 (Emissions/Biodiversity Exchange project). (2003) *EBEX21* [Web Page]. URL http://www.ebex21.co.nz/ [2003, September 25].

EECA. (2002) *Target 10%* [Web Page]. URL http://www.target10.co.nz [2003b, June 2].

EECA. (2003a) *Energy Efficiency and Conservation Authority* [Web Page]. URL http://www.eeca.govt.nz/ [2003a, June 2].

EECA. (2003b) *Energywise* [Web Page]. URL http://www.energywise.org.nz [2003b, June 2].

Embretson, S. E., Steven P. Reise, (2000). Item response theory for psychologists. Mahwah, N.J , L. Erlbaum Associates. (p. 345-362)

EPA (Environmental Protection Authority Victoria). (*Greenhouse calculator* [Web Page]. URL www.epa.vic.gov.au/GreenhouseCalculator/calculator/default.asp [2003, October 28].

Epstein, S. (1983). Aggregation and beyond: Some basic issues on the prediction of behavior. *Journal of Personality, 51*, 360-392.

Fishbein, M., & Ajzen, I. (1974). Attitudes toward objects as predictors of single and multiple behavioral criteria. *Psychological Review, 81*, 59-74.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research*. Reading, MA: Addison-Wesley.

Furuholt, E. (1995). Life cycle assessment of gasoline and diesel. *Resources, Conservation and Recycling, 14*, 251-263.

GPCNZ (Greenhouse policy coalition). (*GPCNZ* [Web Page]. URL http://www.gpcnz.co.nz [2003, October 3].

Hardeman, W., Johnston, M., Johnston, D. W., Bonetti, D., Wareham, N. J., & Kinmonth, A. L. (2002). Application of the theory of planned behaviour in behaviour change interventions: A systematic review. *Psychology and Health, 17*(2), 123-158.

Hargreaves, R. (2002). *Being a Climate Friendly Kiwi*. Wellington: BRANZ.

Hargreaves, R. (in press). Mitigation the Impacts of Climate Change on the Built Environment. *BRANZ*. www.branz.co.nz

Hawken, P., Lovins, A. B., & Lovins, H. L. (1999). *Natural Capitalism - The next industrial revolution*. London UK: Earthscan.

Hunt, J. (2003a). Retrofitting homes for energy efficiency. *Build - BRANZ Ltd.*

Hunt, L. (2003b, July 7). Gas analyst, NGC New Zealand. Personal communication.

InterCity Coachlines. (2002) *New Zealand's Coach Network* [Web Page]. URL http://www.intercitycoach.co.nz/ [2003, June 17].

Interislander. (2003) *The interisland line* [Web Page]. URL http://www.interislandline.co.nz/ [2003, June 12].

IPCC. (1990). *Intergovernmental Panel on Climate Change*. UK: Cambridge University Press.

IPCC. (1995). *Intergovernmental Panel on Climate Change*. UK: Cambridge University Press.

IPCC. (2001). *Intergovernmental Panel on Climate Change - The Scientific Basis*. UK: Cambridge University Press.

IPCC. (2003) *Intergovernmental Panel on Climate Change* [Web Page]. URL http://www.ipcc.ch/ [2003, September 25].

Kaiser, F. G. (1998). A General Measure of Ecological Behavior. *Journal of Applied Social Psychology, 28*(5), 395-422.

Kaiser, F. G. (2003a, April 4). Personal communication. Associate professor of Social and Environmental Psychology, Faculty of Technology Management, Eindhoven University of Technology, Eindhoven, the Netherlands.

Kaiser, F. G. (2003b, April 8). Personal communication. Associate professor of Social and Environmental Psychology, Faculty of Technology Management, Eindhoven University of Technology, Eindhoven, the Netherlands.

Kaiser, F. G. (2003c, April 10). Personal communication. Associate professor of Social and Environmental Psychology, Faculty of Technology Management, Eindhoven University of Technology, Eindhoven, the Netherlands.

Kaiser, F. G., Doka, G., Hofstetter, P., & Ranney, M. A. (2003). Ecological behavior and its environmental consequences: a life cycle assessment of a self-report measure. *Journal of Environmental Psychology*, 11-20.

Kaiser, F. G., & Gutscher, H. (2004). The preposition of a general version of the theory of planned behavior: Predicting ecological behavior. *Journal of Applied Social Psychology*. In press

Kaiser, F. G., & Wilson, M. (2000). Assessing People's General Ecological Behavior: A Cross-Cultural Measure. *Journal of Applied Social Psychology, 30*(5), 952-978.

Kaiser, F. G., & Wilson, M. (2004). Goal-Directed Conservation Behavior: The Specific Composition of a General Performance. *Personality and Individual Differences*. In press

Kaiser, F. G., Woelfling, S., & Fuehrer, U. (1999). Environmental attitude and ecological behaviour. *Journal of Environmental Psychology, 19*, 1-19.

Kiwi Experience. (2003) *The adventure transport system - New Zealand* [Web Page]. URL http://www.kiwiexperience.com/ [2003, June 17].

La Trobe, H. L., & Acott, T. G. (2000). A modified NEP/DSP Environmental Attitudes Scale. *The Journal of Environmental Education, 32*(1), 12-20.

Landcare Research (Environmental Research organisation). (2003) *Landcare Research - Manaaki Whenua* [Web Page]. URL http://www.landcareresearch.co.nz/ [2003, September 25].

LTSA. (2002) *Land Transport Safety Authority* [Web Page]. URL http://www.ltsa.govt.nz/ [2003, June 11].

Magicbus. (2003) *Magic travellers Network New Zealand* [Web Page]. URL http://www.magicbus.co.nz/i [2003, June 18].

MED. (2002a). *Ministry of Economic Development, New Zealand Energy Data File July 2002*. Wellington: MED.

MED. (2002b). *Ministry of Economic Development, New Zealand Energy Greenhouse Gas Emissions 1990-2001*. Wellington: MED.

MED (Manatu Ohanga). (2003a) *Ministry of Economic Development* [Web Page]. URL http://www.med.govt.nz/ [2003a, June 11].

MED. (2003b). *Ministry of Economic Development, New Zealand Energy Data File January 2003*. Wellington: MED.

MfE. (2002a). Ministry for the Environment, National Communication 2001. *New Zealand Climate Change Programme.*

MfE. (2002b). Ministry for the Environment, New Zealand's Renewable Energy Target. *EECA*.

MfE (2005) Ministry for the Environment. (*Environmental reporting programme* [Web Page]. URL http://www.mfe.govt.nz/withyou/do/footprint/calculator.html [2005, July 19].

Mischel, W. (1968). *Personality and assessment*. New York: Wiley.

MOC . (2000). Ministry of Commerce, Ministerial Inquiry into the Electricity Industry. *Issue Paper*.

New Zealand Climate Change Programme. (2001). Kyoto Protocol - Ensuring the future. *Ministry for the Environment.*

New Zealand Climate Change Programme. (2002) *Climate Change Confirmed Policy Package* (Ministry for the Environment) [Web Page]. URL http://www.climatechange.govt.nz/whats_new/policy-govt-confirms.htm [2003, September 30].

New Zealand Climate Change Project. (2002). Climate Change - The Government's Preferred Policy Package. *Ministry for the Environment*, Wellington

NIWA (National Institute for Water & Atmospheric Research). (2002) *NIWA* [Web Page]. URL www.niwa.cri.nz [2003, October 4].

NZAA. (2002) *New Zealand's Automobile Association* [Web Page]. URL http://www.nzaa.co.nz/ [2003, June 19].

Philips New Zealand . (2003, July 31). Personal communication.

Rees, W., & Wackernagel, M. (1996). Urban Ecological Footprints: Why cities cannot be sustainable - and why they are a key to sustainability. *Environ Impact Assess Rev, 16* , 223-248.

Rinnai NZ Ltd . (2003, June 20). Sales mailbox. Personal communication.

Robertson, J. A., & et al. (2002). Energy Use and Power Levels in New Monitors and Personal Computers. *Lawrence Berkeley National Laboratory.*

Schifter, D. E., & Ajzen, I. (1985). Intention, Perceived Control, and Weight Loss: An Application of the Theory of Planned Behavior. *Journal of Personality and Social Psychology, 49*(3), 843-851.

Sheehan, M., Schonfeld, C., Ballard, R., Schofield, F., Najman, J., & Siskind, V. (1996). A three year outcome evaluation of a theory based drink driving education program. *Journal of Drug Educatian, 26*, 295-312.

Sheeran, P., & Orbell, S. (1999). Implementation intentions and repeated behaviour: Augmenting the predictive validity of the theory of planned behaviour. *European Journal of Social Psychology, 29*, 349-369.

Simmons, C. (2002) Can the Earth keep up with human consumption. *Guardian Unlimited.* .(22. February 2002)

Simmons, C., & Chambers, N. (2003). Measure The Size Of The Feet - Not The Numbers Of Heads. *Best Foot Forward - www.bestfootforward.com.*

Sims, R. (2001). Renewable energy options in New Zealand. *Climate Change: the IPCC Third Assessment Report - Wellington Workshop May 2001.*

Sims, R. (2002). *The Brilliance of Bioenergy.* James & James. London, UK

Sims, R. (2003). Renewable energy: a response to climate change. *Solar Energy.* In press

Standards Australia & New Zealand. (2000). Energy Audit AS/ NZS 3598:2000.

Statistics New Zealand (Government Statistician). (2002) *Statistics New Zealand* [Web Page]. URL http://www.stats.govt.nz/ [1903, June 6].

Stern, P. (2000). Psychology and the Science of Human-Environment Interaction. *American Psychologist, 55*(5), 523-530.

Stern, P. C. (1992). What psychology knows about energy conservation. *American Psychologist, 47*(10), 1224-1232.

Stern, P. C. (2000). Toward a Coherent Theory of Environmentally Significant Behavior. *Journal of Social Issues, 56*(3), 407-424.

Stoecklein, A., & Bassett, M. (2000). ALF3 (Version 3rd edition) [The Annual Loss Factor Method]. Wellington: BRANZ.

Stutzman, T. M., & Green, S. B. (1982). Energy conservation: two field tests of the Fishbein-Ajzen model. *Journal of Social Psychology, 117*, 183-201.

Sustainable Solutions Pty Ltd. (2003). A study of home entertainment equipment operational energy use issue. *Final Report Prepared for the Australian Greenhouse Office.*

Swiss Re. (2003). Natural catastrophes and man-made disasters in 2002. *Sigma, 2.*

Tipler, P. A. (1987). *College Physics*. New York: Worth Publisher.

Tranzmetro. (2003) *Fare finder* [Web Page]. URL http://www.tranzmetro.co.nz/fareFinder.asp [2003, September 26].

Tranzscenic . (2003) *Tranzscenic* [Web Page]. URL http://www.tranzscenic.co.nz/default.aspx_ [2003, September 26].

Tucker, A. S. (1999). *Tables of Thermodynamic and transport properties of fluids*. Christchurch: Department of Mechanical Engineering University of Canterbury.

Turner, W. C. (1997). *Energy Management Handbook*. Lilburn: The Fairmont press, Inc.

UNEP Finance Initiatives. (2003). CEO briefing . *UNEP Financial Incentives Climate Change Working Group.*

UNFCCC. (2003). Caring for climate. A guide to the climate change convention and the Kyoto Protocol. *UN.*

Vale, B., & Vale, R. (2001). Life-cycle analysis of New Zealand Houses. *Association of Pacific Rim Universities.*

Vanisha, C. (2003, June 13). Interislander sales person. Personal communication.

VCA. (2000) *Vehicle Certification Agency* [Web Page]. URL http://www.vcacarfueldata.org.uk/ [2003, June 16].

Wackernagel, M., Schulz N.B., Deumling D., Callejas Linares A., Jenkins M., Kapos V., Monfreda C., Loh J., Myers N., Norgaard R., Randers J. (2002). Tracking the ecological overshoot of the human economy. *PNAS, 99*, 9266-9271.

Ward, M. (2001). The policy context. *Climate Change: the IPCC Third Assessment Report - Wellington Workshop May 2001* .

Warehouse. (2003). Store assessment in Palmerston North.

WBCSD. (2003) *World Business Council for Sustainable Development* [Web Page]. URL http://www.ghgprotocol.org/ [2003, June 12].

Weizsäcker, E., Lovins, A., & Lovins, H. (1997). *Factor four*. UK: Earthscan .

White, G. (Energy Efficiency and Conservation Authority). (2002). Monitoring & Targeting Energy Use Seminar.

Wicker, A. W. (1969). Attitudes versus actions: The relationship of verbal and overt behavioral responses to attitude objects. *Journal of Social Issues, 25*, 41-78.

Wises Maps (2002) [Topographical Wall Map]. (4th). Auckland

WWF Switzerland (World Wide Fund). (*footprint* [Web Page]. URL www.footprint.ch [2003, October 29].

Appendices

A.1 Emission of IPCC Annex I parties 1990 and original share of total emissions

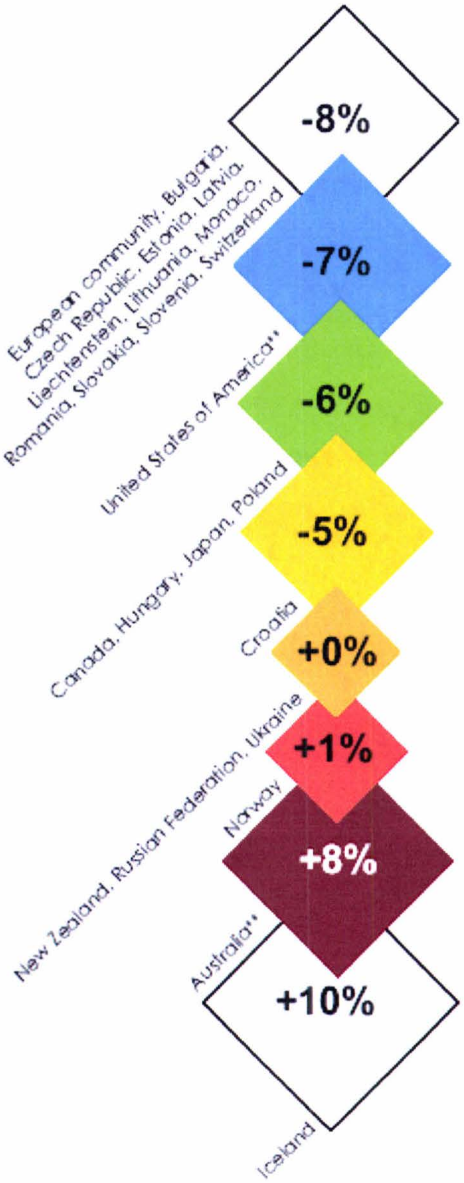
Annex I Party carbon dioxide emissions in 1990 and their share of the total for the purpose of determining entry into force of the Kyoto Protocol

Party	1990 CO_2 emissions (Gg)	%
Australia	288,965	2.1
Austria*	59,200	0.4
Belgium *	113,405	0.8
Bulgaria	82,990	0.6
Canada	457,441	3.3
Czech Republic	169,514	1.2
Denmark*	52,100	0.4
Estonia	37,797	0.3
Finland*	53,900	0.4
France*	366,536	2.7
Germany*	1,012,443	7.4
Greece*	82,100	0.6
Hungary	71,673	0.5
Iceland	2,172	0.0
Ireland*	30,719	0.2
Italy*	428,941	3.1
Japan	1,173,360	8.5
Latvia	22,976	0.2
Liechtenstein	208	0.0
Luxembourg*	11,343	0.1
Monaco	71	0.0
Netherlands*	167,600	1.2
New Zealand	25,530	0.2
Norway	35,533	0.3
Poland	414,930	3.0
Portugal*	42,148	0.3
Romania	171,103	1.2
Russian Federation	2,388,720	17.4
Slovakia	58,278	0.4
Spain*	260,654	1.9
Sweden*	61,256	0.4
Switzerland	43,600	0.3
United Kingdom*	584,078	4.3
USA	4,957,022	36.1
*15 European Community member states combined		24.2

The table does not include Annex I Parties that had not yet submitted a national communication under the Convention when the Protocol was adopted. The emissions of these Parties will not be counted towards the entry into force threshold. Figures exclude the land-use change and forestry sector.

Emissions of the Annex I parties. Source: (UNFCCC, 2003)

A.2 Emission targets of the Annex B countries



* The base year is flexible in the case of EIT countries (see page 17)
** Countries which have declared their intention not to ratify the Protocol

Countries included in Annex B of the Kyoto Protocol and their emission targets 1990 (base year) to 2008-2012. Source: (UNFCCC, 2003)

A.3 Energy conversion factors

Energy form	Unit of measure	Energy conversion factor to GJ
Natural gas	GJ	1
Electricity	kWh	0.0036
Petrol	litre	0.0342
Diesel	litre	0.0384
LPG	litre	0.0266
Coal	tonne	x 19.7

Energy conversion factors. Source: (Standards Australia & New Zealand, 2000)

1 BTU = 252cal=1.054 kJ (Tipler, 1987)

1kWh = 0.0036 GJ, 1.054 kJ = 1BTU

36000kJ = 1kWh = 3.6 MJ

1.054kJ = 2.928e-5 kWh = 0.02928 Wh

→ 1BTU = 0.02928 Wh

cp(15°C)=1.008 kJ/(kg °K) (Tucker, 1999)

p(15°C)=2.041 kg/m^3

→ HC(15°C)=cp p=2.3617 kJ/(m^3 K)

A.4 PREM – Manual

Excel version

The Personalised Residential Energy Model (PREM) will assess your ecological behaviour and energy usage in your household and individual transport. The results will be shown in a monthly bill, where the amount of money for each service such as car usage, bus usage, refrigeration or hot water heating will be shown. Apart from showing you where the energy is going (how much you pay for each service per month), the CO_2 emissions caused by each service is shown as well. In addition to the current situation, some suggested ways for future improvement will be given.

This model contains six parts:

- General ecological behaviour assessment
- Your house
- Electricity and gas bills
- Transport
- Domestic appliances
- Monthly bill with some improvements possibilities

Information you need before you start the model:

- The last available electricity and gas bill
- Any vehicle documents from the Registration or warrant of fitness (WOF) with a date and the odometer reading
- The present odometer reading
- Home light bulb power readings (Watts) and the hours of usage
- Brand name and type from the following appliances:
    - Fridge, freezer and combinations
    - Clothes washer
    - Dryer
    - Dishwasher

The model uses four colours:

Yellow:	fields to fill in your answers
Green:	important comments
Orange:	alternative input, this should be used if your specific appliance is not in the provided database

Open the excel file: PREMMASTER.xls and choose the worksheet "main"

1. General ecological behaviour (GEB): Answer all the questions by choosing your answer with the drop down list. When you are finished, your personal GEB will appear on the right of the screen.

2. Your house: Answer the questions in the yellow fields for the house you live in. If you like to have a very accurate figure of your required heating energy, download the simulation program:
http://www.branz.co.nz/main.php?page=ALF%203%20Download%20and%20Install
To do this simulation you need to know your house in great detail.

3. Electricity and gas bills: Take your last available gas and electricity bill and fill in the information.

4. Transport:
Car: To assess the distance driven take the registration or warrant of fitness documents and fill in the odometer reading 1 and the recording date. The older these documents are the better the average figure for the driven kilometres. Odometer reading 2 is the current odometer reading and the current date.
Help exists for the maintenance and depreciation costs. Choose the car size you are driving. If you do know your actual expenses, fill in the orange fields.

Train: All the inputs are per month. To give some help with distances:

Auckland to Wellington	680.7kms
Auckland to Rotorua	139.0kms by train balance by coach total 246.0kms
Palmerston North to Wellington	136.2kms
Picton to Christchurch	347.3kms
Greymouth to Christchurch	223.8kms

Bus: The inputs are per month. To find out the distances travelled use the table below:

DISTANCE TABLES

The tables show distances in kilometres between places via the shortest route on highways only

North Island

Whangarei	167	660	265	708	671	294	600	587	154	715	794	585	532	687	401	452	446	371	271	377	492	554	617	805	483
Whakatane	316	389	748	429	214	193	321	458	637	444	516	306	416	409	86	277	167	112	223	141	213	277	388	535	
Wellington	639	145	1070	193	530	512	302	280	960	91	98	319	352	140	449	353	368	528	579	437	322	259	189		
Wanganui	450	43	882	126	463	323	235	95	771	98	179	251	166	72	301	164	220	377	425	286	174	127			
Waiouru	387	113	819	186	436	261	264	228	709	168	239	247	295	132	190	103	110	270	321	179	63				
Turangi	326	176	757	249	372	201	199	247	647	231	302	184	258	195	127	66	45	206	257	115					
Tokoroa	210	291	642	331	330	85	223	321	531	346	418	208	278	311	55	139	69	91	142						
Thames	106	434	537	473	412	103	365	395	427	489	560	350	340	453	167	261	211	111							
Tauranga	204	382	635	422	301	105	314	398	525	437	508	299	343	402	82	230	160								
Taupo	279	223	711	262	327	154	154	294	600	278	349	139	305	242	81	112									
Taumarunui	286	208	717	289	438	159	265	182	607	262	342	249	193	235	191										
Rotorua	235	303	666	343	275	110	235	372	556	358	429	220	330	323											
Palmerston North	521	29	952	54	390	394	163	163	842	58	107	180	236												
New Plymouth	365	207	796	290	605	238	399	72	686	262	343	415													
Napier	418	209	850	126	213	293	18	343	739	236	232														
Masterton	627	136	1059	107	443	501	216	270	948	163															
Levin	548	55	980	111	447	421	220	189	869																
Kaitaia	321	814	111	862	826	448	754	741																	
Hawera	420	134	852	217	554	293	326																		
Hastings	433	192	865	109	229	308																			
Hamilton	127	366	558	416	382																				
Gisborne	505	419	936	336																					
Dannevirke	541	83	973																						
Cape Reinga	431	925																							
Bulls	493																								
Auckland																									

South Island

Westport																									
Timaru																									463
Te Anau																								489	832
Reefton																							810	412	80
Queenstown																						638	172	325	660
Picton																					811	274	983	497	288
Omarama																				647	164	562	336	161	614
Oamaru																			116	580	280	495	406	83	546
Nelson																		657	727	142	849	212	1020	577	226
Mt Cook																	741	204	91	661	255	576	426	207	628
Milford Sound																543	1137	519	449	1096	285	923	121	602	945
Kaikoura															941	506	244	424	492	156	656	324	828	341	390
Invercargill														757	271	433	992	333	341	912	180	818	158	416	840
Hokitika													700	428	808	531	337	447	517	392	520	117	691	367	140
Haast												277	423	706	528	341	607	366	250	669	243	395	415	410	417
Greymouth											317	41	740	401	848	528	296	443	513	352	560	78	731	363	100
Gore										675	358	635	68	689	254	365	925	265	274	845	163	752	141	348	775
Dunedin									151	562	415	565	218	540	405	323	775	116	232	695	280	610	292	199	662
Collingwood								880	1029	394	711	433	1096	378	1239	845	134	764	831	276	954	316	1126	681	330
Christchurch							524	364	513	254	535	258	581	184	765	330	420	248	316	340	480	255	652	165	334
Bluff						610	1125	247	96	769	452	729	29	785	303	462	1021	365	370	941	210	847	186	444	869
Blenheim					915	314	248	670	819	325	642	364	886	130	1070	635	114	554	621	27	785	247	957	471	261
Balclutha				751	165	445	961	82	68	643	377	646	136	621	323	385	856	197	293	776	232	691	210	280	743
Ashburton			357	393	522	88	603	276	426	287	478	291	493	264	677	242	499	161	228	419	392	334	564	77	388
Arthur's Pass		203	558	409	723	170	478	477	627	84	366	88	694	340	878	443	374	362	429	436	593	162	765	279	185
Alexandra	567	366	155	759	232	454	933	193	136	539	222	499	203	630	372	229	829	228	138	785	87	617	259	298	639

Source: (Wises Maps, 2002)

Aeroplane: The inputs here are per year. The domestic (in New Zealand) and the international ones need to be assessed separately.

Auckland to Wellington	480km
Auckland to Christchurch	740km
Wellington to Christchurch	300km
Auckland to Sydney	2170km
Auckland to London	19000km

Ferry: The most common ferry connection exists between Wellington and Picton. For this ferry ride you simply need to fill in how many times per year you use it. For any other ferry, you will need to know the travelled distance per year.

5. Appliances: The appliance usage is in general for the entire household except TV and computer. Choose your appliance you are using from the database. If you can't find your specific device use the alternative input. To use the alternative input you need to know the power (W or kW which is 1000W) of your device. This label is often on the back of the device. If you can find the appliance keep the alternative input on "0".

6. **Monthly bill:** After filling in all the yellow fields correctly you can see the results on the work sheet "monthly bill"!

On the bottom of the excel file you can click on the work sheet "monthly bill".

A.5 PREM Questionnaire

General ecological behaviour:

1. I intend to buy energy efficient household devices.	yes/no
2. I wait until I have a full load before doing my laundry.	yes/no
3. I wash dirty clothes without pre-washing.	yes/no
4. In hotels, I have the towels changed daily.	yes/no
5. I intend to use a clothes dryer.	yes/no
6. I intend to buy solar panels to produce energy.	yes/no
7. I intend to use renewable energy sources.	yes/no
10. In the winter, I keep the heat on so that I do not have to wear a sweater.	yes/no
11. In the winter, I leave the windows open for long periods of time to let in fresh air.	yes/no
12. In winter, I turn down the heat when I leave my apartment for more than 4 hours.	always/often/occasionally/ seldom/never
12. I drive my car in or into the city.	yes/no
13. I drive on freeways at speeds under 100kph (= 62.5 mph).	yes/no
14. I keep the engine running while waiting in front of a railroad crossing or in a traffic jam.	yes/no
15. At red traffic lights, I keep the engine running.	always/often/occasionally seldom/never
16. I drive to where I want to start my hikes.	always/often/occasionally/ seldom/never
17. I refrain from owning a car.	yes/no
18. I am a member of a carpool.	yes/no
19. I drive in such a way as to keep my fuel consumption as low as possible.	yes/no
20. I intent to buy a fuel-efficient automobile (less than 7 litres per 100 km; i.e., less than 3 gallons per 100 miles).	yes/no
21. For longer journeys (more than 6 hours), I take an airplane.	yes/no
22. In nearby areas (around 30 kilometres; around 20 miles), I intend to use public transportation or ride a bike.	yes/no
23. I ride a bicycle or take public transportation to work or school.	always/often/occasionally/ seldom/never

Your way to work/school:

24. How long is your way to your work? ....km

25. How many times per week are you doing this journey (there and back counts as 2)? ....times

26. Which transport are you using: (car/bicycle/walk/train/bus)? ....

27. How much of your way to work to school is in the city (distance)? ....%

Your house:

28. Number of occupants: ....

29. Construction type:
    lightweight construction (softwood walls)
    heavy construction (brick walls)
    super insulated construction (230mm fibre glass wall insulation)

30. Alternative input, if the house was simulated with ALF:
    Annually required heating energy: ....kWh

Electricity bill: (for the entire household)

31. Start date of the bill: ....

32. End date of the bill: ....

33. Fill in the gaps with the information on your bill:

	Tariff:	Bill start meter reading:	Bill end meter reading:
Day tariff:			
Night tariff:			
Economic tariff:			

34. What are your fix cost per day? NZ$/day ....

Mains gas bill: (for the entire household)

35. Start date of the bill: ....

36. End date of the bill: ....

37. Fill in the gaps with the information on your bill:

Tariff:	Bill start meter reading:	Bill end meter reading:	Unit: (m^3 or kWh)

38. What are your fix cost per day? NZ$/day ....

Car:

39. Brand, type and manufacturing year ....

40. Fuel type (e.g. LPG, diesel, premium or regular petrol) ....

41. Approximate car new price NZ$....................

42. City use (percentage due to driven kilometres) ....%

43. Fill in the gaps with two odometer readings, the longer the time between the two readings the better, minimum one week.

	Date:	Odometer [km]
Reading 1:		
Reading 2:		

Train:

44. Distance travelled last month: ....km

45. Ticket price for the travelled distance last month (sum of all train tickets) NZ$......................

Bus:

46. Distance travelled last month: ....km

47. Ticket price for the travelled distance last month (sum of all train tickets) NZ$......................

48. Intercity use compare to intracity (percentage due to driven kilometres) ....km

Air travel:

Domestic:

49. Distance travelled last year: ....km

50. Ticket price for the travelled distance last year (sum of tickets) NZ$......................

International:

51. Distance travelled last year: ....km

52. Ticket price for the travelled distance last year (sum of tickets) NZ$......................

Ferry:

53. How many times did cross the cook strait last month?: ....times

54. Distance travelled with other ferries: ....km

55. Ticket price for the travelled distance last year (sum of tickets) NZ$......................

Hot water:

56. Which energy source do you use (e.g. solar, gas or wood)? ....

Heater:

57. How much of each energy source do you use?: .....% electric. ...% gas... .....% wood.

58. If you used wood how much did you pay per loose cubic metre?: NZ$........................

59. What kind of gas do you use (e.g. mains gas or LPG)? ....

Lighting:

60. Fill in the gaps with the right information:

Light bulbs: Compact fluorescent 11W, 13W, 14W, 15W, 18W, 20W or incandescent 60W, 75W, 100W

Room	Light bulbs:	Number of bulbs:	Number of usage hours per day:
Living room 1			
Living room 2			
Kitchen			
Bathroom 1			
Bathroom 2			
Bedroom 1			
Bedroom 2			
Bedroom 3			
Bedroom 4			

Refrigeration:

61. What brand and type of fridge/freezer combination do you have?: ....

62. What brand and type of fridge do you have?: ....

63. What brand and type of freezer do you have?: ....

Cooking

64. Which energy source do you use: (electric or gas)? ....

Dryer:

65. What brand and type of dryer do you have?: ....

66. How many times does your household use it per month?: ....loads/month

Dishwasher:

67. What brand and type of dishwasher do you have?: ....

68. How many times does your household use it per month?: ....loads/month

Television:

69. What kind of TV do you use: (CRT or LCD)? ....

CRT: Traditional screen, Cathode ray tube. LCD: Flat screen, Liquid crystal display

70. How many hours do you use it per day?: ....h/day

Personal computer:

71. What kind of PC do you use?: (AMD Athlon, Intel 3, Intel 4 or laptop) ....

72. How many hours do you use it per day?: ....h/day

73. What kind of screen do you use?: (LCD or CRT including size) ....

74. How many hours do you use it per day?: ....h/day

A.6 GEB scale

50 conservation behaviours grouped into six performance domains (Kaiser & Wilson, 2004)

Note. The estimates in Table 1 are based on the 1998 data (N = 895). Items underlined indicate negatively formulated behaviours; they are recoded and should be read as "I refrain from ...". **Bold figures** highlight the mean squares (MS) of poorly fitting behaviours. These MS correspond with either more than a 10% lack (MS < 0.90) or with more than a 10% excess (MS > 1.10) of variation in the model prediction compared to what is in the data. Behaviour difficulties (δ) are expressed in logits; the more negative a logit value the easier and the more positive the more difficult the particular behaviour is. Logits stand for the natural logarithm of the performance/non-performance ratio or the natural log odds. The subscript $_{uni}$ indicates findings from the unidimensional calibration of the behaviours, while $_{mult}$ refers to those from the six-dimensional calibration.

Energy Conservation		δ	MS
1.	I own energy efficient household devices.	-1.40	.99
2.	I wait until I have a full load before doing my laundry.	-2.54	.99
3.	I wash dirty clothes without pre-washing.	-1.07	1.05
4.	In hotels, I have the towels changed daily.	-2.52	1.03
5.	I use a clothes dryer.	-0.79	1.00
6.	I bought solar panels to produce energy.	3.99	.98
7.	I use renewable energy sources.	2.34	.99
8.	In the winter, I keep the heater on so that I do not have to wear a sweater.	-0.61	1.06
9.	In the winter, I leave the windows open for long periods of time to let in fresh air.	-0.83	1.02
10	In the winter, I turn down the heater when I leave my apartment for more than 4 hours.	0.96	1.02
11.	I prefer to shower rather than to take a bath.	-2.13	1.08

Mobility and Transportation		δ	MS
12.	I drive my car in or into the city.	-0.32	.95
13.	I drive on freeways at speeds under 100kph (= 62.5 mph).	1.38	.93
14.	I keep the engine running while waiting in front of a railroad crossing or in a traffic jam.	-1.79	.98
15.	At red traffic lights, I keep the engine running.	-0.33	.99
16.	I drive to where I want to start my hikes.	-0.28	.94
17.	I refrain from owning a car.	1.35	.97
18.	I am a member of a carpool.	3.36	.98
19.	I drive in such a way as to keep my fuel consumption as low as possible.	-1.84	1.01
20.	I own a fuel-efficient automobile (less than 7 litres per 100 km; i.e., less than 3 gallons per 100 miles).	1.34	**1.12**
21.	For longer journeys (more than 6 hours), I take an airplane.	0.14	1.04
22.	In nearby areas (around 30 kilometres; around 20 miles), I use public transportation or ride a bike.	0.42	.92
23.	I ride a bicycle or take public transportation to work or school.	-0.38	.97

Waste Avoidance		δ	MS
24.	I buy milk in returnable bottles.	1.50	1.10
25.	If I am offered a plastic bag in a store, I take it.	1.09	.99
26.	I reuse my shopping bags.	-4.64	.98
27.	I buy beverages in cans.	-2.52	.98
28.	I buy products in refillable packages.	-1.57	.97

Consumerism		δ	MS
29.	I use fabric softener with my laundry.	-0.66	1.00
30.	I use an oven cleaning spray to clean my oven.	-1.20	1.02

31.	I kill insects with a chemical insecticide.	-1.00	.98
32.	I use a chemical air freshener in my bathroom.	-1.01	1.03
33.	I buy convenience foods.	-1.37	1.01
34.	I buy seasonal produce.	-2.77	.98
35.	I buy bleached and coloured toilet paper.	-0.49	1.02
36.	I buy meat and produce with eco-labels.	0.39	.98
37.	I buy domestically grown wooden furniture.	-0.26	.99

Recycling		δ	MS
38.	I collect and recycle used paper.	-4.55	1.00
39.	I bring empty bottles to a recycling bin.	-4.47	.98
40.	I put dead batteries in the garbage.	-4.19	.97
41.	After meals, I dispose of leftovers in the toilet.	-1.26	1.04

Vicarious, Social Behaviours Toward Conservation		δ	MS
42.	After a picnic, I leave the place as clean as it was originally.	-3.40	1.03
43.	I am a member of an environmental organisation.	1.22	.94
44.	I read about environmental issues.	2.17	.93
45.	I contribute financially to environmental organisations.	1.75	.92
46.	I talk with friends about problems related to the environment.	0.98	.96
47.	I have pointed out unecological behaviour to someone.	1.80	1.05
48.	I boycott companies with an unecological background.	-0.25	1.01
49.	I have already looked into the pros and cons having a private source of solar power.	0.82	1.05
50.	I requested an estimate on having solar power installed.	2.54	1.00

A.7 GEB - Questionnaire

Underlined items indicate negative formulated behaviours.

The third column shows the response format. "Poly" indicate a 5-point polytomous, which is categorised by "never", "seldom", and occasionally" as a negative response (0) and "often" and "always" as a positive response (1). "Dich" means a dichotomous response format, Yes (1) and No (0). (Kaiser, 2003a)

It is suggested to use for all items "I don't know" as an additional response. Missing values are not a problem, when the correlation matrix is not analysed. Experiences of former studies shows, missing values are rarely above 5%. Source: (Kaiser, 2003a)

The items where slightly changed to meet the models purpose to find the target behaviour, this is possible without changing anything significant in the scale. (Kaiser, 2003b; Kaiser & Gutscher, 2004)

Energy Conservation

1.	I intend to buy energy efficient household devices.	dich
2.	I wait until I have a full load before doing my laundry.	dich
3.	I wash dirty clothes without pre-washing.	dich
4.	In hotels, I have the towels changed daily.	dich
5.	I intend to use a clothes dryer.	dich
6.	I intend to buy solar panels to produce energy.	dich
7.	I intend to use renewable energy sources.	dich
13.	In the winter, I keep the heat on so that I do not have to wear a sweater.	dich
14.	In the winter, I leave the windows open for long periods of time to let in fresh air.	dich
15.	In winter, I turn down the heat when I leave my apartment for more than 4 hours.	poly
11.	I prefer to shower rather than to take a bath.	dich

Mobility and Transportation

12. I drive my car in or into the city.	dich
13. I drive on freeways at speeds under 100kph (= 62.5 mph).	dich
15. I keep the engine running while waiting in front of a railroad crossing or in a traffic jam.	dich
15. At red traffic lights, I keep the engine running.	poly
16. I drive to where I want to start my hikes.	poly
17. I refrain from owning a car.	dich
18. I am a member of a carpool.	dich
21. I drive in such a way as to keep my fuel consumption as low as possible.	dich
22. I intent to buy a fuel-efficient automobile (less than 7 litres per 100 km; i.e., less than 3 gallons per 100 miles).	dich
23. For longer journeys (more than 6 hours), I take an airplane.	Dich
24. In nearby areas (around 30 kilometres; around 20 miles), I intend to use public transportation or ride a bike.	dich
25. I ride a bicycle or take public transportation to work or school.	poly

Investment potential

26. How much could you invest per month to reduce your energy costs in the long-term and to reduce greenhouse gases?	NZD

A.8 Rasch formula

The Rasch formula (Equation 3) calculates probabilities P of performing an item for a person i when passing ($X_{is}=1$) an item s (Embretson, 2000). The independent variables are the item difficulty β (behaviour's difficulty) and the persons trait level Θ (person's ability).

$$P\left(X_{is}=1\middle|\Theta_s,\beta_i\right)=\frac{e^{\Theta_s-\beta_i}}{1-e^{\Theta_s-\beta_i}}$$

Equation 3: Probability calculation by ability and difficulty

The simple Rasch model uses the dichotomous response (yes/no, endorsed/not endorsed or 1/0) for a particular person i to a specific item s. This is the dependent variable X_{is}, which is assessed with the question to a person of passing an item. If X_{is} is assessed as 1 the outcome will be the probability of success P, else it will be the probability of failure $Q=1-P$.

A.9 Maximum likelihood

To find a person's trait level (person's ability) requires a search process (Embretson et al, 2000). The maximum likelihood method is the typical way to estimate the trait level. The required inputs are the item difficulty β and the response pattern $\underline{X_{is}}$.

Assuming the difficulties are $\underline{\beta}=(-2, -1, 0, 1, 2)$ and the response pattern $\underline{X_{is}}=(1,1,1,1,0)$. This means that the person succeeded at the first four items up to the difficulty of 1 and failed the most difficult one. To find the maximum likelihood, hypothetical trait levels have to be computed. In this example trait levels from –3.5 to 7 in intervals of 0.5 (Table A.9.1). The smaller the interval is the more precise the estimation. This process with small intervals can get burdensome for the computer calculation.

			P(Θ)	P(Θ)	P(Θ)	P(Θ)	P(Θ)	P(Θ)	P(Θ)	P(Θ)	P(Θ)	P(Θ)	P(Θ)	P(Θ)	P(Θ)
		Θ	-3.5	-3	...	0.5	1	1.5	2	2.5	3	3.5	...	6.5	7
Item	β	Xis													
1	-2	1	0.18	0.27	...	0.92	0.95	0.97	0.98	0.99	0.99	1.00	...	1.00	1.00
2	-1	1	0.08	0.12	...	0.82	0.88	0.92	0.95	0.97	0.98	0.99	...	1.00	1.00
3	0	1	0.03	0.05	...	0.62	0.73	0.82	0.88	0.92	0.95	0.97	...	1.00	1.00
4	1	1	0.01	0.02	...	0.38	0.50	0.62	0.73	0.82	0.88	0.92	...	1.00	1.00
5	2	0	1.00	0.99	...	0.82	0.73	0.62	0.50	0.38	0.27	0.18	...	0.01	0.01
L(Xis)			0.000	0.000	...	0.145	0.224	0.284	0.301	0.274	0.220	0.161	...	0.011	0.007
Max L	0.301														

Table A.9.1:Maximum likelihood method

The probabilities are calculated according to the Rasch formula (Equation 3). For the first four difficulties, which were successful ($X_{is}=1$), the number in the table is the probability P. For the fifth, unsuccessful one ($X_{is}=0$) the number shows the probability of failure ($Q=1-P$). The likelihood of a persons response ($\underline{X_{is}}$), is taken across all the items, by taking the product of the probabilities of success or failure, according to the likelihood formula (Equation 4). The persons response pattern in this example is $\underline{X_{is}}=(1,1,1,1,0)$. The likelihood formula takes the probability of success P if the response is $X_{is}=1$ and the probability of failure $Q=1-P$ if the response is $X_{is}=0$.

$$L(X_{is}) = P_{1s} \cdot P_{2s} \cdot P_{3s} \cdot P_{4s} \cdot (1 - P_{5s})$$

Equation 4: Likelihood

After calculating the likelihood for all the hypothetical trait levels, it is possible to plot the results in a graph (Fig. A.9.1). The graph shows the likelihood in the y-axis and the trait level in the x-axis.

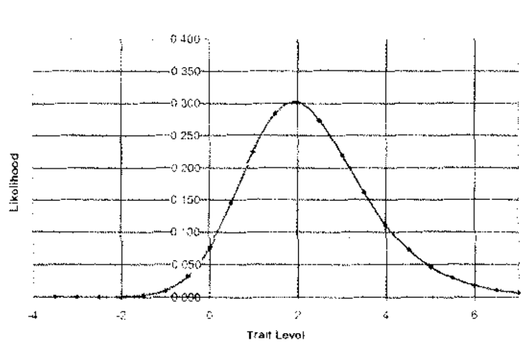


Figure A.9.1 : Maximum likelihood method

The culmination point of the curve shows the maximum likelihood. In this example it is a likelihood of 0.30 at a trait level of 2. The maximum likelihood is an indicator of the consistency. For example a person who intend to perform some difficult behaviours, but not some easy ones, the consistency would be low (Embretson, 2000).

People, who just intend to perform the easiest two of eleven energy conservation behaviours, would have a trait level of –2.8 (Fig. A.9.2). This person would agree to the behaviour: "I wait until I have a full load before doing laundry" and "In hotels I have the towels changed daily", but not to the next difficult one "I prefer to shower than to take a bath"

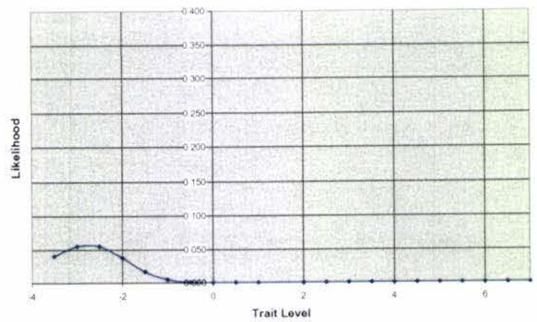


Figure A.9.2: Unecological (11000000000) example in the domain Energy conservation, resulting trait level (ability) 2.8

A person who would agree to almost all behaviours in this domain, including the quite difficult one: " I intend to use renewable energy sources" (Fig. A.9.3).

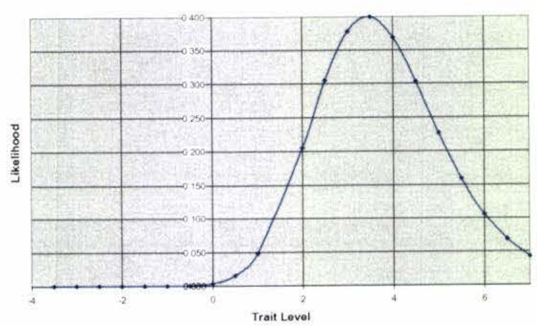


Figure A.9.3: Ecological (11111111110) example in the domain Energy conservation, resulting trait level (ability) 3.5

The only item this person didn't agree with would be, the most difficult in this domain: "I intend to buy solar panels to produce energy". He or she would have a trait level of 3.5.

A.10 House constructions

1. Lightweight Construction:

softwood framing to walls and roof; 94 mm glass fibre insulation to walls; fibre cement weather boarding as external cladding; plasterboard internal lining; corrugated steel roofing; 75 mm glass fibre to sloping and flat ceilings; plasterboard ceiling; raised timber floor with draped foil insulation (R 1.1 m2degC/W); aluminium ti-amed windows with single clear glass.

2. Heavy Construction:

softwood faming to walls with external brick veneer; plasterboard internal lining; 94 mm glass fibre insulation to walls; softwood framing to roof with concrete tile covering; 75 mm glass fibre insulation to sloping and flat ceilings; plasterboard ceiling; concrete slab floor with 25 mm expanded polystyrene perimeter insulation to a depth of 500 mm; aluminium framed windows with single clear glass.

3. Superinsulated Construction:

This super insulated construction has the double of the required insulation. It has R 4.4 all round the envelope. The windows are double-glazing.

Source: (Vale & Vale, 2001)

A.11 Conversion factor

Joules to kWh:	2.778×10^{-7}
kWh to Joules:	3.6×10^{6}
Btu to kWh:	2.931×10^{-4}

Source: (Baines, 1993)

A.12 Combustion emission factors

	Unit	EBEX [6]	WBCSD [7]				
Diesel	l	0.002617470	0.002745800	t CO2/Unit			
Premium Gasoline	l	0.002297700	0.002382200	t CO2/Unit			
Regular Gasonline	l	0.002297700	0.002382200	t CO2/Unit			
CNG [1]	kg	0.002590000	0.002931900	t CO2/Unit	density [2]	259.68	kg/m3
	l	0.000672571	0.000761356	t CO2/Unit (calc)			
LPG	l	0.001600600	0.002905900	t CO2/Unit	specific gravity [3]	0.53	kg/l
	kg	0.000848318	0.001573700	t CO2/Unit			
Mixed Gas	l	0.000002070		t CO2/Unit			
	kWh	0.000014668		t CO2/Unit (calc)	CV	0.0392	MJ/l
International flights	pkm	0.000110000	0.000110000	t CO2/Unit			
Domestic flights	pkm	0.000180000	0.000180000	t CO2/Unit			
Train [4]	pkm	0.000098900		t CO2/Unit			
intra city Bus	pkm	0.000085665		t CO2/Unit			
Intercity Bus	pkm	0.000051400		t CO2/Unit			
Ferry [5]	pkm	0.000450000		t CO2/Unit			

Combustion emission factors. Sources: 1: (Berndt, 2003); 2: (Hunt, 2003b); 3: (Baines, 1993);4: (Becken, 2002);5: (Hargreaves, in press); 6: (EBEX21, 2003);7: (WBCSD, 2003)

A.13 Highway distances

DISTANCE TABLES

The tables show distances in kilometres
between places via the shortest route on highways only

North Island

Whangarei	167	660	265	708	671	294	600	587	154	715	794	585	532	687	401	452	446	371	271	377	492	554	617	805	483
Whakatane	316	389	748	429	214	193	321	458	637	444	516	306	416	409	86	277	167	112	223	141	213	277	388	535	
Wellington	639	145	1070	193	530	512	302	280	960	91	98	319	352	140	449	353	368	528	579	437	322	259	189		
Wanganui	450	43	882	126	463	323	235	95	771	98	179	251	166	72	301	164	220	377	425	286	174	127			
Waiouru	387	113	819	186	436	261	264	228	709	168	239	247	295	132	190	103	110	270	321	179	63				
Turangi	326	176	757	249	372	201	199	247	647	231	302	184	258	195	127	66	45	206	257	115					
Tokoroa	210	291	642	331	330	85	223	321	531	346	418	208	278	311	55	139	69	91	142						
Thames	106	434	537	473	412	103	365	395	427	489	560	350	340	453	167	261	211	111							
Tauranga	204	382	635	422	301	105	314	398	525	437	508	299	343	402	82	230	160								
Taupo	279	223	711	262	327	154	154	294	600	278	349	139	305	242	81	112									
Taumarunui	286	208	717	289	438	159	265	182	607	262	342	249	193	235	191										
Rotorua	235	303	666	343	275	110	235	372	556	358	429	220	330	323											
Palmerston North	521	29	952	54	390	394	163	163	842	58	107	180	236												
New Plymouth	365	207	796	290	605	238	399	72	686	262	343	415													
Napier	418	209	850	126	213	293	18	343	739	236	232														
Masterton	627	136	1059	107	443	501	216	270	948	163															
Levin	548	55	980	111	447	421	220	189	869																
Kaitaia	321	814	111	862	826	448	754	741																	
Hawera	420	134	852	217	554	293	326																		
Hastings	433	192	865	109	229	308																			
Hamilton	127	366	558	416	382																				
Gisborne	505	419	936	336																					
Dannevirke	541	83	973																						
Cape Reinga	431	925																							
Bulls	493																								
Auckland																									

Westport																									
Timaru																									463
Te Anau																								489	832
Reefton																							810	412	80
Queenstown																						638	172	325	660
Picton																					811	274	983	497	288
Omarama																				647	164	562	336	161	614
Oamaru																			116	580	280	495	406	83	546
Nelson																		657	727	142	849	212	1020	577	226
Mt Cook																	741	204	91	661	255	576	426	207	628
Milford Sound																543	1137	519	449	1096	285	923	121	602	945
Kaikoura															941	506	244	424	492	156	656	324	828	341	390
Invercargill														757	271	433	992	333	341	912	180	818	158	416	840
Hokitika													700	428	808	531	337	447	517	392	520	117	691	367	140
Haast												277	423	706	528	341	607	366	250	669	243	395	415	410	417
Greymouth											317	41	740	401	848	528	296	443	513	352	560	78	731	363	100
Gore										675	358	635	68	689	254	365	925	265	274	845	163	752	141	348	775
Dunedin									151	562	415	565	218	540	405	323	775	116	232	695	280	610	292	199	662
Collingwood								880	1029	394	711	433	1096	378	1239	845	134	764	831	276	954	316	1126	681	330
Christchurch							524	364	513	254	535	258	581	184	765	330	420	248	316	340	480	255	652	165	334
Bluff						610	1125	247	96	769	452	729	29	785	303	462	1021	365	370	941	210	847	186	444	869
Blenheim					915	314	248	670	819	325	642	364	886	130	1070	635	114	554	621	27	785	247	957	471	261
Balclutha				751	165	445	961	82	68	643	377	646	136	621	323	385	856	197	293	776	232	691	210	280	743
Ashburton			357	393	522	88	603	276	426	287	478	291	493	264	677	242	499	161	228	419	392	334	564	77	388
Arthur's Pass		203	558	409	723	170	478	477	627	84	366	88	694	340	878	443	374	362	429	436	593	162	765	279	185
Alexandra	567	366	155	759	232	454	933	193	136	539	222	499	203	630	372	229	829	228	138	785	87	617	259	298	639

South Island

Highway distances. Source: (Wises Maps, 2002)

A.14 Fridges and freezer combinations, and freezer figures

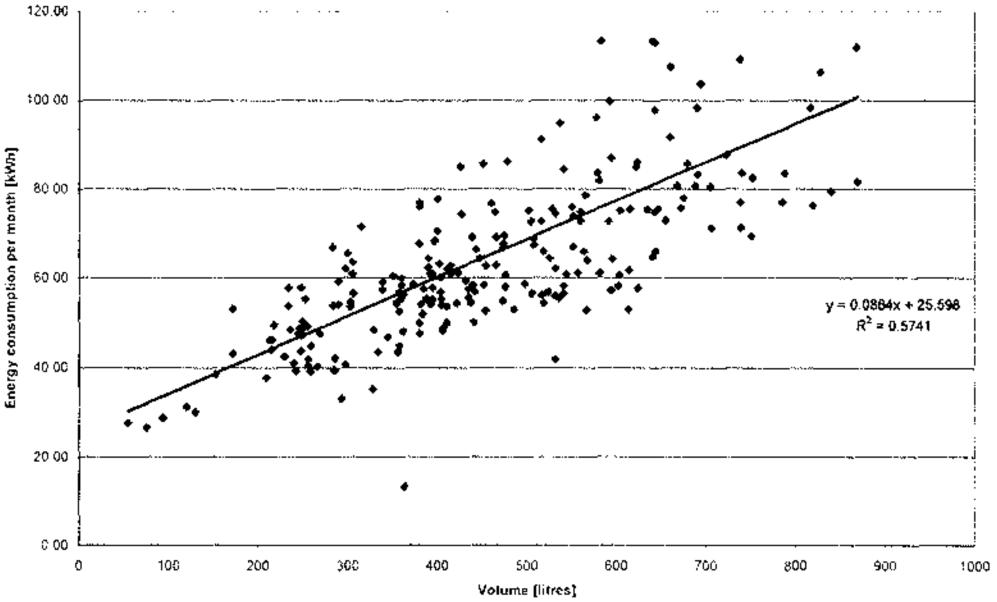


Figure A.14.1: Combinations of fridges and freezers; Volume to energy consumption. Source data: (AGO, 2003a)

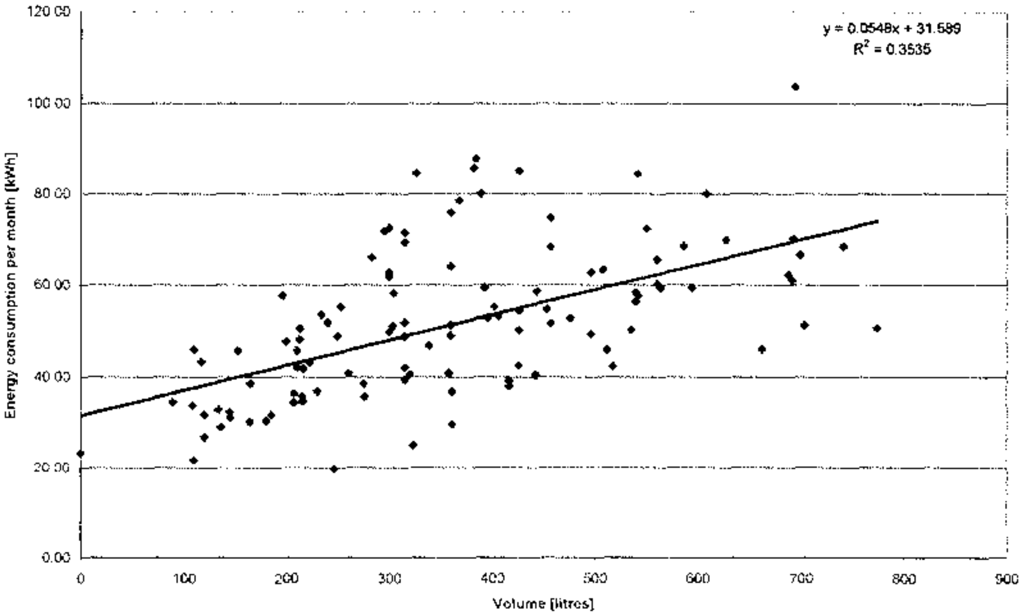


Figure A.14.2: Freezers; Volume to energy consumption. Source data: (AGO, 2003a)

A.15 Light bulbs

	Input [W]	Light output compared to incandescent [W]	Brand
CFL 11W Longstar	11	45	Longstar
CFL 11W Philips	11	60	Philips
CFL 13W Longstar	13	55	Longstar
CFL 14W Philips	14	75	Philips
CFL 15W Longstar	15	60	Longstar
CFL 18W Philips	18	100	Philips
CFL 20W Connections	20	80	Connections
CFL 8W Longstar	8	35	Longstar
CFL 8W Philips	8	40	Philips
Incand. 100W Philips	100	100	Philips
Incand. 60W Philips	60	60	Philips
Incand. 75W Philips	75	75	Philips

Source: (Warehouse, 2003)

A.16 Television

Flat screen, LCD	Liquid cristal display	32	Watt
Traditional TV, CRT	Cathode ray tube	70	Watt

Source: (Sustainable Solutions Pty Ltd, 2003)

A.17 Desktop Computer on power by CPU brand, model and speed

CPU		Measured on power [W]	
Brand, Model	Speed range [MHz]	Range	Average
Intel Pentium 3	733-1000	28-47	38
Intel Pentium 4	1300-1800	59-94	67
AMD Athlon	1000-1400	93-117	104

Source: (Robertson et al, 2002)

A.18 Variation in Monitor On Power [W], for selected Monitors with average power calculation; Power measured with the desktop image

Display type	Screen size	Variation on power [W]	Average on power [W]
CRT Cathode Ray Tube	15"	63	59.5
		56	
	17"	86	86
		96	
	19"	90	90.5
		91	
	21"	118	108.5
		99	
LCD Liquid Crystal Display	15"	17	25
		33	
	18"	59	49.5
		40	

Source: (Robertson et al, 2002)

A.19 Case study inputs

a) Mr. Greeny

House:	Heavy construction (specified in Appendix A.10) Living room, kitchen, bathroom and three bedrooms 2 occupants
Electricity bill:	216 kWh/month (39% below average, (BRANZ, 2002)) 31.40 NZ$/month, with the average electricity price of 0.14 NZ$/kWh
Gas bill:	361 kWh/month (80% above average, (BRANZ, 2002)) All natural mains gas, 22.90 NZ$ /month, with an average mains gas price of 0.0635 NZ$/kWh
Car:	2002 model, Peugeot 307, diesel (4-6l/100km), 30% city use 1411 km (NZ average)
Train:	Auckland to Wellington 680.7km, NZ$ 102, Saver fare (Tranzscenic, 2003)
Air:	Auckland – Hong Kong return, 18,264km, NZ$ 1900 (Air New Zealand, 2003)
Ferry:	Wellington to Picton without car, NZ$ 50(Interislander, 2003)
Hot water:	Natural mains gas (no appliance database)
Heater:	50% wood and 50% natural mains gas (no appliance database)
Lighting:	12 compact fluorescent bulbs (CFL) 14W (same light power as a 75W incandescent) running time 1.8 hours per bulb per day

Refrigeration:	Fridge/freezer Vestafrost BSKF352 (293litre, 4 stars, 33.09 kWh/month) Freezer Vestafrost SE325 (323litre, 4.5 stars, 25.24 kWh/month)
Cooking:	Electric (no appliance database)
Clothes washer:	Miele W1986, 6.5kg capacity, used 4 times a week (0.45 kWh/usage, 4.5 stars)
Dishwasher:	Kelvinator K300, 12 place settings, used 5 times a week (0.701 kWh/usage, 3 stars)
Television:	Flat screen LCD, 3 hours a day
PC:	Laptop, 3 hours a day

b) Mr. Careless

House:	Light weight construction (specified in Appendix A.10) Living room, kitchen, bathroom and three bedrooms 2 occupants
Electricity bill:	832.85 kWh/month (49% above average, (BRANZ, 2002)) NZ$ 120.76/month, with the average electricity price of 0.14 NZ$/kWh
Gas bill:	196.04 kWh/month (2% below average, (BRANZ, 2002)) 49 kWh/month natural mains gas and 147 kWh/month LPG (20litre) 6.64 NZ$/month, with the average mains gas price of 0.0635 NZ$/kWh and LPG 0.65 NZ$/litre
Car:	2002 model, Jeep Cherokee, premium petrol (10.5-16l/100km) 1411 km (NZ average)
Bus:	Auckland to Wellington 639km, NZ$ 89
Air:	24 times Auckl – Christchurch, 18,240km, 24*NZ$200 (Economy class (Air New Zealand, 2003))
Ferry:	Wellington to Picton without car, NZ$ 50 (Interislander, 2003)
Hot water:	Natural mains gas (no appliance database)
Heater:	50% natural mains gas and 50% electric (no appliance database)
Lighting:	12 incandescent bulbs 75W running time 1.8 hours per bulb per day

Refrigeration: Fridge/freezer Kelvinator N300 (300litre, 1.5 stars, 65.6 kWh/month)
Freezer Amada ATX518V (326litre, 2 stars, 84.56 kWh/month)

Cooking: Natural mains gas (no appliance database)

Clothes washer: Samsung SW65ASP2, 6.5kg capacity, used 4 times a week
(1 star, 2.19 kWh/usage)

Dryer: AEG, Lavatherm T-500, used 4 times a week
(2 stars, 5.269 kWh/usage)

Dishwasher: Haier WQP12-HFE, 12 place settings, used 5 times a week
(1 star, 1.644 kWh/usage)

Television: Traditional CRT, 3 hours a day

PC: Desktop Intel Pentium 4, CRT Monitor 17"

A.20 Monthly bills

Monthly figures averaged throughout the year and assuming a CO_2 tax of 25 NZ$/t CO_2.

Mr. Greeny: Energy conservation ecological behaviour: 2

Mobility & Transport ecological behaviour: 2.5

Mr. Careless: Energy conservation ecological behaviour: -1.5

Mobility & Transport ecological behaviour: -3.5

	Mr. Greeny			Mr. Careless		
	NZD	kg CO2	CO2 tax	NZD	kg CO2	CO2 tax
Transport						
Car	508.14	174.87	4.37	973.25	406.22	10.16
Train	102.00	67.32	1.68	0.00	0.00	0.00
Bus	0.00	0.00	0.00	89.00	32.84	0.82
Domestic air	0.00	0.00	0.00	401.10	274.35	6.86
International air	158.77	167.88	4.20	0.00	0.00	0.00
Ferry	4.18	3.12	0.08	4.18	3.12	0.08
Total transport	**773.08**	**413.19**	**10.33**	**1467.52**	**716.54**	**17.91**

	NZD	kg CO2	CO2 tax	NZD	kg CO2	CO2 tax
Residential						
Hotwater	7.72	1.85	0.05	17.69	21.66	0.54
Heating	4.92	0.89	0.02	15.50	26.99	0.67
Lighting	0.68	0.83	0.02	3.65	4.47	0.11
Refrigeration	4.23	5.18	0.13	10.89	13.33	0.33
Cooking	4.23	5.18	0.13	1.86	0.45	0.01
Cothwashing	0.57	0.70	0.02	2.77	3.39	0.08
Dryer	0.00	0.00	0.00	6.11	7.48	0.19
Dishwasher	1.11	1.36	0.03	2.60	3.18	0.08
Television	0.42	0.52	0.01	0.93	1.14	0.03
Computer	0.25	0.31	0.01	2.10	2.57	0.06
Miscellaneous	4.21	5.14	0.13	4.23	5.17	0.13
Total appliances	**28.34**	**21.96**	**0.55**	**68.32**	**89.81**	**2.25**
Total appliances and transport	**801.42**	**435.15**	**10.88**	**1535.84**	**806.35**	**20.16**

A.21 Monthly difference between Mr. Greeny and Mr. Careless without CO_2 taxes.

Negative values show where Mr. Careless chose the cheaper or less polluting option.

	cost		emissions	
	$NZ	factor	kg CO2	factor
Car	465.11	1.92	231.36	2.32
Train	-102.00		-67.32	
Bus	89.00		32.84	
Domestic air	401.10		274.35	
International air	-158.77		-167.88	
Ferry	0.00	1.00	0.00	1.00
Total transport	**694.44**	**1.90**	**303.35**	**1.73**
Hotwater	9.97	2.29	19.81	11.70
Heating	10.58	3.50	26.09	30.16
Lighting	2.97	5.36	3.63	5.36
Refrigeration	6.66	2.57	8.15	2.57
Cooking	-2.37	0.44	-4.73	0.09
Cothwashing	2.20	4.87	2.69	4.87
Dryer	6.11		7.48	
Dishwasher	1.49	2.35	1.82	2.35
Television	0.50	2.19	0.62	2.19
Computer	1.84	8.32	2.26	8.32
Miscellaneous	0.02	1.00	0.02	1.00
Total appliances	**39.97**	**2.41**	**67.85**	**4.09**
Total appliances and transport	**734.41**	**1.92**	**371.20**	**1.85**

A.22 Improvement assumptions

Work distance:	4km, only city
Train instead of airplane:	1000km, North Island → South Island (once crossing the cook strait)
Bike instead of car in nearby areas:	20km, only city
Fuel efficient car:	4litre/100km

A.23 Possible behaviour changes for Mr. Greeny and Mr. Careless

a) Mr. Greeny

	Probability	Cost difference	CO2 emission difference	CO2 tax
	%	$	kg	
Buy energy efficient appliances	96.77			
Ride a bike or walk to school or work	94.68	-12.82	-5.63	-0.14
Take the train to school or work	94.68	-7.59	-2.19	-0.05
Take the bus to school or work	94.68	-7.24	-2.65	-0.07
Don't use a dryer	94.21	0.00	0.00	0.00
Take the train instead of the airplane for longer journeys	91.68	-82.59	-51.96	-1.30
Take the bus instead of the airplane for longer journey	91.68	-91.62	-95.52	-2.39
Ride a bike or walk to nearby areas instead of taking the car	89.09	-7.29	-3.23	-0.08
Take a train to nearby areas instead of taking the car	89.09	-4.29	-1.26	-0.03
Take a bus to nearby areas instead of taking the car	89.09	-4.09	-1.52	-0.04
Buy a fuel efficient car	76.85	-5.41	-22.81	-0.57
Total		**-222.93**	**-186.76**	**-4.67**

b) Mr. Careless

	Probability	Cost difference	CO2 emission difference	CO2 tax
	%	$	kg	
Buy a fuel efficient car	99.18	-117.41	-272.49	-6.81
Ride a bike or walk to nearby areas instead of taking the car	98.02	-13.95	-7.58	-0.19
Take a train to nearby areas instead of taking the car	98.02	-10.95	-5.60	-0.14
Take a bus to nearby areas instead of taking the car	98.02	-10.75	-5.87	-0.15
Take the train instead of the airplane for longer journeys	97.34	-75.61	-51.96	-1.30
Take the bus instead of the airplane for longer journey	97.34	-66.78	-95.52	-2.39
Ride a bike or walk to school or work	95.77	-24.51	-13.22	-0.33
Take the train to school or work	95.77	-19.28	-9.77	-0.24
Take the bus to school or work	95.77	-18.94	-10.23	-0.26
Don't use a dryer	67.04	-6.11	-7.48	-0.19
Buy energy efficient appliances	52.50			
Total		**-364.29**	**-479.71**	**-11.99**

A.24 Hot water cylinder saving potential

Behaviour	Cost	Energy savings	Simple Energy Payback	GHG savings
Replacing a 180l D grade cylinder with a new A grade	~$1200	$100/yr	12 yr	$7.3/yr
Cylinder wrap	$100	$88/yr	1.1yr	$6.4/yr
Hot shot heat pump	~$1800	$274/yr	6.4yr	$20/yr
Solar	$3500+	$356/yr	10yr	$26/yr
New gas cylinder	~$2000	~$300/yr	6.7yr	~$25/yr

Source: (BRANZ, 2002)

A.25 House retrofit saving potential

- Ceiling insulation can save you up to $285 a year in heating bills.
- Thermal lined curtains and Pelmet can save you up to $58 a year in heating bills.
- Under floor insulation keeps the cold from getting in, and your heat from escaping. This can save you up to $194 a year in heating bills.
- An energy efficient wood burner keeps the heat in the house, not escaping out the chimney.
- Draught stopping doors and windows can save you up to $58 a year in heating bills.

Source: (EECA, 2003a)

A.26 Behaviour changes to reduce energy demand

- Take showers instead of baths and keep them reasonably short (This could save two people about $10 per month).
- Turn off any heated towel rails once the towels are dry. This could save about $5 per month.
- Install a water-efficient shower head if your shower delivers more than 12-13 litres per minute (check with a bucket and watch).
- If it's only a bit cool, put on warmer clothes before you put on a heater.
- Only heat the room you're in and close doors to colder parts of the house.
- Block any obvious drafts (e.g. unused fireplaces) Use a draft stopper snake under any external doors.
- Close curtains at night to keep the heat in.
- Only use lights you really need and remember to turn them off when you leave the room.
- For lighting that you use a lot, buy some compact fluorescent lamps
- Unplug chargers for cell phones (etc) once they are charged.
- Turn off computers, screens and printers when not in use.
- Turn TV, Video and set-top box off at the wall after it has been switched off at the set, when not in use.
- Cook more than one item in same pot and cover with a lid.
- Use a microwave to cook as much as possible; it uses less power.
- Turn off microwave and range at the wall when not in use.
- Cook more than one dish in the oven at the same time.
- Don't boil more water than you need in your jug and only fill it from the cold tap.
- Install an insulating hot water cylinder wrap.
- Wash clothes in cold water. (This could save you about $5 a month).
- Unplug your washing machine when not in use.
- If you have a waterbed, make sure there is a warm duvet or plenty of blankets on it, otherwise it will be heating the room.
- If you use heaters in bedrooms, make sure they have thermostats and timers.
- Turn off any bedside clocks that you don't need
- Fix any dripping hot taps (this could save you $2 a month, per tap!).

- For cordless drills etc, remove battery and turn off charger once battery is charged.
- Have shorter showers instead of baths and save around 5% on your power bill.
- If you have a second fridge or freezer, empty it into your main fridge or freezer and switch it off. Second fridges and freezers are usually older and less efficient types, so waste a lot of power.
- Only heat the room you're in and close your curtains when the sun goes down, keeping in the free warmth from the sun.
- Turn your heated towel rail off in the morning after your shower, and on again at night. There's no point heating the towels when there's no one home.
- When buying a new appliance, ask for an energy efficient model (check its star rating label)
- Don't leave appliances on stand-by - switch off the TV, video, computer, microwave, washing machine, oven and stereo at the wall when not in use.
- Check your hot water cylinder to see if it is set at 60°C (140°F)

Source: (EECA, 2003b), (EECA, 2002)

A.27 Energywise Rally results

ENERGYWISE RALLY 2002 - RESULTS

Class & Rally Number	Vehicle	Driver	Fuel	Engine Size cc	Box Volume m3	CO2 kg/litre	Legs Completed	Fuel Economy Over 4 Legs l/100km	mpg (UK)	Ranking	Environmental Score for Legs to Date CO2 g/km	CO2 g/km-vol	Ranking for Legs to Date Class	Class-Envir	Environ	Leg 1 litres	km	l/100km	Leg 2 litres	km	l/100km	Leg 3 litres	km	l/100km	Leg 4 litres	km	l/100km
AA Under 1000cc																											
1	Daihatsu Sirion	McMillan	P	989	6.53	2.2977	4	5.3	53.8	6=	121	14.1	1=	1	28	12.92	273	4.73	19.82	340	5.83	22.47	460	4.88	23.57	427	5.52
2	Suzuki Alto	Brown	P	996	7.31	2.2977	4	5.2	53.9	6=	120	16.5	1=	2	34	11.41	273	4.18	20.89	340	6.14	19.30	460	4.20	26.97	427	6.32
A Small, 1001-1400cc																											
10	Honda Jazz Man	Askew	P	1339	9.78	2.2977	4	5.1	55.2	5	118	12.0	2	2	11	15.00	273	5.49	17.56	340	5.16	21.72	460	4.72	22.53	427	5.28
11	Honda Jazz CVT	Berridge	P	1339	9.75	2.2977	4	4.7	59.5	2=	109	11.1	1	1	9	11.34	273	4.15	17.59	340	5.17	21.92	460	4.77	20.32	427	4.76
13	Toyota Echo	Madelin	P	1299	9.06	2.2977	4	5.3	53.8	6=	121	13.3	3	3	24	11.78	273	4.32	19.56	340	5.75	24.37	460	5.30	23.09	427	5.41
B Small, 1401-2000cc																											
20	Honda Civic Sedan	Johnston	P	1493	10.99	2.2977	4	5.8	48.6	10	134	12.2	1	1	12=	17.11	273	6.27	23.45	340	6.90	23.15	460	5.03	23.56	427	5.52
21	Renault Clio RS	Cassidy	P	1998	8.67	2.2977	4	6.4	44.4	13	146	16.9	3	3	35	14.67	273	5.37	26.13	340	7.69	27.30	460	5.93	27.36	427	6.41
22	Kia Rio	Adams	P	1493	10.17	2.2977	4	6.0	46.8	11=	139	13.6	2	2	25=	14.58	273	5.34	19.23	340	5.66	28.90	460	6.28	27.90	427	6.53
C Small-Med, 1600-2500cc																											
30	Honda Civic Hatch	Price	P	1668	10.86	2.2977	4	6.0	47.3	11=	137	12.6	1	1	17=	15.50	273	5.68	22.22	340	6.54	27.11	460	5.89	24.62	427	5.81
31	Toyota Corolla	Lester	P	1794	10.40	2.2977	4	6.6	42.6	14=	152	14.6	2=	2	31	15.55	273	5.70	22.14	340	6.51	25.57	460	5.56	36.15	427	8.47
32	Ford Focus	Dallow/Finn	P	1988	10.12	2.2977	4	6.6	43.0	14=	151	14.9	2=	3	32	17.30	273	6.34	22.72	340	6.68	28.51	460	6.20	30.09	427	7.05
D Med-Large, 1600-2500cc																											
40	Ford Mondeo	Cooper	P	1999	12.25	2.2977	4	6.7	42.1	16	154	12.6	1	2	17=	17.55	273	6.43	26.05	340	7.66	28.79	460	6.26	28.28	427	6.62
41	Mazda 6	Blaber	P	2261	11.93	2.2977	Day 1 pen	7.4	38.3	18=	169	14.2	3	4	29	17.27	273	6.33	25.33	340	7.45	32.23	460	7.01	34.97	427	8.19
42	Toyota Camry	Linklater	P	2362	12.85	2.2977	4	7.1	40.0	17	162	12.6	2	3	17=	17.16	273	6.29	26.81	340	7.89	31.46	460	6.84	30.56	427	7.16
43	Toyota Previa	Amon	P	2362	15.10	2.2977	4	8.1	34.7	23	187	12.4	4	1	14=	19.93	273	7.30	30.61	340	9.00	36.30	460	7.89	35.18	427	8.24
E Executive-Premium 2001-3500cc																											
50	Audi A6	Hudson/Tulloch	P	2393	12.61	2.2977	4	7.5	37.9	20	171	13.6	2	2	25=	17.16	273	6.29	28.74	340	8.45	32.27	460	7.02	33.58	427	7.86
51	Honda Odyssey	Willmot	P	2997	14.19	2.2977	4	7.7	36.9	21=	176	12.4	3	1	14=	16.50	273	6.04	30.66	340	9.02	34.93	460	7.59	32.71	427	7.66
52	Mitsubishi Diamante	Porter/Robinson	P	3497	12.32	2.2977	4	7.4	38.2	18=	170	13.8	1	3	27	19.50	273	7.14	24.23	340	7.13	34.61	460	7.52	32.55	427	7.62
F Large-Luxury over 3500cc																											
60	Holden Commodore	Murphy/Richards	P	5665	12.64	2.2977	4	9.9	28.6	25	227	17.7	1	1	36	27.38	273	10.03	36.37	340	10.70	43.44	460	9.44	40.93	427	9.59
G Diesel Cars, 0-2000cc																											
70	Citroen Picasso	Myhre	D	1997	12.26	2.617	4	5.1	55.7	106	133	10.8	5	4	8	6.10	273	2.97	24.94	340	7.34	20.33	460	4.42	22.76	427	5.33
71	Fiat Multipla	Barry	D	1910	12.63	2.617	4	5.0	56.1	105	132	10.4	4	2	6	10.01	273	3.67	20.63	340	6.07	22.94	460	4.99	21.91	427	5.13
72	M/Benz A170	Dick	D	1689	9.76	2.617	4	4.8	59.1	104	125	12.8	3	5	15	6.19	273	2.27	19.15	340	5.63	23.63	460	5.14	22.74	427	5.33
73	Peugeot 307	Marshall	D	1997	10.96	2.617	Day 2 pen	4.4	63.6	102	116	10.6	2	3	7	6.20	273	2.27	20.35	340	5.99	19.57	460	4.25	20.06	427	4.70
74	Peugeot 406	Anderson	D	1997	11.46	2.617	4	4.2	66.9	101	111	9.6	1	1	3	9.50	273	3.48	16.85	340	4.96	18.71	460	4.07	18.31	427	4.29
H Diesel Cars over 2000cc																											
80	Volkswagen Passat	Smith/Keller	D	2496	12.01	2.617	4	6.1	46.7	107	158	13.2	1	1	23	16.01	273	5.86	22.71	346	6.56	25.42	460	5.53	27.00	427	6.32
I 4WD, Petrol																											
90	Honda CR-V	Watkin	P	2354	13.80	2.2977	4	7.7	36.9	21=	178	12.7	1	1	20=	18.51	273	6.78	26.53	340	8.39	34.99	460	7.61	32.72	427	7.66
91	Suzuki XL7	Inglis	P	2736	14.51	2.2977	4	9.2	30.8	24	211	14.5	2	2	30	23.97	273	8.78	33.26	340	9.78	40.29	460	8.76	40.03	427	9.37
J 4WD, Diesel																											
100	L/R Freelander TD4	Sloane	D	1951	13.31	2.617	4	6.4	44.5	109	166	12.5	1=	1	16	13.86	273	5.08	25.85	340	7.60	25.23	460	5.48	30.33	427	7.10
101	Suzuki Grand Vitara	Aitken	D	1997	13.05	2.617	4	6.3	44.5	108	166	12.7	1=	2	20=	8.85	273	3.24	24.72	340	7.27	28.32	460	6.16	33.33	427	7.81
102	Ssangyong Rexton	Coleman	D	2874	15.53	2.617	4	9.7	29.2	110	253	16.3	3	3	33	13.20	273	4.84	46.21	340	13.59	43.84	460	9.53	41.80	427	9.79
K LPG Cars																											
110	Ford Falcon	Kooge	LPG	3984	13.19	1.6	4	10.0	28.2	L1	161	12.2	1	1	12=	27.04	278	9.73	35.21	342	10.30	46.51	464	10.02	43.05	429	10.03
L Hybrids and Non-Commercial Fuel Options																											
120	Honda Civic Hybrid	Maetzig	PEH	1339	10.89	2.2977	4	4.7	60.6	2=	107	9.8	2=	3	4=	9.40	273	3.44	19.00	340	5.59	20.93	460	4.55	20.56	427	4.81
121	Honda Insight	Summerfield	PEH	995	9.03	2.2977	Day 2 pen	3.6	78.6	1	83	9.1	1	2	2	9.49	273	3.48	13.80	340	4.06	14.37	460	3.12	15.93	427	3.73
122	Toyota Prius	Cowan	PEH	1497	10.79	2.2977	4	4.9	58.2	4	112	10.3	4	4	4=	11.26	273	4.12	19.09	340	5.61	22.10	460	4.80	20.42	427	4.78
123	Volkswagen Golf	Sims/Bernt	BD	1896	10.39	0.3	4	4.7	60.7	103	14	1.3	2=	1	1	9.83	273	3.60	17.73	340	5.21	21.80	460	4.74	20.40	427	4.78
124	Toyota Prius	Personality	PEH	1497	10.79	2.2977	4	5.5	51.0	9	127	11.8	5	5	10	10.76	218	4.94	19.61	340	5.77	25.32	460	5.50	24.34	427	5.70

P Petrol D Diesel LPG PEH Petrol-Electric Hybrid BD Bio-Diesel