Quantifying Sustainability for Industry: A New Zealand Electricity Power Sector Case Study.

Bernard C M Cheng

A thesis submitted to the
Auckland University of Technology
in fulfillment of the requirements for the degree of
Doctor of Philosophy (PhD)

2008

School of Engineering

Primary Supervisor: David I Wilson

Table of Contents

List of Figures

List of Tables

Attestation of Authorship

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning.

SIGNED:

DATE:

In loving memory of
my mother, Joyce.

Acknowledgements

I would like to acknowledge my primary supervisor Associate Professor David I Wilson for his guidance for I have learnt much from his near-impeccable approach of critical thinking and a joyous pool of wisdom. Despite changes of direction in the course of these four years and the need to meet various deadlines, he has provided invaluable encouragements and has been dependable like a rock. My thanks also go to my secondary supervisor Professor Thomas Neitzert who, despite joining this project at a later stage, has given valuable advice and directions. My acknowledgements also go to Professor John Buckeridge and Professor Pare Keiha who initiated my PhD programme and I am grateful to Garry Law and Vanessa Atkinson for their expert consultation in Chapter 5. I am much obliged to Dr. Robyn Ramage of the AUT library for her professional help, and Benneth Gilbert of the administrative office for their invaluable support. The Contestable PhD Scholarship awarded to me by the Auckland University of Technology is also much appreciated.

I acknowledge the following organizations, among the many, for providing me with help and information for use in this research: Electricity Commission for electricity use statistics, the Energy Efficiency and Conservation Authority for updates on their projects and M-Co for electricity spot price data. Thanks also go to Marianne Todd for providing a professional proofreading service.

This thesis would be impossible without the moral support from my family. I thank my wife Chloe and father Kit, for their unfailing love and their belief in me and this PhD, and my son Howard for excusing my disappearance into an office full of strange paperwork for long hours.

I dedicate this work to all the researchers and practitioners whose passion and mission is to safeguard the sustainability of our society.

Abstract

Sustainable development is now being recognised as a vital component of our society in the environmental, ethical, social, technological, economic, and institutional aspects, or dimensions, so, this thesis develops a framework to quantitatively measure sustainability. This thesis is distinctive in that it focuses on quantitative methods encapsulated in a formal assessment procedure and includes sustainability concepts that have rarely been put into practical use in sustainability reports.

The framework is designed along the strategy that the methodology needs to be scale invariant and recursive, meaning the procedure is the same irrespective of the scale the user is interested in, and that different people can focus at different levels of sustainability by following a similar procedure.

While the quantification process is aimed to be as unbiased as possible, a configuration of the tools from Total Quality Management (TQM) is adapted to identify sustainability indicators which are then mapped onto a scalar with mathematical functions. The sustainability indices are presented according to the amount of details needed by different users ─ some may need just one overall figure while others may need sustainability indices broken down by the six sustainability dimensions and presented on a spider diagram, while others may need all the details for analysis. This methodology also caters for sustainability analysis by different stakeholders.

To fully demonstrate the potential of the methodology, the author has chosen to test it on a large-size industry sector so that it can have the capacity to be scaled up to a country or down to a small business, and on an industry sector that is important on its own right. Furthermore, this sector needs to be illustrative and has nontrivial complex problems. Under these criteria, the electricity sector of New Zealand was selected.

The robustness of the methodology was investigated with inputs from three evaluators with different views: a standard view from the author that was made after much research in the sector and in the concepts of sustainability, a view with an environmental bias and one that focuses on commercial interests.

In a complex system, the effects of a single action, never mind a chain of them, may not materialise as originally planned and sometimes work in the opposite direction. This methodology can be a tool to analyze these actions and policy makers can make use of it to test the overall result of a policy change before it is implemented to find out the possible side effects.

The author is not proposing that this thesis can solve all the issues in measuring and improving sustainability, but suggest that this framework is one of the steps that will help us to move forward along our journey to a sustainable future.

List of publication

The following papers are derived from work contained in this thesis.

Cheng, B. C. M., & Wilson, D. I. (2004, 3rd May). *Predicting the unpredictable: Is the electricity spot price chaotic?* Paper presented at the International Conference on Sustainability Engineering and Science, Auckland.

Cheng, B. C. M., & Wilson, D. I. (2003). *Retrospective performance analysis of electricity predictive models*: AUT.

Cheng, B. C. M., & Wilson, D. I. (2006, April 6-8 , 2006). *A Total Quality Management (TQM) approach to determine an industrial sector's sustainability - a New Zealand electricity sector case study.* Paper presented at the 12th Annual International Sustainable Development Research Conference, Hong Kong.

Chapter 1 Overview

1.1 The need to quantify sustainability.

This introductory chapter first provides a broad view of the past Sustainable Development efforts, then it proposes a workable definition and selects an industry deemed worthy of investigation. Finally the research questions are announced which form the basis for the rest of this thesis.

In the past decade, the power market in New Zealand seemed to be fairly unsustainable. The country is heavily reliant on hydro generation and has experienced two dry seasons immediately prior to the start of this research causing power shortages and forcing the government to call for power saving campaigns. The main local gas field, Maui, was reported to be running out faster than previously thought, and there was a threat of falling supply and escalated gas price. The proposed hydro generation scheme Project Aqua was faced with a number of hurdles and had to be cancelled. The energy improvement projects initiated by EECA were subsequently short of targets and energy improvement reports set out to be compiled by EECA did not materialise. These overwhelming series of events in the 2000's made the society seriously question if the New Zealand electricity sector is indeed sustainable. These motivate our investigation, not only into the electricity industry which was clearly in trouble, but to take a wider view of quantitative sustainability assessment of the generic industry sector.

An industry sector cannot be classified as sustainable if it does not address Sustainable Development (SD) issues. As a result, the criteria for business sustainability need to be integrated with those for general Sustainable Development to analyse, measure, monitor and improve the sustainability issues in a systematic and scientific manner.

Currently, a number of common frameworks are available to assess and report on how industry sectors contribute to SD, but rarely on the sustainability of an individual sector, and never-mind to reduce it to a scalar. Realizing the significance of these issues, this thesis proposes an alternate methodology to perform the task of quantifying sustainability with a special framework and demonstrate the proposed theory by using a case study on the electricity sector of NZ. However, Sustainable Development is an illusive issue and the details are still being debated. It remains a challenge to obtain consensus on definitions and methodologies but within our resource, the author has developed a definition and a methodology suitable for use in this thesis.

1.2 The illusiveness of defining and quantifying Sustainable Development

What distinguishes human from the other hominids is that human has a civilisation that originates from a sense of self and has values that are associated with an individual's self existence. Human has the intelligence to, first, adapt to the environment and then to change it according to our list of priorities, ranking our own survival as the top one and then moving on to increase our level of comfort, meeting our sense of aesthetics and self-actualisation (Maslow 1998). Meeting our basic needs and increasing wants has thus become a hallmark of human behaviour. While caring for offspring is not a uniquely human ability, nor is the intelligence to plan for future actions, the combination of the two, planning for the future generations that do not exist right now and leaving our legacy to them, is definitely uniquely human and is likely to be the foundation of Sustainable Development. This hallmark, plus our political, cultural and religious beliefs, together with our ability to find innovative ways to solve technological issues, is the key to the future survival of mankind.

As a starting point to consider the details of sustainability, an appropriate timescale needs to be considered. In our average lifetime of 80 years, a human may get to see his/her children or grandchildren. For us, an individual, to care for events that we can control in our lifetime of, say, 80 years, we should then look 160 years into the future, but there are other interpretations. Elected governments usually make plans only for their term of office of a few years, and for less political issues, the western governments usually have plans for 50 (2003; Australia's National Local Government Newspaper Online 2003) and rarely 100 years. As an alternate option, Briguglio (2003) suggested that about 200 years is a reasonable planning time span for sustainability. As a contrast, for some cultures that focus significantly on spirituality, the side-effects from any major government-proposed actions will be considered for seven generations, which comes to about 300 years (Dalai Lama, Quaki et al. 1999).

The consideration of the continuity of the society and the respect for nature and environment has not been new in various native cultures (Snively and Corsiglia 1998;

Berkes, Colding et al. 2000; Turner, Ignace et al. 2000). In fact, sustainability is so interwoven into the folklores of native cultures that it forms part of their daily life. However, most countries in their developing stages, such as the industrial revolution period (for the western world) and the present wave of economic growth (for the developing nations), have been putting factors such as industrial development, economy growth or political ideology at a higher priority than their side-effects. It is not until recently that international communities realised that modern society has the ability to destroy the economy, the society and the very environment that has been supporting human life. It is now classified as a global issue and worldwide concern was voiced in the first International Conference on the Human Environment, Stockholm, 1972, while the awareness was raised even more in the United Nations Conference on Environment and Development in 1992, also know as the Earth Summit (2002). In the past, the undesirable effects, such as pollution, could be solved locally, but with the proposed threats of global warming and the possibility of abrupt climate change (Alley, Marotzke et al. 2003), enough drive has been developed for putting more resources into studying and analyzing the causes of un-sustainability, deriving solutions for Sustainable Development, and managing the implementation of actions aligned with the concepts of Sustainable Development.

During the recent years, an increased number of governments have put Sustainable Development, hereafter abbreviated to SD, policies into action and industry sectors, as well as individual companies, have also started to report their sustainability status and identify areas for improvement.

While these efforts are all admirable and done with good intent, sustainability without a formalised way to be quantified remains illusive and difficult to be controlled. It is thus the purpose of this thesis to recommend a methodology to quantify sustainability for industry sectors, with a case study applying this method to New Zealand's electricity sector.

1.2.1 Overall view of international Sustainable Development efforts

The first attempt to explicitly define SD on an international scale was in the World Commission on Environment and Development report "Our Common Future" (Brundtland Commission 1987) and the definition was given as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". While this original statement is vague, open to challenge and has been criticised for its ambiguity (Taylor 2002), it was the first in a stream of followers who have their own interpretations. One of those was the Earth Summit 1992 in Rio de Janeiro which concluded in Agenda 21, that SD is comprised of a chain of actions to be carried out by global, national and local organisations to improve sustainability in their own ways. The UN Millennium Declaration (United Nations 2000) has also set clear goals for SD including ensuring environmental sustainability. While goals have been set in the form of projects to improve the different dimensions of SD, it remains unclear how these goals can contribute to improving SD in a quantitative way ─ without quantification it is hard to measure progress and clarify their effects.

While these campaigns were put forward by international organisations, questions have been raised regarding the ethics of imposing the Western concept of SD on developing countries (Steger 2005), and this remains a debatable point.

1.2.2 Establishing indicators to quantify the health of sustainability

Initiatives such as Agenda 21 have identified comprehensive lists of indicators of SD. Some indicators, collectively called the Headline Indicators, were also set up to measure the overall performance of the social, economic and the environmental aspects. Examples are indicators by: the World Economic Forum (the Environmental Sustainability Index), World Wildlife Fund (the Living Planet Index) and United Nations (Human Development Index). Other indicators include the Wellbeing Index (World Conservation Unions), the Global Scenario Group's 65 indicators, Ecological Footprint (Wackernagel, Monfreda et al. 2002) and the Genuine Progress Indictor (GPI) (Henderson 2002). Some individual businesses have also developed their own set of indicators.

While many initiatives exist, the present situation is that it is virtually impossible to have a consensus to: 1) choose a set of suitable indicators for a specific industry, 2) quantify qualitative indicators according to a set of common standards and 3) put complicated indicators on a scalar for easy understanding and monitoring.

To demonstrate defining the SD of an industry sector and to quantify it, the author has chosen the electricity sector of New Zealand. This choice was made because it is local and important, big enough and general enough to be illustrative.

1.2.3 The sustainability of the Electricity Sector of New Zealand

Energy is the driving force of our society and we human will not run out of energy before we run out of ingenuity. Over a thousand years of coal reserve is available in New Zealand (Ministry of Economic Development 2006) for generation by direct burning or gasification; renewable energy such as solar, hydro, wind, wave, tidal and geothermal are being used for generation and how popular they are will be determined mainly by economic factors. Nuclear power has the potential to expand if only its technical benefits are considered, and new technologies and power sources, such as fuel cells and fusion, are being developed and tested. Thus, the electricity business sector is sustainable ─ in an idealistic sense ─ but what is unknown is towards which direction and at what rate.

In order to investigate the direction the electricity sector is moving, a statement from the discipline of statistical quality control can be referred to, it states: “if you cannot measure it, you cannot control it”. It is crucial, therefore, to select appropriate attributes for monitoring as the first step towards understanding the state of sustainability. To rate indicators and indices, it is important for international agencies, government policy makers, business operators and stakeholders to perform their own sustainability analysis and to plan actions for improvement.

With the Kyoto Protocol that will start accounting for Green House Gas (GHG) emission from 2008 and putting an economic value on it, evidence shows that the electricity sector is one of the major GHG producers. While much work has been done on the impact of the electricity sector on SD, they are limited on coverage, such as

Melhuish (2002) which focused mainly on environmental factors and did not provide a comprehensive list of solution-focused indicators, or Gross, Rufin, Vitelli, & Jhirad (2003), that studied the political impact of the electricity sector, or just focusing on GHG emission such as Schenler, Gheorghe, Connors, Hirschberg, & Haldi (2002). They also did not put enough emphasis on the link between the sustainability of the electricity sector itself and the effect it has on general SD.

For individual electricity companies, some do produce sustainability reports such as Mighty River Power (2003) but they are more towards the interest of the investors, mostly following the triple bottom line framework covering social, economic and environmental impacts but what is lacking is a comprehensive cover on the sustainability of the sector itself.

In the recent history of the NZ electricity sector, numerous incidents have challenged its sustainability; examples are: the building of a power plant that has been mothballed for over 25 years (Marsden B), the Clyde Dam hydro plant at cost way above original estimated ($500 million above budget in 1990 money) (The National Business Review 2001), a 52-day power cut in the Auckland Central Business District in 1998 (Hancock 2004), failure of the free market to self-govern resulting in the setting up of the Electricity Commission, failure to invite private investments to build sufficient reserve capacity, the Resource Management Act (RMA) hinders numerous proposals to build new generators or improve transmission capacity, the underestimation of the Maui gas reserve, a lack of hydro firming initiative to have enough cheap reserve power for the peak usage seasons.

With such a wide range of sustainability problems in the electricity sector that results in being called “in vulnerable position” (NZPA 2007), there is a great need to develop a methodology to categorise and prioritise sustainability issues, analyze them and convert them into measurable metric so that benchmarks can be made and any improvements can be measured objectively and monitored. It is time to convert qualitative reports into quantitative measures.

1.3 Research objective

The objective of this thesis is to develop a methodology to analyse sustainability and quantify it in a scale invariant, recursive and robust manner for an industry sector.

This research objective can be further broken down into the following seven research questions:

Global questions:
1) What framework is suitable for quantifying sustainability in an industry sector?
2) What is an effective methodology for increasing sustainability for industry sectors?
3) What are the concepts behind the analysis?
4) How robust is the methodology to extreme value input?
5) What are the limitations of the method?

Questions specific to the case study:
6) What is a suitable definition of sustainable development for the electricity sector?
7) How predictable is the development of the electricity sector?

To answer these questions, indicators will be established for the sustainability of the electricity sector in New Zealand from which a set of indices will be produced. In order to perform sensitivity studies on the methodology, besides the standard viewpoint, two extra ones will be used to produce results for sensitivity analysis.

The target audience for this work includes government decision makers, power generators, consultants preparing reports for government agents, researchers in the SD field, students who seek to get a comprehensive, and complete analysis of the SD concept and its ethics, as well as researchers seeking new methodologies to analyze SD data.

1.4 Methodology overview

The thesis employs the following standard methodologies: *literature review*, *conceptual development*, *conceptual analysis*, *data comparison*, *feature extraction*, *systems* *analysis, qualitative information classification, relationship analysis, data preparation, data scaling, data normalization, data presentation, back-tracking, consultation, sensitivity analysis and self-review*.

A *literature review* (Chapter 2) is carried out on the definitions and concepts of sustainability as well as SD frameworks. With *conceptual analysis,* a number of sustainability concepts that are important but rarely considered by other works are identified. *Review* is also performed on the sustainability issues of the electricity sector in general and in New Zealand. Through *conceptual development*, a definition for the sustainability of the electricity sector is created.

Data comparison (Chapter 3) is used to compare the accuracy of various electricity demand models, and in order to investigate the nature of electricity spot price changes, *feature extraction* is used.

In the process of quantifying sustainability, the concepts are investigated through *conceptual analysis* (Chapter 4) and a framework is set up through *conceptual development.* Also, *systems analysis* is used to identify the relationships between stakeholders in the industry. To identify and categorise issues that threaten sustainability of the industry, *qualitative information classification* is performed. Indicators are selected and through *data scaling*, a metric is created for each of them. The relationships between the indicators and the stakeholders are established with *relationship analysis*. Indicator data is obtained through *data preparation*, and the list of indicators is summarised to indices through *data normalization* and presented through *data presentation* methodologies. Finally the issues that affect the unsustainable indices and the possible solutions are traced down through *back-tracking.*

Obtaining the sustainability indices for the electricity sector in New Zealand is done through *consultation* (Chapter 5). While a standard view is given by the author, two extra views are obtained through *consultation* with two evaluators who hold different views of the sector to test the robustness of the proposed method against possible extreme input values. *Sensitivity analysis* is used as a tool on the three sets of results to test their variations. In Chapter 6, a *self-review* discusses the limitations of this method and areas for further research are identified.

The relationship between the research questions, the chapters and the methodologies can be seen in Table 1.

Table 1 Research questions, location of coverage and methodology.

	Research question	Location	Methodology
1	What framework is suitable for quantifying sustainability in industry sector?	Chapter 4	conceptual development
2	What is an effective methodology for increasing sustainability for industry sectors?	Chapter 4	relationship analysis, qualitative information classification, data preparation, data scaling, data normalization, data presentation, back-tracking
3	What are the concepts behind the analysis?	Chapter 4	conceptual analysis
4	How robust is the methodology to extreme value input?	Chapter 5	consultation, sensitivity analysis
5	What are the limitations of the method?	Chapter 1	self-review
6	What is a suitable definition of sustainable development for the electricity sector?	Chapter 2	literature review, conceptual analysis, conceptual development
7	How predictable is the development of the electricity sector?	Chapter 3	data comparison, feature extraction

1.5 Structure of the thesis

The structure of the thesis is shown in Figure 1.

Chapter 1 starts off by introducing the research objective, pointing out its significance and outlining the methodology; it is followed by Chapter 2, Literature Review, which reviews the concepts and frameworks of SD, including approaches for SD, dimensions of sustainability and indicators, and consequently arrives at a definition for this thesis.

In Chapter 3, the hypothesis that modeling is an accurate way of predicting SD is tested. The author also has selected a sustainability issue within the electricity sector, which is spot price fluctuation, and test for its predictability and chaotic nature. The results indicate that some approaches other than pure modeling will be more suitable in tackling sustainability problems. Bearing that in mind, a methodology is proposed in Chapter 4 which creates sustainability indices by utilizing tools from the Total Quality Management (TQM) discipline to categorise sustainability issues, analyze problems, and create a spreadsheet model that generates the indices.

This methodology is applied in a case study in Chapter 5 which calculates a set of sustainability indices for the electricity sector of New Zealand from the author’s point of view, which is called the standard view. The robustness of the method is then tested by comparing results that are obtained through using different viewpoints and an investigation is made on the variation in the results. Finally, the conclusion of this thesis is given in Chapter 6. This last chapter also points out the difficulties and limitations encountered and areas suitable for further research are suggested.

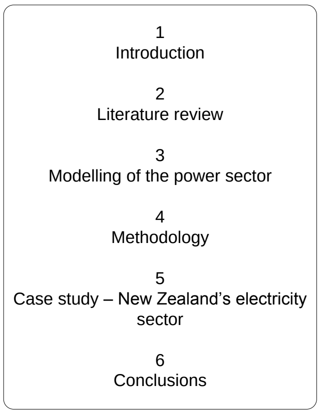


Figure 1 Structure of thesis

1.6 Topics outside the scope of this work.

It is not the intention of this thesis to address sustainability as a single-discipline work for it involves inputs from business, economics, engineering, science and philosophy among many other fields.

It is not practical to expect this thesis to solve all sustainability problems; rather, it is a tool for measuring, quantifying and identifying the sources of problems and their solutions.

This thesis does not propose or develop sophisticated technical solutions to known deficiencies in Sustainable Development and does not cover details in the technical side of statistics and modelling.

Government policies play a major role in the development of business sectors. While indicators will be created to cover policy issues, it is not the intention of this work to perform policy analysis such as cost-benefit analysis or risk assessment, by using methodologies such as decision theory, game theory and linear programming.

While an attempt has been made to select and use the most appropriate set of indicators for this study, other interpretations of the same case may lead to different choices.

The weighting system of the indicators, which will be further explained in Chapter 4, and the way qualitative information is interpreted is open to question and opinion and will naturally intervene with the final results.

Invariably, the choice of participants at various steps of the methodology will affect its final results - although this can be minimised by the robust nature of the methodology - so, the study can only be as impartial as it is can be practically.

Sustainability of the electricity sector is a subset of the SD of the society, therefore, different research organizations have their own agendas to work with. This work reflects the views of the writer only.

There is a risk of quoting sustainability indices out of context - sustainability indices should be interpreted through referring to the issues considered, the dimensions and sub-dimensions used, and the way the indices are constructed.

1.7 The recent acceleration of interest in sustainability

In the beginning of this chapter, a bleak picture of the electricity sector of New Zealand in 2003 was painted, doubting its sustainability. Few could have foreseen that now in 2007, the situation has improved significantly as new power plants have been built, new gas fields developed, proposals for extra transmission lines put forward, an Electricity Commissioner appointed, new regulations set up, as well as a new reserve power plant at Whirinaki built to meet unforeseeable needs (Ministry of Economic Development 2006). There have been regulatory updates by other government bodies in the power market, such as the Government Policy Statement 2004 update (Ministry of Economic Development 2006), and reviews have been made to simplify the Resource Management (RMA) process. There has been an increase in the number of wind power generators installed, meeting 1.4 percent of national power generated. The quest of SD has received more attention and the community is getting engaged more as indicated in the Prime Minister’s address to the nation speech at the opening of the 2007 Parliament, therefore, I hope that the material presented in this thesis is useful and timely in solving these sustainability issues that the New Zealand society is currently facing.

Chapter 2 Literature review

In this chapter the numerous definitions given to Sustainable Development are reviewed and the concept, as applicable to this thesis, is defined. Highlights will be put on issues that remain unresolved by the current sustainability reporting styles. The research problem, which is significant and timely, is then formulated and it will be the focus of this work. An analytical methodology is then proposed which will enable the users to identify sustainability problems and quantify them so as to provide an alternative tool for sustainability planning and for scenario analysis.

2.1 Introduction

"Sustainable development" (SD) has been summarised by Viederman (1995) as "a vision of the future that provides us with a road map and helps us focus our attention on a set of values, ethics and moral principles by which to guide our actions", but the exact definition of it is elusive as it has been given multiple definitions ─ some are more comprehensive and encompassing such as those given by Non Government Organizations (NGO), such as the United Nations (UN), while some are more focused on specific issues (such as those on a particular industry sector). This vagueness of definition adds to the debate of what needs to be done to improve the situation. Despite the differences, in their own ways, they are all important in setting the theme of the study that they are part of and they also share some common features. The various SD definitions focus on the future society and generations and share a sense of dynamic change, realizing that despite the complex dynamic forces that change the future, one has a moral obligation to improve it. The different sustainability reports do this by classifying aspects of sustainability in their own situations and selecting issues for monitoring and analysis but what is lacking are quantitative methods to measure sustainability.

The NZ Herald Editor (2007) echoed the general concern that sustainability has been turned into a slogan and the society is not looking hard enough for solutions; it needs a "precise yardstick" to "measure the contribution" of the various proposals and actions. From this, the author believes developing effective methodologies is the most effective way to improve sustainability.

Because there is no consensus on the definition of sustainable development or the sustainability of an industry sector, therefore, the author will take ownership of the definition in this thesis and define a sustainable electricity sector as one that "reliably supplies electricity at a reasonable price while satisfying social, environmental, technological, ethical, economic and institutional requirements, and all the time operating as an economically viable business, both in the short, medium and long term" (Cheng and Wilson 2004) and to develop a quantifying methodology for it.

Some researchers improve sustainability by intensive methods such as modeling and scenario analysis as in Ministry of Commerce (1994), Iyer, Fung, and Gedeon (2003), Verschuere (2003) , Yao, Chi, and Chen (2003), Yamin, Shahidehpour, and Li (2004), Potter, McAuley, and Clover (2005), and some by more direct methods such as simply reporting values of the attributes, showing trends or creating indices for easy interpretation in reports such as Barrera-Roldan and Saldivar-Valdes (2002), Thienen (2002), Wackernagel, Monfreda, and Deumling (2002).

Despite these efforts, some issues remain unresolved in the current works on this topic. One of these is that most reports have an absence of the definition for sustainability thresholds for each indicator being measured and, partly resulting from this, a lack of target values for improvements (Esty, Levy et al. 2005); also they tend to focus only on policy and strategy without spelling out what exactly needs to be done to achieve sustainability in a quantitative way. Even when measurements are made, sustainability reports either provide too much data without comments, as in a report like United Nations (2003), where readers might find it difficult to prioritise problem areas, or, too little coverage, as in Melhuish (2002), making the report not comprehensive enough on all the sustainability dimensions. Among these approached, the common rationale of the analysis, plans and policies is to find out the causes of unsustainability and to create plans for future improvements.

This thesis attempts to incorporate the common concepts of sustainability with the facets often found missing in sustainability reporting, such as analyzing sustainability thresholds and the interest of the stakeholders, as well as ideas from modern management practice such as Total Quality Management (TQM), to synthesise a methodology for analyzing, quantifying and presenting sustainability in Chapter 4.

2.2 A Review of the sustainable development definitions

The justification of the sustainability definition of the electricity sector chosen in section 2.1 is motivated by the large spread of definitions on Sustainable Development (SD) that have been previously published or proposed. This section covers in detail some of the more important ones from which the author has adopted his own definition which then forms the basis of the framework proposed in this thesis.

2.2.1 Sustainable development concepts and definitions review

The development of sustainability ideas has a long history and its chronology has been much described as in Murcott (1997) and RMIT University (2001) and will not be repeated here in detail but several stages are worth investigating.

The complexity of the SD concept is well appreciated by experts and in order to better define it and unravel its complexity, different efforts have been made to classify and categorise it. One of such ways is to classify it into Macro Sustainability, where the objective is to focus on the society as a whole, and Micro Sustainability, as used in this thesis, when it focuses on individual sections of the society or business sectors. The SD definitions used by international organizations are the Macro sustainability type while it is Micro Sustainability which is used in the studying of sectors sustainability. Sustainability can also be classified as "Strong Sustainability", where natural resources are not allowed to deteriorate (Pearce and Warford 1993) and "Weak Sustainability" where "natural reserve is allowed to deteriorate as long as bio resources are maintained at a minimum level and wealth generated by exploitation of natural resource is preserved for future generations" (Costanza 1995). Considering these definitions, the "strong" one is perhaps overly idealistic, theoretical and impractical because if it does not allow natural resource to deteriorate, that means our society must not expand its cities even if the population grows because that involves taking over vegetation space and using materials to build from natural resource such as wood and metal, or, if new wind generation plants were to be built, metal must not be extracted or refined to make it because taking metal ore deteriorates natural resources. Thus most societies have adopted the Weak Sustainability concept in preference where, while the focus is on resource management and conservation, growth and sustainability are both permitted concurrently.

Current works have categorised SD in much more detail than the school of thought above and some of the common themes and aspects of sustainability are reviewed below. Concepts will be selected from this comprehensive list and re-categorise into a framework that will be used in this thesis.

To demonstrate the difficulty in defining SD, two internationally renowned definitions of SD are reviewed. First, as a source of general knowledge, Encyclopedia Britannica which looks at SD from the economic view in its definition: “an approach to economical planning that attempts to foster economic growth while preserving the quality of the environment for future generations” (Encyclopædia Britannica 2006).

As with many general definitions, this fails to indicate the scope of coverage in the statement and the approach to make the planning. It does not indicate which disciplines SD should be under – for example, many works suggest that including only the physical “environment” and the economy as defined here is not sufficient for the well-being for the future generations – cultural and spiritual issues need to be addressed too. The question about who shall have the authority to plan, take action and judge the resulting actions is left open.

The second review that is analysed in more detail is the SD definition in the Brundtland report. The Brundtland report was written by the Brundtland Commission, officially known as the World Commission on Environment and Development (WCED). The commission was set up in 1983 by the United Nations and in 1987 it was asked to investigate the causes and solutions of environmental, economic and social development problems globally, thus producing the report which officially was called “Our Common Future”. It proposes a long term strategy to address these solutions for the world community.

The Brundtland definition of sustainable development has been widely adopted by nations and industries which states that Sustainable Development is a type of “development that meets the needs of the present without compromising the ability of future generations to meet their needs.” (Brundtland Commission 1987).

It has the advantage that it is succinct and open ended but as in the previous example, it does not specify which aspects of the society the term “development” should cover. Furthermore, the word “needs” as in “needs of the present” is open to interpretation and controversy (Beckerman 1994). It was argued that “perceived needs” is a subjective concept (Verburg and Wiegel 1997) as needs are socially and culturally determined and that even the same people at different times have different needs (Beckerman 1994).

On further examination, the statement has made “meeting the needs of the present” a priority over and a prerequisite for “not compromising the future generations”. The fact is, on the practical level, there will always be needs of the present that cannot be met, such as population in the third world that are dying of illness, malnutrition or poor hygiene. These can be caused by famine and drought, and can be the result of war or political regime. Even within a country, there is poverty, slumps and unemployment and no government has successfully eradicated all of them for good. If the society chooses to meet the current humanity needs as the top priority, maybe then all wars and luxurious lifestyles need to be put on hold and have the resources re-directed to those whose lives are under immediate threats – such is the controversy.

Another concept that raises questions is: “the needs of the future generation”. Having concluded that it is impossible to define and meet all the needs of the current generation, it is thus even more difficult to estimate the true needs of the future generations as they are affected by the constant change in the economic, social, cultural, legal and technological environment. For example, while our basic “need” is the floor area to sleep on, as inside a tent, new regulations in New Zealand said there is a legal “need” to make studio apartments with floor area of at least $35m^2$ each (Orsman 2005).

While defining the term “need” has proven to be challenging, estimating the “ability” of the future generations to meet their needs is even more so. The society today cannot know what abilities the future generations will have since they are affected by education, technological innovation and social change. As the saying goes “Stone Age did not end because humans ran out of stone, and Iron Age did not end because we ran out of iron”, it is virtually impossible for one generation to predict the ability of another.

If it is assumed that the “ability of the future generations to meet their needs” can be defined, it is equally difficult to identify what actions the society do today will “compromise” that ability and what actions can be taken to correct the situation. If education, training, research and development and innovation are halted, this ability will be compromised, but that is unlikely to happen and it is virtually impossible to measure that and then say what exactly needs to be done to correct the situation.

Even if what is proposed in the Brundtland Commission (1987) is achievable, the question remains how bounded are we, this generation, to our future generations, who are not yet conceived, for maintaining their living environment, improving their way of life and ensuring they have the ability to meet their needs. If that becomes law, our previous generations would also be held responsible for damages done to the society and environment such as political blunders and WWI and WWII, but that is not generally practical. This is a point on inter-generation equity that has been much debated by Taylor (2002). If SD as defined here is to be understood literally and enforced, all nations would then first be ethically or legally bound to meet the needs of the least advantaged of today’s society (inter-generation equity) before considering the needs of the future generation (intra-generation) and their ability to meet that need. Such rules seem un-enforceable, thus this point on intra-generation justice remains a concept in waiting for a different legal system or value system to make further developments.

There are further works that criticised the concept of sustainable development in general such as the Brundtland Commission (1987) which suggested that nearly all activities lead to some form of unsustainability. The sustainable development concept is also criticised as an oxymoron by Daly (as cited in Hopwood, Mellor, and O'Brien 2005) and Redcliff (2005). The concept is called contradictory (Langhelle 1999), unrealistic (Gray and Milne 2002) and causing confusion (Hopwood, Mellor et al. 2005). One more criticism is that very few reports can even describe what a sustainable state is like (Gray and Milne 2002).

While the exact definition of SD is debatable, the section below reviews some additional sustainability concepts and approaches and concludes on how appropriate it is for them to be incorporated in this thesis.

2.2.2 Additional Supplementary Sustainable Development Concepts and Approaches

In this section the author reviews eight concepts of sustainability from the engineering and management points of view that are deemed to be important but are often missing in the construction of sustainability indicators. They are the concept of sustainability thresholds, the nature of sustainability functions, systems concepts, control system concepts, the ability to adapt, improve and innovate, data collection issues, the use of a scalar to measure sustainability and cultural views of sustainable development. This thesis incorporates these ideas into the framework and the design of the methodology.

2.2.2.1 The concept of threshold in Sustainability

SD is a planning philosophy and it is built on the threat that certain aspects of our life, society or culture may go past a threshold and will deteriorate beyond recovery. The logical step is then is to locate that threshold. In current SD studies, this is rarely addressed and even in high profile issues like global warming or sea level rise, there is not even a consensus on the “tipping points”.

Understandably, establishing a threshold may be difficult as sometimes the science for measuring it cannot be exact. In such cases, a ranking system of alternatives needs to be established with peer review, and the definitions must be transparent.

Quantifying risk remains an important element of business operation, so the task of pointing out how close the society is to the tipping point of sustainability and how likely it is that this point will be crossed remains an important issue and the methodology in this thesis will address this point in section 4.4.5.

2.2.2.2 The nature of the sustainability function of an attribute

In order to steer an issue away from its sustainability threshold, its sustainability function needs to be analyzed in a scientific way and find out the characteristics of the attribute such as the rate it is approaching the sustainability threshold, how much time is left to alleviate the situation and the actions needed to slow down or reverse the trend of deterioration. The effectiveness of the corrective actions needs to be reviewed. For an even better understanding, the stages of degeneration need to be identified after the unsustainable point is passed and investigations need to be made on what remedies, if any, can be used to recover to a sustainable status.

Without learning more about the issues and their functions of deterioration, there can be no solid answers for the above questions. This issue can be temporarily addressed by setting up a metric to indicate where the current situation is with respect to the threshold, as applied in this thesis.

2.2.2.3 Systems concepts in Sustainable Development

SD should take on a systems approach (Bossel 1999) and the author agrees this is an effective approach. In order for a system to be sustainable, each individual element or sub-dimension needs to be sustainable as well (Brundtland 1986). The author argues that in designing indicators, besides measuring the individual sub-system, indicators are also needed to measure the relationships between them.

2.2.2.4 Suitability of a Control System approach in Sustainable Development analysis

While sustainability needs to be looked at from a systems view, whether that system is deterministic and can be modeled or controlled needs to be established, and if it is so, there is a chance it can be manipulated out of an unsustainable situation. One needs to consider, if the system cannot be modeled per se, what alternate methods can be used to monitor and improve it.

When a system is controllable or deterministic, the condition is that it can be moved from any state at time t_o to time t_1, in a finite time interval, by applying an input (Umez-Eronini and Eronini 1999), but, if some elements of the system are chaotic, it becomes virtually impossible to estimate the medium term (MT) to long term (LT) outcome.

In a study of the chaotic nature of the electricity sector in New Zealand, Cheng and Wilson (2004) have speculated, and then proved to be the case, that the spot price of the electricity sector in New Zealand has chaotic elements in it. This is further explained in Chapter 3 but it puts a question on whether it is worth the effort for the detailed breaking-down of a very complex system and deriving simulations that use relationships, some of which may be chaotic, to make MT and LT predictions that intrinsically cannot be accurate.

With the outcome in Chapter 3, drawing from the author's own management experience, the next best alternative action to improve sustainability is to take on a management approach and use management tools to design a methodology that can monitor the electricity sector's sustainability (see Chapter 4).

2.2.2.5 Ability to adapt, improve and innovate

SD studies have not taken into account the ability of our society and the science and engineering community to adapt, improve and innovate, as understandably it is difficult to do so accurately.

In retrospect, London's smog was a major problem in the seventeenth century and the Thames was polluted in the nineteenth century. These large scale issues were solved over the years with man's determination, improved planning and technology. By definition, development is an on-going process and we human must not underestimate our society's ability to improve and innovate, learn and adapt (TERI 1997). Because of its unpredictable nature, the measurement of our ability to learn and improve is not incorporated into this thesis.

2.2.2.6 Data collection and statistical issues

In designing indicators, a number of statistical issues will arise such as: minimizing the errors in the data, finding ways to solve missing data problems and the availability of a reliable technique and scientific base for measuring sustainability (Freudenberg 2003; International Atomic Energy Agency 2005). These are issues faced in data collection and manipulation and the details are beyond the scope of this thesis, but they will need to be addressed in real life situations of data collection, manipulation and the calculation of the indices.

In choosing a method to summarise our data, the median method will be used, instead of the mean, to minimise distortions of the results by extreme input values. It can be argued that valuable information may be extracted from the rare extreme values, but the objective in this methodology is to analyse the overall situation and the majority of the problems, thus employing the median is appropriate. The raw data of the extreme values is preserved in the model and additional projects can be created to specifically looked at these if required.

2.2.2.7 Use of a scalar to measure sustainability

Traditionally, sustainability indicators are presented in their absolute form or as a percentage change from their past values. While these methods can present data with precision, they mean little to the average readers whose main interest is to know how sustainable the indicator is on a relative term or in a ranking. That can be best represented on a scalar. For example, as used in this thesis, 0 is defined as the level of the threshold, any number below zero is unsustainable, and positive value is sustainable. A small number of studies have used a scalar such as the Sustainability Dashboard (European Statistical Laboratory 2007), but they only cover a limited range of indicators.

2.2.2.8 Cultural views on Sustainable Development.

In this section, SD is looked at from a cultural point of view and question the range of agendas besides the obvious ones.

The worst possible consequences of unsustainable development are economic breakdown and extinction of species, including the human race. It is highly unlikely that humans will be exterminated as humanity has survived different ice-ages with only stone-age technology, and at one time the entire human global population was estimated to have gone down to only 1000-10000 (Shreeve 2006). The author does not believe modern man with our modern technology will fare worse. What is likely to happen is that a number of humans will have a shortened lifespan due to changes in our environment, but it seems the real fear is the loss of, or a change in, lifestyle that will move us away from the comfort zone of our modern-day culture. If that is so, what is then a sustainable culture? Existing indigenous cultures that have lived in isolated locations over hundreds of years can be classified as relatively sustainable, like the aboriginals of Australia and the tribes in the Amazon. Through adaptation or trial and error, their ancestors had the intelligence to create a society that is relatively in balance with nature and the tribe survived for long periods. They may have a primitive way of living, facing the brutal reality of a primitive lifestyle, have a relatively short lifespan and have a social structure and spiritual values that are unimaginable to us, but they have lived within the means of their surroundings and have learnt to be responsible for the environment, otherwise, their population would have died off and would not be a living testimony of their sustainable way of life. The main sustainability concern for their group is that their race survives and their culture gets passed on. It would appears to be the case that only when western ideas, commodities and weapons were introduced that the equilibrium of these sustainable cultures was disturbed and their indigenous sustainability system collapsed.

Thus, question can be raised on whether the objective of SD is to maintain a way of life or a culture. Should one country or a culture impose its own values, standards and culture (like the West) on another culture? Would there not be a conflict of interest, or a clash? How can a military or economically invasive country/culture decide what is best for another country/culture? It seems that the Western way of living is unsustainable, but is the West at the same time so sure of its sustainability concepts and ability to resolve sustainability problems for the world that it can offer advice and guidelines to the once really sustainable but not so modernised cultures? An example of the difference in values is, while the Western culture would avoid personal death at great cost, some other cultures look at death with welcome hands and they truly believe the afterlife is better than life on earth. With this fundamental difference in life’s value and what sustainability means, a common ground or consensus on sustainability may be difficult to achieve.

2.2.3 Issues in approaches to solving sustainability problems

While there are numerous sustainability reporting methodologies available, what determines their effectiveness in improving the situation is whether or not they have an effective approach. Sustainability reports, such as those referring to the GRI guidelines, describe the sustainability situation of an organization by referring to a standardised check list. These may be comprehensive in reporting sustainability status, but they are not designed to easily identify the crucial areas for improvement and then tracking down the causes of the problems. There are a number of approaches that are important in assessing sustainability, as seen in the following sections, but their application is often missing in existing reports.

2.2.3.1 Solution focused approach ─ tracing back to the source of the problem.

Most reports stop at the stage of identifying the indicators with sustainability problems but that is only the start of the process of solving sustainability issues. An effective approach will allow users to trace back to the source of a problem through a back tracking mechanism. This is incorporated in the methodology proposed in chapter 4.

2.2.3.2 Improve sustainability by addressing unsustainability issues.

Development can be made more sustainable by eliminating unsustainable practices (Wright 1991). The author proposes that unlike most reports that look at all the attributes of sustainability, an effective methodology should start from identifying areas of unsustainability and find out their causes. Criteria of unsustainability can be looked at from the resource point of view. It is unsustainable if it requires continuous input of non-renewable resources, and it uses renewable resources faster than their rate of renewal. From the environmental side, it is unsustainable if it causes cumulative degradation of the environment and leads to the extinction of other life forms. (Nickerson 1995)

With respect to this, the author would define the power market as not sustainable when "it has blackouts and/or is faced with solvable long term or short term power shortage threats".

2.2.3.3 Focus on significant issues

The objective of selecting and measuring sustainability indicators is to improve sustainability. From a project management point of view, an effective approach is to first select the essential few to make improvements on, which is the approach taken by this thesis.

2.2.4 Framework for Indicators

Having previously considered the concepts of sustainability, the next step is to take a more detailed approach to review the frameworks of sustainability and the criteria of selecting indicators.

In analyzing what the phrase "Sustainable Development" means, "Development" is a set of planned actions with a strategic direction. It would have predicted outcomes with an anticipated progress rate and is controlled by policies and directives, but as a contrast, Sustainable Development (SD) has been defined historically in such simplistic terms such as that by the Brundtland Commission (1987) that the society is left on its own to interpret its exact meaning, and the stakeholders have to find the most appropriate way to report, measure and to improve it. Numerous frameworks for designing the structure of indicators and different sets of criteria for selecting indicators have been published (see Table 5) based on different assumptions and scopes that suit their special needs. The review below identifies the framework and criteria that are applicable for selecting our sustainability indicators.

2.2.4.1 Different sustainability frameworks

A number of assessment frameworks have been developed. One is the Driving Force, State and Response (DSR) system as introduced in United Nations (1996), see **Error! Reference source not found.**. Due to its simplicity and ease of application, most of the existing sustainability works follow this framework and they analyze sustainability issues by looking at dimensions of sustainability. Bossel (1999) gives another approach which classifies sustainability into three systems: human, support and natural, then divides them into aspects called orientors before creating indicators which is in the same line as the DSR approach (see Figure 2, Figure 3 and Figure 4). An alternative framework was developed by the Commissioner on Sustainable Development (CSD) which divides sustainability into themes and sub-themes (United Nations 2003) (see Figure 5). While it is reputedly to be better in capturing the complexity of SD and more comprehensive in principle, it may be too general for specific applications such as that for a sector or a business.

The cause-and-effect framework has been used by Janic (2004). This approach is appropriate for finding out the relationship between two sustainability attributes that have correlations. In the case study of the electricity sector, examples of this type of analysis could be: power supply interruption per month (in minutes) versus total power transmitted (GWh) in that month, or, spot price level ($) versus the lake levels (GWh reserve) for hydro generation. This framework is seen as an exercise to improve sustainability of one attribute by varying another but because of the systems nature of business sectors, the relationships between attributes are rarely as simple as such, thus this framework is not adopted in this thesis.

From the choice of frameworks, this thesis takes on the DSR framework, which is in line with the engineering and managerial methods of finding solutions to problems.

Table 2 A template for the DSR framework for Sustainable Development Indicators (United Nations 1996)

SD Dimension	Chapter of Agenda 21	Driving Force Indicators	State Indicators	Response Indicators
Social				
Economic				
Environmental				
Institutional				

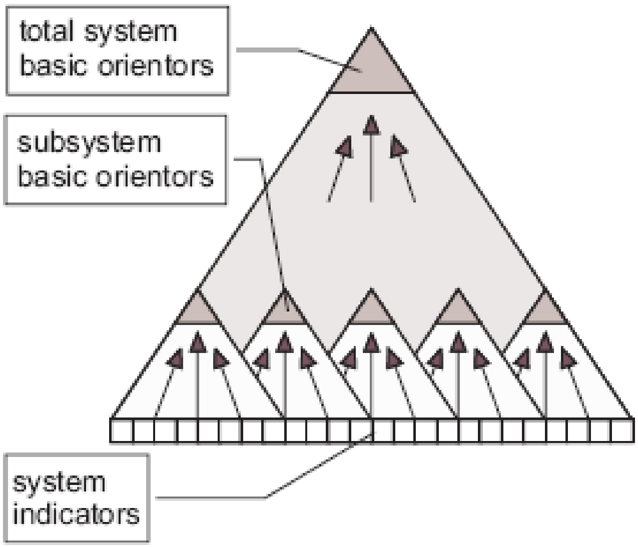


Figure 2 Orientor Indicator framework (Bossel 1999)

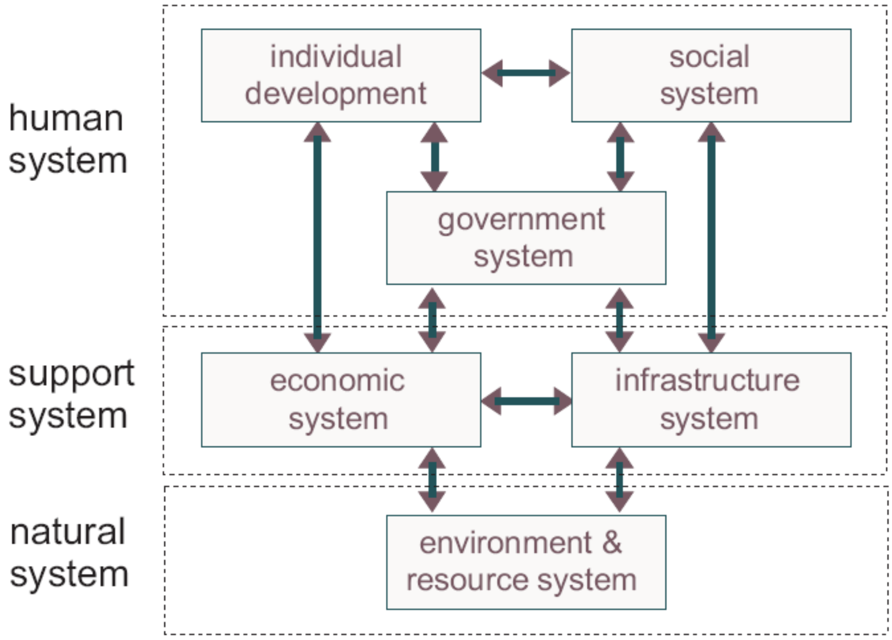


Figure 3 The six major systems of the anthroposphere and their major relationships. These six sector systems can be aggregated to the three subsystems: human system, support system and natural system (Bossel 1999).

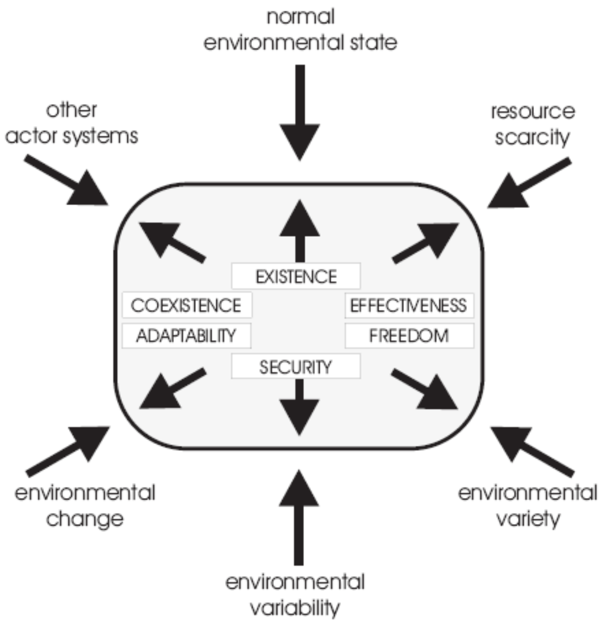


Figure 4 Fundamental properties of system environments and their basic orientor counterparts in systems (Bossel 1999).

Table 3 Themes Suggested by Commissioner on Sustainable Development (United Nations 2003)

Social	Environmental
Education	Freshwater/groundwater
Employment	Agriculture/secure food supply
Health/water supply/sanitation	Urban
Housing	Coastal Zone
Welfare and quality of life	Marine environment/coral reef protection
Cultural heritage	Fisheries
Poverty/Income distribution	Biodiversity/biotechnology
Crime	Sustainable forest management
Population	Air pollution and ozone depletion
Social and ethical values	Global climate change/sea level rise
Role of women	Sustainable use of natural resource
Access to land and resource	Sustainable tourism
Community structure	Restricted carrying capacity
Equity /social exclusion	Land use change
Economic	**Institution**
Economic dependency/Indebtedness/ODA	Integrated decision-making
Energy	Capacity building
Consumption and production pattern	Science and technology
Waste management	Public awareness and information
Transportation	International conventions and cooperation
Mining	Governance/role of civic society
Economic structure and development	Institution and legislative framework
Trade	Disaster preparation
Productivity	Public participation

Figure 5 Themes Suggested by Commissioner on Sustainable Development (United Nations 2003)

2.2.4.2 Criteria for selecting indicators

Criteria for selecting effective indicators are crucial for they affect the design of the research methodology. Some of these are the "common sense" attributes for general indicators such as: the indicators' needs to be measurable, the data's needs to be available, the indicators' needs to be easily understood (Hens and Wit 2003); they need to be relevant to the issue and can be accurately measured (Esty, Levy et al. 2005). The indicators for SD serve to complement each other and their use in an effective methodology is essential in reporting the status of the area under study (Brown, Liverman et al. 1988; Hardi and Zdan 1997). Next, the criteria of the indicators will be looked at and how these can be turned into practice in designing an effective methodology will be considered.

The “Bellagio principles” (International Institute for Sustainable Development 1996) serve as the foundation principles for SD indicators. As quoted in the work Hardi and Zdan (1997) they consist of the points in Table 4.

Table 4 Bellagio Principles (International Institute for Sustainable Development 1996)

Bellagio Principles	
1	It needs to have clear guiding vision and goals
2	Have a holistic approach
3	Essential elements
4	Include an adequate scope
5	Be practically focused so that the assessment is practical
6	Openness for methodologies and data
7	Effective communication – easy to understand, address needs of audience
8	Broad participation
9	Ongoing assessment
10	Have institutional capacity in having a structure to support the project

While these principles are crucial in selecting indicators, a number of them are rarely addressed in the existing reports and they are discussed below.

One of the principles proposed is that while selecting indicators, the team needs to have clear guiding vision and goals. For many SD reports the only goal is to report the general sustainability status whereas in this thesis the primary goal is to identify areas weak in sustainability that need improvement. This difference affects the way indicators are selected.

Next is the “holistic” principle which this thesis interprets as a systems approach that it will adopt. While some Non-governmental organizations (NGOs) may be using a systems approach in analyzing the country or sector under study, that has not been explicitly obvious to the readers and the mechanism has not been found to be transparent – they do not describe nor produce systems diagrams nor do have they shown they have considered the relationships between stakeholders.

The Bellagio Principles, next, call for a focus on “essential elements” for analysis. While, unavoidably, subjectivity is intrinsic in the selection of these elements, objectivity can be introduced if the process is standardised, transparent, and open to stakeholders' participation so that it is repeatable - if the conditions remain the same, similar elements can be selected and if the conditions have been changed, as often it is in reality, different elements need to be chosen. The procedure proposed in this thesis has taken on this more objective approach. International sustainability assessments such as Wackernagel, Monfreda, and Deumling (2002), United Nations (1990) and national ones such as UK Government (2004), Australia Government (2004) and National Round Table on the Environment and the Economy (2003) focus on areas that they believe are important but the selection processes are not transparent to the readers and there is no evidence that the organisations are prepared to update their list of indicators if and when there is a change of focus on the essential sustainability elements in the society. Furthermore, the pre-selected lists of indicators are deemed to be essential, but not necessarily areas under urgent and significant sustainability threat, and users of a pre-selected list risk having the real sustainability threats hidden among a mountain of data. This thesis interprets "essential elements" as items that are threatening sustainability and takes the approach of identifying these threatening issues, developing indicators for them and even locating proposed solutions.

Another principle involves "address(ing) the needs of audience". Most sustainability reports for NGO and industry sectors provide just one set of indicators for the average audience. In practice, different audiences or stakeholders have different needs (Janic 2004) and a set of tailor-selected indicators for each of them will fulfill this principle. This thesis notes the importance of this point and creates a methodology that analyzes the needs of each stakeholder and selects the relevant indicators for each stakeholder from a pool of indicators. Understandable, this approach may cause controversy on the weighting of each indicator and on the methods to summarise the indicators for reporting. The fact that this process is transparent and consistent may help to ease this controversy and make it an objective exercise.

Besides the Bellagio Principles, on the technological side, some other sustainability indicator criteria that are crucial for the effective design of the monitoring system have also not been incorporated into most sustainability works. For example, B. J. Brown, Liverman, Hanson, and Merideth (1988) specifies that a reference level or a threshold level needs to be available for users to know exactly when the issue becomes unsustainable. Understandably, this may not be obvious in many cases, such as the exact amount of CO_2 in the air for global warming to be irreversible but if this really is a contributing factor, an estimate needs to be made. Unfortunately, neither sectoral, national nor international sustainability reports take this into account. Despite of that, it does not make it less important. To fill in the gaps that these reports miss, the methodology proposed in this thesis will incorporate a mechanism for establishing a threshold for the indicators.

Another criterion advocated for indicators is to incorporate "appropriate data transformation to form an index". Readers of sustainability reports appreciate the significance of sustainability attributes more when they are presented well, such as putting on a scale for easy understanding, but that is not applied in most reports, which typically show only the absolute values of the attribute or a percentage change from the past. In this study, a function will be defined for each indicator to convert its absolute value into a number on a sustainability scale and the indicators will be summarised into indices under different levels of details.

Lastly, indicators need to be "integrative", meaning several indicators need to be summarised with a statistical method such as weighting or taking the median, into an index for ease of understanding. This thesis uses a transparent and logical method to achieve this.

To summarise, various concepts emphasised as important in sustainability research papers have not been systematically and practically applied in most of the reports published on sustainability issues reviewed in this research. These elements have been identified and some are judged to be applicable to this study and are integrated into the design of the proposed methodology.

2.2.5 The various facets of sustainability – dimension of sustainability.

Many aspects of our society may cause sustainability concerns, for example, these can be environmental problems like pollution, social problems like employment rate, as well as ethical problems and economic ones. For these aspects that broadly cover our society, there is a common convention to call them "dimensions of sustainability". Analyzing sustainability using dimensions helps us break down complex issues into more manageable chunks, but even so, there is not a consensus on what is the most suitable selection of dimensions to use. They range from three in Triple Bottom Line Reporting (TBL), to the four used in the PEST market analysis (political, economic, social, technological) which can be extended to seven (by adding ecological, legal and industrial analysis) (Chapman 2006), to nine (environmental, material, ecological, social, economic, legal, cultural, political and psychological) as proposed in Bossel (1999). The analysis of 11 sustainability reports reveals that they cover a total of 16 SD topics (see Table 5), but since there are overlapping concepts in some of the topics, they are regrouped into 6 categories that the author will use in this thesis, as per the list below. These are also called the "dimensions of sustainability".

Regrouping of sustainability topics (as per Table 5):

1) Environmental: Ecological, Ecosystem, Environmental, Life support (one of the TBL dimensions).
   Ecological, ecosystem and life support are grouped in this environmental dimension because the environment has a direct effect on them.
2) Ethics: Cultural, Spiritual, Genetics, Future generation.
   All of the cultural, spiritual and genetics aspects involve judgments based on our personal value or the value of the society at the time, thus they all fall under the ethics dimension. The concept of future generation is also of this nature.
3) Social: Welfare, Well being, Social (one of the TBL dimensions).
   Welfare and well being affects human on the social level, thus they fall under this social dimension
4) Technological: Technological, Production
   Improvements or innovation in production techniques is a technological contribution in improving the sustainability of the society, thus falls under this dimension.
5) Economic: Economic (one of the TBL dimensions).
6) Institutional: Institutional, Political
   Government and political decisions set the rules of the society in terms of what must be done and what can be done, also, by setting political and economic instruments, the political decisions can affect the direction the society is going, thus it plays a major part in the sustainable development of the society.

Table 5 Aspects covered by SD definitions

SD Topics Covered	References on SD Definition (see below)										
	1	2	3	4	5	6	7	8	9	10	11	This work's dimension
Ecological		■	■						■			Environmental
Ecosystem			■		■	■						Environmental
Environmental								■			■	Environmental
Life support										■		Environmental
Spiritual			■		■				■			Ethical
Genetics			■	■								Ethical
Cultural									■			Ethical
Future generations					■							Ethical
Welfare								■				Social
Well being					■	■			■		■	Social
Social							■					Social
Technological							■					Technological
Production											■	Technological
Economic	■	■							■		■	Economic
Institutional							■			■		Institutional
Political							■					Institutional

■ = a SD topic covered in a reference, space = the topic not covered in a reference.

References mentioned above:
1 OECD (1960)
2 Meadows, Meadows et al. (1974)
3 IUCN, UNEP et al. (1980)
4 Brundtland Commission (1987)
5 United Nations (1992)
6 IUCN, UNEP et al. (1991)
7 Strong (1992)
8 World Bank (1992)
9 IUCN (1993)
10 Brown, Liverman et al. (1988)
11 Schultink (1992)

This thesis will use this set of dimensions as the framework to build indicators on and to create quantitative measures of sustainability. Their six dimensions are discussed in more detail below.

2.2.5.1 Environment and Ecosystem

The most important and obvious concern is environmental as our earth needs to be maintained as a habitable place for human and other life forms. The need for the protection and management of the ecosystem is a common notion as brought up in UN (1992), and IUCN, UNEP, and WWF (1980). The main focus is on maintaining earth's life support systems (i.e. the environment), maintaining its generic diversity, and the sustainable utilization of species and ecosystems. This dimension is interpreted to be the physical environment that our society has, whether it is natural or man-made. An example of threatened man-made environment is cities that were built near sea-level or flood plans that can be flooded during a hurricane or sea level rise.

The environment is protected through our ethical views which is the next dimension being discussed.

2.2.5.2 Ethics

As SD is about what our society should do rather than can do, it thus comes down to a matter of choice that originated from our sense of ethics and virtue (Williams 2007) and is loosely related to the Institutional dimension where rules and regulations are formed for the society. The point mentioned by Jon Wetlesen (as cited in Langhelle , 1999), is that the importance of ethics is often implied and only occasionally spelled out. Ethics is culture dependent and different societies, and even the same society in different times, may have different interpretations of it, thus, creating a set of ethical indicators is a delicate but crucial step for this thesis. This dimension is interpreted to be aspects that deal with fairness and cultural values of the society and so sustainability will be looked at next from a social point of view.

2.2.5.3 Social

The author interprets this dimension as the general well-being of man and conditions for him to sustain his daily living in areas such as employment, sufficient income, good mental and physical health and making a contribution to the larger human society.

The social dimension remains an important aspect of SD and is concerned with our well-being and meeting our needs. The definitions are quite “woolly” in the literature, such as it is said to involve improving the quality of human life (IUCN, UNEP et al. 1991), to fulfill basic needs and improved living standards for all (UN 1992), or to fulfill people’s cultural, material, and spiritual needs in equitable ways (IUCN 1993). It has even been described as the indefinite survival of the human species (Brown 1988).

For each person to be fairly paid and have a good quality of life, an economy needs to be supported by an appropriate level of technology and so, technology is the next dimension considered.

2.2.5.4 Technological

Despite various early gloomy predictions that our society is not sustainable (Malthus 1798; Jevons 1866), the fact is that they did not eventuate because those predictions underestimated humans' ability to develop new technology in solving problems, to discover and extract resources, and to use them more efficiently (Patterson 2002). Even just in our lifetime, countless technological innovations have been made that could not have been envisaged by our ancestors. As a result, technology is considered a major factor in contributing to sustainability (WCED 1987; Langhelle 1999) and should be monitored in this study. This dimension is interpreted to be skills that can identify and analyze problems, to develop ways to improve performance, to make scientific discoveries and to develop technical solutions in solving sustainability problems.

The utilization of appropriate technology affects the economy as it creates a more efficient electricity market or improves the efficiency from the users' side thus the economic dimension is our next concern.

2.2.5.5 Economic

The economy is the driving force of our society and its sustainability is crucial. This concept is reflected in the "going concern" principle in accounting. The economic aspect of SD was voiced by OEDC when it was formed in 1960 to promote policies "to achieve the highest sustainable economic growth and employment" (Organisation for Economic Co-operation and Development 1960). These points are similarly echoed in the "limit to growth concept" brought on by the Club of Rome (Meadows, Meadows et al. 1974) which advocates that the stability of the economy and ecology could be "sustainable far into the future". It was also said that "the (sustainability) lessons of ecology can and should be applied to economic processes" (Redcliff 1987). This dimension is interpreted as issues that deal with the economy of the country such as GDP, unemployment rate, interest rate, exchange rate, and different economic figures.

The economy is partly driven by the government's policy and regulations which can also affect the environmental, ethical and social aspects of sustainability. This aspect, called Institutional, is described next.

2.2.5.6 Institutional

Sustainability covers all the aspects in the society and for managing sustainability of such scale, studies have agreed that the government is the most effective instruments for implementing it. The importance of political and institutional influence has been pointed out in works such as WCED (1987), Mebratu (1998) and B.J. Brown (1988). Strong (1992) even suggests that a fundamental political change is needed to achieve SD. The International Atomic Energy Agency (2005) pointed out the significance of the institutional structure (i.e. dimension) as it acts as a foundation for the other dimensions of SD, and M. M. Brown, Desai, and Doucet (2000) pointed out that institutions need to work effectively and efficiently with the rest of the society to achieve SD.

In the electricity sector, inconsistent policies will cause problems for the regulations (Hubbard 2001; Anon 2002) and poor planning will result in issues such as insufficient capacity due to underestimated growth of demand (Edwards 2001; PriceWaterhouseCoopers 2005), a lack of transmission capacity (Hubbard 2001) and in the case of New Zealand, being un-prepared for scenarios of low hydro seasons (Taylor and VanDoren 2001).

It is therefore essential to monitor the effects of government policies and regulations, which are collectively called institutional instruments. These can be, for example: government's financial support, tax incentives, R&D funds, government and industry procurement policy, green labeling scheme and public benefit charge (Brown, Desai et al. 2000). TERI (1997) also propose that government policies can be divided into four main types: economic instruments, direct expenditure instruments, regulatory instruments and institutional instruments and the details can be seen in Table 6.

Table 6 Institutional instruments (TERI 1997)

Instruments	Implementation options
Economic instruments	tradable permits, deposit refund, performance bonds, taxes, earmark taxes and funds, user fees, subsidies, tax breaks, and administered prices
Direct expenditure instruments	program/project operations, green procurement, research and development, and education and awareness
Regulatory instruments	legislative instruments, liability and competition and deregulation policies
Institutional instruments	targeted institutional arrangements and internal policies and procedures

Having agreed upon the significance of the Institutional Dimension, ironically, no political style has been singled out as the best mode for running a sustainable society and in fact doubts have been put to whether democracy is the mode of governance that can actually deliver sustainable solutions (Wells 2006). The society is open to the risk that, despite having technological ability and economic resources, the government may have difficulty in implementing all of them because these options are not in line with the in-power party's policy or such changes may cause too much controversy and may not be "political correct". This dimension is interpreted as the policy-setting mechanism that sets policies and regulations to affect the sustainability of the society and of its industries.

Having reviewed the six dimensions of sustainability, the criteria that can be used in selecting the indicators will be discussed next.

2.2.6 International Sustainable Development Indicators and their presentation.

Sustainability reports need to have multidimensional coverage to fully analyse such complex systems and they need to be able to present complex data in a simple and visual way. The current practice will be reviewed next and the path this thesis takes will be pointed out.

A number of SD indicator frameworks have been designed over the years, but many of these measures have limited scope and are not suitable for measuring the overall SD of a society. Examples are: the Ecological Footprint has been criticised for the misleading concept that land is the only scarce resource (Patterson 2002); the Environmental Sustainability Index is limiting as it only focuses on the environmental stress and the relating human vulnerability; the Living Planet Index focuses only on biodiversity; the Human Development Index only measure three criteria: life expectancy, literacy and the log of the Gross Domestic Product (GDP). The Wellbeing Index focuses only on human and ecosystem wellbeing (Parris and Kates 2003); the Genuine Progress Indicator is limited as it only measures economic performance and social factors.

While the above methodologies share the same intention to define sustainability and set indicators to measure and monitor them, due to the difficulty of defining such a concept as SD, different interpretations were made. They share the common thread of focusing on the environmental or ecological issues (Parris and Kates 2003) and they have been well criticised for their shortfalls in papers such as Patterson and Jollands (2004), Hens and Wit (2003), and Parliamentary Commissioner for the Environment (2002). The details of the criticism will not be repeated here but a brief analysis will be carried out to see what elements of these well-established indices are suitable for our purpose of assessing sustainability of an industry sector.

These methods all focus on the sustainability of selective parts of the society but from an overall point of view, the failure of even one part will cause the whole system to fail, therefore, monitoring just parts does not give a comprehensive and effective measure on sustainability. It is therefore important to get a comprehensive coverage for the report and one of the methods to do so is to take on a systems approach (Bossel 1999).

Some sustainability measuring methods such as the one adopted by the World Economic Forum (2001) simply rank countries on the points of sustainability and some have a comprehensive list of indicators such as the 58 used in the United Nations Commission on Sustainable Development index (CSD index) (UN 1992; United Nations 2003). While they are rich in coverage, they do not specify SD targets. In another works, such as the Dashboard of Sustainability in European Statistical Laboratory (2007), International Institute for Sustainable Development (International Institute for Sustainable Development 2006), Swanson (2003) and The Energy and Resources Institute (2005), a visual tool is used to present sustainability on a dashboard showing the levels of the main sustainability issues (see Figure 6) and in some variation of the dashboard, their progress rates (see Figure 7). It also shows progress on the policy side, assessing how well policies have been implemented by the government. While this method presents data in a clear and easily understood way, the scope of coverage is still limited and the methodology remains non-transparent and does not address the issue of sustainability threshold.

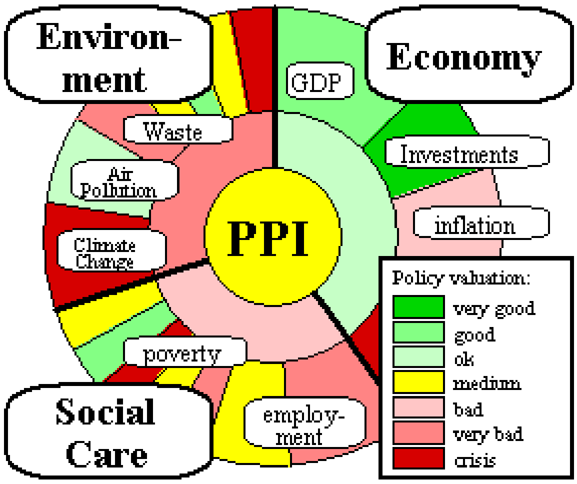


Figure 6 Dashboard of sustainability (European Statistical Laboratory 2007)

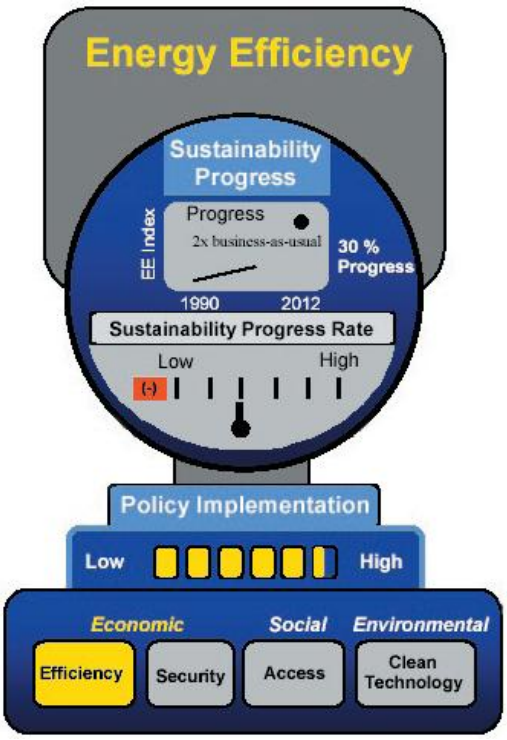


Figure 7 Dashboard of sustainability, showing progress rate (Swanson 2003)

Another reporting method adopted is the Global Reporting Initiative (GRI) (Henderson 2002). It aims to be an international guideline on corporate sustainability reporting. While addressing the many TBL aspects for companies, it remains a voluntary exercise and it is not a code, a performance standards nor a management systems guideline. Moreover it specifically says that it does not provide instruction for designing reporting system and does not offer any methodology for preparing reports (Henderson 2002) but in reality, such as in the ISO 9000 (International Organization for Standardization 2005) and ISO 14000 standards (International Organization for Standardization 1996), these properties are exactly what the industry needs for benchmarking against each other to improve sustainability performance.

From the above observation, it can be concluded that the surveyed internationally acclaimed sustainability measuring methods are not suitable for the purpose of measuring the sustainability of an industry sector. By addressing their weak points, I have formulated a framework and methodology in this paper to analyze the sector. Also, a scalar with different levels of details is developed to present the data.

2.2.7 Summary & conclusion

In this section, the definition of sustainable development has been reviewed, its concept investigated and some reporting concepts identified that would make measuring sustainability more holistic and comprehensive from an environmental, ethical, social, technological, economic and institutional point of view. Considerations have also been given as to how SD measurements can be presented in a easily understood manner.

Next, a review will be made on how different industry sectors, including the electricity sector, have been reporting and measuring sustainability. This review will also identify techniques that can be adopted in this thesis, as well as shortfalls that this thesis can make suggestions to address.

2.3 Specific concerns of Sustainable Development in industry sectors.

International and national sustainability indicators and methodologies have a general scope of coverage. They look at macro-sustainability and although they can assess the impact of the sectors on the society (Hunter 2002) they are not capable of measuring the sustainability problems and issues that are specific to the individual sectors. As a result, sustainability methodologies are needed that can focus on the intrinsic details for industry sectors.

The difference between national and sector sustainability indicators and methodologies is mostly not a matter of scale or putting a different weighting on the indicators but the latter requires detailed technical knowledge about how the sector works as well as the products and the intrinsic processes and relationships involved, whereas the former one may require more political knowledge.

There has been various definitions for sector sustainability such as Blaza & Chambers (1997) Gordan, Blaza, and Sheate (2005) and Porritt (2003) but the main theme is dominated by the "continuous business viability" as proposed in Blaza & Chambers (1997) and the approach is to focus on analyzing and eliminating areas that pose sustainability risks. Sustainability reports are to show "where you are, where you are going, how you are getting there and how soon" (Porritt 2003). Unfortunately, this section discovers that many sectors' sustainability reports have not achieved these objectives and these crucial elements are identified and incorporated into the methodology for this thesis.

The "*sustainability of an industry sector"* can be defined as: "the development in the environmental, ethical, social, technological, economic, and institutional aspects of a sector that would enable it to operate in the long term" and "*the improvement of sustainability of an industry sector"* as: "the development in the environmental, ethical, social, technological, economic, and institutional aspects of a sector that would improve its ability to operate in the long term".

The common theme for the reviewed sector sustainability report, while the sectors produces different products and using different processes, is the focus on its specific areas of interest as in International Aluminium Institute (2004), Webb (2004), Macgowan (2004), Morrison (2002). Many of them address sustainability with the Triple Bottom Line (TBL) approach, analyzing issues relating to economic, environmental and social dimensions and some even extend the coverage to sector specific issues that “describe the day-to-day activities” of the industry (Morrison 2002). For example, the oil exploration sector measures the amount of flaring at oil platforms (Webb 2004), the motor industry measures a car’s fuel consumption (Macgowan 2004) and the aluminium industry monitors the amount of material recycled (International Aluminium Institute 2004). Using sector specific indicators is an effective approach and is recommended for use in the proposed methodology in this thesis.

Some sector sustainability studies, such as Melhuish’s (2002) on the electricity sector, select a small number of indicators to show historical trends and are mainly descriptive in the reports. While that is informative to readers who are not familiar with the scientific principles or the history of the sector or are not up-to-date with the current events, these reports remain a summary of historical events and do not provide vigorous data analysis nor can they arrive at solid and enforceable improvement plans.

Although it has been pointed out that indicators need to be analyzed to show their relevance to specific stakeholders (Morrison 2002), none of the reviewed sector reports have this feature. Stakeholders have different needs and would require different data analysis for decision making. With such hindsight, the methodology in this thesis will address this feature.

Despite having a complete range of indicators, many reports such as Webb (2004), Macgowan (2004) and Morrison (2002) do not spell out the target values for their indicators. Instead, some only present a list of sustainability ideas and plans without any numerical targets as in Macgowan (2004) and Steel Construction Sector Sustainability Committee (2003). Reports that actually indicate sustainability improvement targets can make sustainability more of a practical and less of a philosophical exercise and the methodology proposed in this thesis will take on this approach.

As a summary, companies and business sectors have their own interpretation of sustainability and present their version of the sustainability report but the common point is that they are all based on a fundamental set of dimensions. While most of them adhere to the TBL, namely the environmental, social and economic dimension, in making indicators, it may be time to expand that and have a finer definition of the dimensions. That involves analyzing the sector as a system as it is only through this approach that an active role can be taken to improve sustainability and not just to report it.

In this thesis the electricity industry of New Zealand has been chosen as a case study to demonstrate the proposed methodology because this is a local sector that is facing challenges. Despite having ample natural electricity resource, there are still on-going power problems – examples for physical problems are fuel shortage, low hydro lake level, lack of generation capacity, shortage of transmission capacity, and non-physical problems are public objections that delay electricity projects, internal politics in the companies and public objections to power installations and distribution.

If a methodology can handle issues in this sector, it could also be adapted for use in other sectors and provide an alternate quantitative tool for sustainability researchers and practitioners.

2.4 Sustainability issues in the electricity sector

2.4.1 Introduction

Commercial and economic activities rely entirely on a reliable and sustainable electricity sector. This section examines this concept and reviews what has been considered the major factors that affect the electricity sector's sustainability. Improvements opportunities are identified from the present reporting system. This acts as a foundation for identifying threatening issues in the power industry and for establishing indicators for measuring them.

2.4.2 Sustainable Development definition applied to the electricity sector

Numerous attempts have been made to define SD in the electricity sector such as Blaza & Chambers (1997), Anon (2002), World Business Council for Sustainable Development (2002) and Cheng & Wilson (2004). Although it has been suggested that it is difficult to put this sector into a sustainable framework (Wright 1991), it has been agreed that it plays a vital role in the sustainability of the society (Blaza and Chambers 1997). Reliability and affordability are the widely accepted criteria in this sector (e7 Network of Expertise for the Global Environment 2002; World Business Council for Sustainable Development 2002; EPRI 2003).

While realizing the degree of sustainability in the electricity sector is often relative, a more detailed definition is still needed, and the definition adopted in this thesis is that a sustainable electricity sector is one that "reliably supplies electricity at a reasonable price while satisfying social, environmental, technological, ethical, economic and institutional requirements, and all the time operating as an economically viable business, both in the short, medium and long term" (Cheng and Wilson 2004).

In the following paragraph, the possible factors that affect the sustainability of the electricity sector is reviewed.

2.4.3 Electricity sector sustainability study

There are different causes for an electricity sector to be unsustainable but they often have the same outcome ─ blackouts. Blackouts are traumatic, politically important and peculiar to the electricity sector but they are not necessarily symptomatic of an industry that exhibits poor sustainability, although reading the definition one may think so. Only if the blackouts occur regularly and are preventable is the industry is poor shape. The industry could just have had bad luck, or it may be underdeveloped.

If the causes are of stochastic nature such as hardware breakdown or weather damage, this type of power cut is then short-term and might not cause sustainability problems. Also, some developing countries' electricity demand exceeds their current power supply capacity and that results in regular electricity outage. If these countries are in the developing stage and are making efforts to expand their electricity capacity, these then are not strictly unsustainable. However, if they are prevalent rolling blackouts caused by an ongoing lack of generating resource, they may then affect the sector in the medium and long term and their causes need to be identified as the first step in improving the sustainability of that sector.

With the complex dynamics of the electricity sector, it is therefore important to have a methodology that can look beyond the immediate and obvious causes and can analyze the sector in detail to identify the other symptoms and causes of unsustainability that might, singularly or in any combination, cause a complete breakdown of the sector. Some cases of power interruption in New Zealand are looked at and the factors causing electricity power problems in other countries are investigated in this section of the thesis.

In New Zealand, a recent major power interruption happened in Auckland on 12th June 2006 for four hours (NZ Herald Editor 2007) and was caused by a hardware fault (a broken shackle) (Connell Wagner Pty Ltd. 2006). There is a range of estimated underlying causes ranging from inappropriate maintenance procedure to a lapse in maintenance quality due to contracting the service out.

In January 2004, the HVDC line transmitting power from the South Island to the North was interrupted for three days due to foul weather resulting in extreme high spot prices in the North and low in the South (Baker and Sise 2004).

Low reservoir level and high demand was the cause of the power shortage period in February 2001 (Ministry of Economic Development 2001) causing a lot of media outcry, and the longest recent interruption was the February 1998 Auckland central power failure which affected the city centre for over four weeks due to faulty cables and an absence of any backup design. The causes for these cases are all different and should be treated as such.

Examples abroad are the series of blackouts that happened in North America (August 2003), in UK (August and September 2003), and in Sweden, Denmark and Italy (September 2003). A survey in 2005 showed an increasing proportion of respondents are concerned about the current security of supply (72% in 2005 vs 65% in 2004), and 88% respondents from Europe expect more blackouts in the future

(PriceWaterhouseCoopers 2005). While a electricity sector that has the occasional blackout can be sustainable (as that might have been caused by unpredictable, unpreventable and uncontrollable events such as mechanical breakdown and equipment damaged by weather conditions and natural phenomenon), Bower (2004), Edwards (2001), Crow (2003), Berkeley University (2001), PriceWaterhouseCoopers (2005) and Hubbard (2001) revealed other unsustainable factors that are more fundamental to the electricity sector.

They reveal that while traditional blackouts are mainly due to factors such as unexpected high demand, inadequate transmission capacity, a lack of generation capital investment, and corporate malpractice, the recent ones have quite different causes. They are more due to the structure of the market. Bower (2004) and Berkeley University (2001) accuse the sector of having out-dated procedures originally designed for a regulated market that are still used in a liberalised market, under-investing in staff training, having conflict of interest between system operators and transmission operators, and having poor sector regulations and standards. These electricity sectors are not properly managed as they are either over-regulated (Hubbard 2001), under-regulated or the regulations are uncertain or simply unclear (PriceWaterhouseCoopers 2005), although it can be argued that if a sector requires legislation to ensure sustainability, that does not bode well for the future ─ a truly sustainable system should be naturally sustainable. As a result of these criticisms, indicators in this thesis would measure the appropriateness of the regulations and their effectiveness.

It is a common view that in the electricity sector, inappropriate regulations create an unstable investment environment, increasing investment risks, which in turn deters further investments (Anon 2002; IEA/ODEC 2004; PriceWaterhouseCoopers 2005). In fact, without investment, the electricity sector is not sustainable as funds are needed to replace retiring plants and to increase capacity to meet increasing demand. To improve the situation, the sector needs to correct the inconsistent regulations in the energy sector and tax regimes and to revise the stringent environmental policies (PriceWaterhouseCoopers 2005). Overall, the sector needs to cater better for investments in generation and transmission (EPRI 2003). As a result, measurements will be made on the investment environment and a rating will be given on how attractive it is to make investments in this country.

As a summary, the sustainability of the electricity sector involves a number of non-traditional as well as traditional factors and existing sustainability reports lack a solution-focused approach that is comprehensive enough to address the dimensions of sustainability and relate the results to the stakeholders. The methodology proposed in this thesis aims to overcome these issues.

On the other hand, even if the current reports focus on the possible causes of the unsustainable issues, they rarely make measurements, especially on qualitative issues, nor propose methodologies to do so. Scientific or management methodologies are not utilised in the current reports reviewed, and they do not provide solid quantitative data for sustainability analysis and for taking actions on. These descriptive reports, focusing on policy, plans or philosophical issues without listing targets, make it virtually impossible for improvements to be measured objectively. This thesis, in Chapter 4, proposes a method that addresses these issues in a quantitative way. By reviewing the sustainability issues in this section, it brings awareness to the aspects of sustainability that need urgent attention. As a vital element, the sustainability aspects need to be measured and monitored and it is the aim of this thesis to develop a methodology to do so.

2.5 The electricity sector in New Zealand

This section first describes the composition and the performance of the electricity sector in New Zealand and reviews how sustainable development has been implemented there, following that, its potential problems are pointed out. Next, to provide a background for designing indicators, this section first lists some notable historical events in this sector that point towards un-sustainability and then reviews its sustainability reports, pointing out areas that need extra attention and aspects that need to be added to existing methodologies.

2.5.1 Background of the electricity sector in New Zealand

The power market in New Zealand originated and operated as a state owned enterprise called Electricity Corporation of New Zealand (ECNZ) up until 1996 when Contact Energy split from it. In 1999 ECNZ was further broken up into three State Owned Enterprises (SOES): Meridian Energy, Genesis Power and Mighty River Power. There are now five main generators: Meridian Energy generating 30 percent of total power, Contact Energy 27 percent, Genesis Power 19 percent, Mighty River Power 12 percent and Trustpower 4 percent. In total they generate 92 percent of the power (Ministry of Economic Development 2006). The rest is met by independent generators and co-generation plants. Transpower is responsible for high voltage, long-distance transmission and it is distributed in lower voltage by 28 local distribution companies. Its operation is governed by the Electricity Commission who has the power to change the sector's regulations, and its activities are monitored by the Ministry of Economic Development and the Commerce Commission. The overall layout of the sector can be seen in Figure 8.

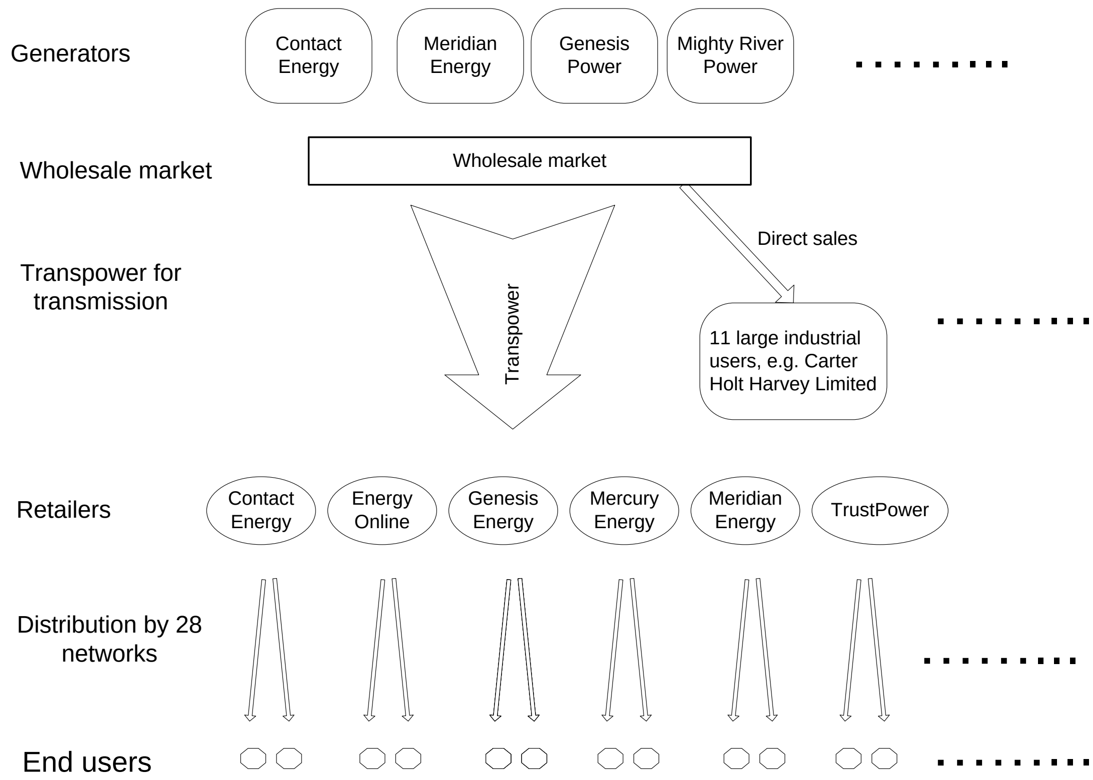


Figure 8 Overview of the New Zealand electricity sector (PriceWaterhouseCoopers 2004; Ministry of Economic Development 2006)

2.5.1.1 Generation mix

A review of the different sources of generation in 2005 can be seen in Figure 9 . The main generating source is from the renewable hydro generation, contributing 56 percent, then it is gas at 21.3 percent and coal at 13.1 percent. The power generated by hydro plants in 2005 was 14 percent less than the figure for 2004 due to lower hydro generation reservoir inflow, and out of the different generation sources, wind has the biggest percentage increase from 146Gwh in 2003 to 610GWh in 2005.

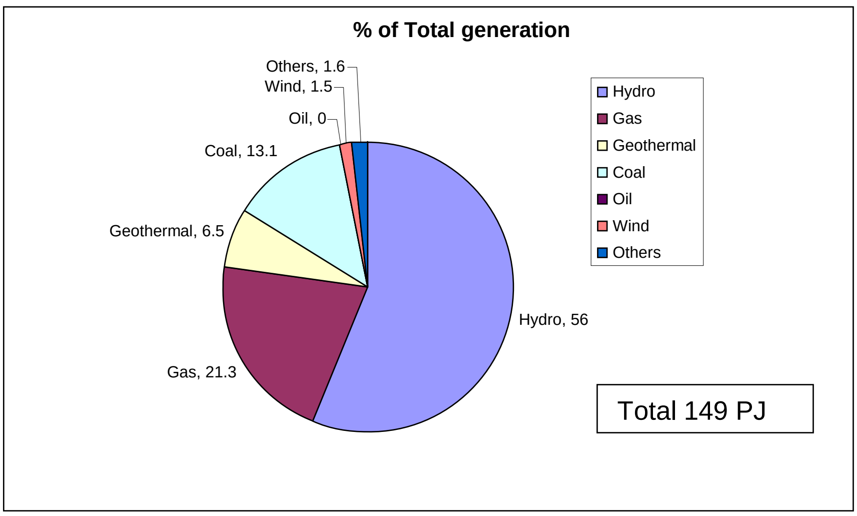


Figure 9 Generation mix New Zealand 2005, Pie Chart (Ministry of Economic Development 2006)

The use of electricity by sector is seen in Figure 10 with the industrial sector being the largest.

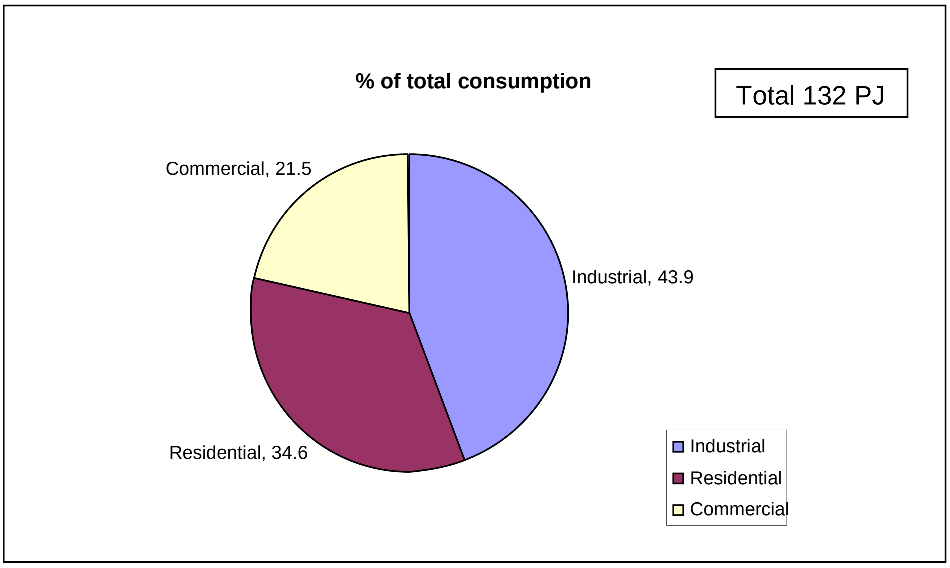


Figure 10 Electricity consumption by sector, New Zealand 2005, Pie Chart (Ministry of Economic Development 2006)

2.5.1.2 The market

New Zealand operates a wholesale "free" power market. Power is sold by generators to retailers in a "pool" type offer-and-bid mechanism, and also directly to large commercial and industry users, some at spot price and some through longer term hedge contracts. The general idea of the hedge market is to insure the users against price spikes; further details are available in Hasen (2004) and Layton (2005) which provide detailed description and analysis. Power is sold from nodes along the transmission line set at half-hourly prices. The wholesale market is controlled by regulations such as the Electricity Governance Regulations 2003 and Electricity Governance Rule 2003, (replacing the multilateral industry contracts: New Zealand Electricity Market (NZEM), Metering and Reconciliation Information Agent (MARIA), and Transpower's Common Quality Standards), and small generators can sell the power to retailers directly without going through the wholesale market. In the retail market, retailers resell power to consumers.

Currently in New Zealand there are ten retailers, including generators/retailers, such as Contact Energy, Genesis Power, Meridian Energy, Mighty River Power and TrustPower. The 2005 retail market grew by three percent from 2004. As an observation on the retail market, the New Zealand industrial power price is one of the lowest in the industrialised world but the residential price is more than two and a half times that paid by the industry (See Figure 11), that is because residential price is fixed at a stable price but it has to cater for price spikes, thus, it needs to carry a premium (Layton 2005).

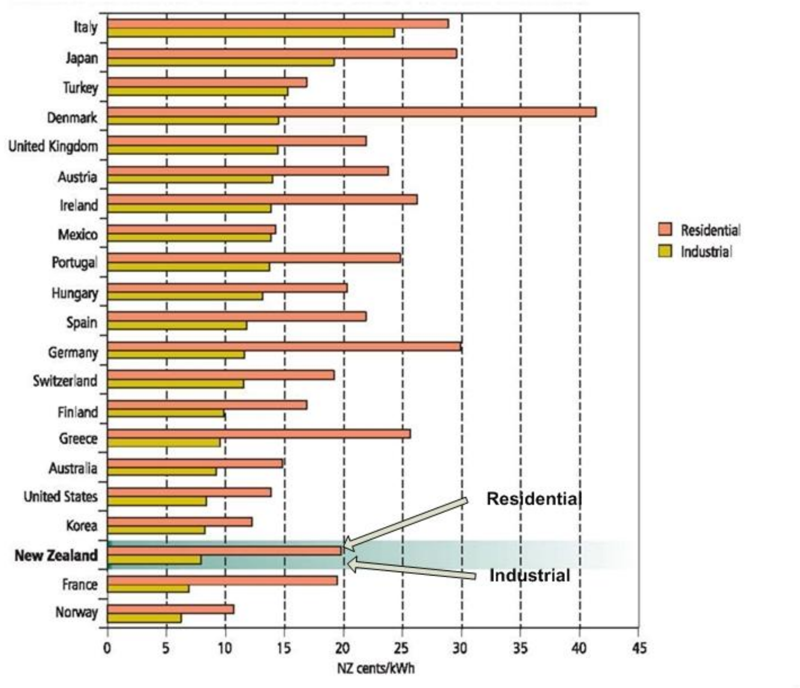


Figure 11 Electricity prices comparison (MED 2006)

The historical growth of the power consumption market can be seen in Figure 12 and Figure 13, showing the contribution of different generating resources through the years and seasons.

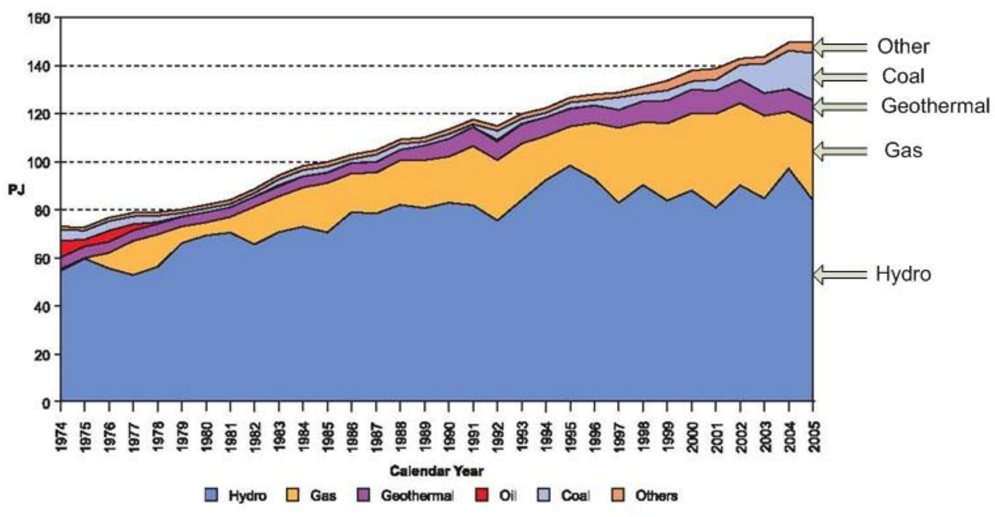


Figure 12 New Zealand annual electricity consumption (MED 2006)

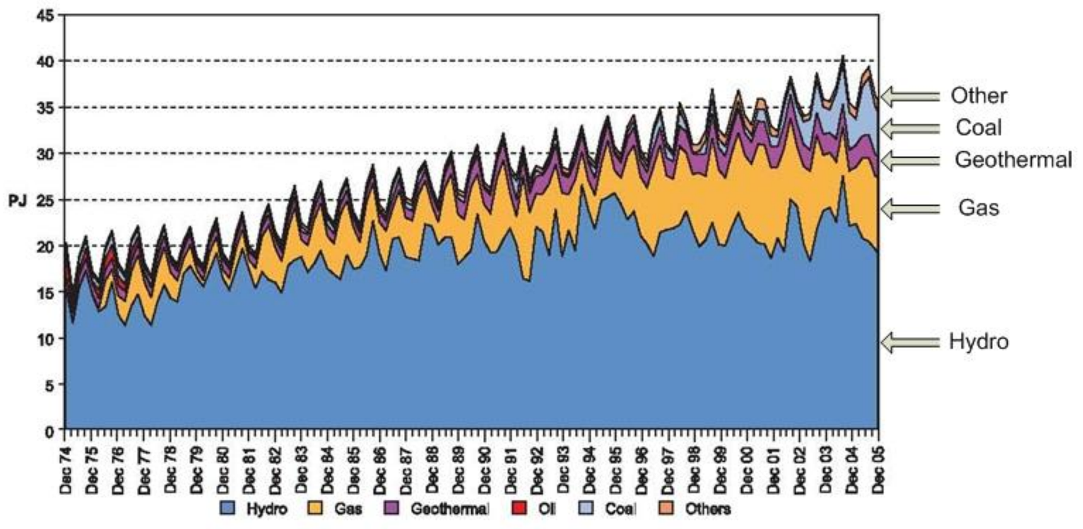


Figure 13 New Zealand quarterly electricity consumption (MED 2006)

This sector was supposed to be self governing but there was a general concern by the government in 2003 that the industry arrangements and security of supply problems could not be solved in their current states, so, an Electricity Commission was set up in 2003 to address four priority issues: security of supply, investment in the transmission grid, hedge market arrangements and promoting the efficient use of electricity (Ministry of Economic Development 2006).

2.5.2 Sustainability implementation in New Zealand

This section reviews the implementation of SD in New Zealand in general and in the electricity sector. Cases and issues causing sustainability concerns are also considered.

2.5.2.1 History of Sustainable Development in NZ

New Zealand was one of the 178 governments that adopted Agenda 21, a sustainable development guideline, which was set up as a result of the Rio Earth Summit in 1992 with the announcement of the Rio Declaration on Environment and Development. One of the first actions the New Zealand Government took towards SD was to pass the Resource Management Act in 1991, and it set up the Energy Efficiency and Conservation Authority (EECA) in 1992. SD activities in New Zealand had been quiet until 2000 (McGuinness 2005) and New Zealand has made a rather weak effort in the area of measuring SD ─ even in 2006, there is still a lack of a permanent single agency that can collect, analyze, manage and present information in SD, and consolidated data is not available for an "objective assessment" of the state of SD in New Zealand (United Nations 2006). Even with a lack of effort in measuring sustainability, evidence shows the government is immensely concerned with establishing sustainability policies in the electricity sector. General ones were made such as Hobbs (2003) and Ministry of Economic Development (2005) as well as specific ones such as the ratification of the Kyoto Protocol and the setting up of energy efficiency improvement targets and renewable energy targets by EECA (EECA 2005). Ironically these Kyoto and EECA commitments seem now unachievable. The original estimated economic benefit by ratifying the Kyoto Protocol, the selling point of the idea, is out by $1,000 million ─ instead of making a $500 million gain, New Zealand will now be having an estimated $656 million liability (Woodham 2005; Fallow 2006); at the same time EECA also cannot reach its target ─ it has a target of a 20 percent improvement in energy efficiency between 2001 and 2015 (Hobbs 2002), but now that is declared unlikely to be unattainable (NZPA 2006) , only a two percent increase was achieved in the period 2001 to 2005. The ability to make an accurate forecast, set realistic targets and then achieving them has been put to challenge, so it is all the more important to develop effective methodologies to measure sustainability objectively, analyze the situation thoroughly, and set realistic targets.

2.5.2.2 Development of sustainability in the power industry of New Zealand

SD has been adapted mostly as a planning philosophy in New Zealand. Experience tells us that a well-coordinated effort to improve sustainability, with clear roles of the participants, is crucial in its success. Unfortunately, in New Zealand, the responsibility to manage the sustainability of the electricity sector was divided up and handed to various government departments. They are, for example, the Energy Minister, Ministry of Economic Development, Ministry of Commerce, Ministry for the Environment, Department of Conservation, Energy Efficiency and Conservation Authority and Electricity Commission (Williams 2003; Hemmingway 2004). This mode of operation has not proven to be too efficient, as even in 2006 there was still the need to clarify the roles of the Electricity Commission and the Commerce Commission in the management of the power industry with the result that a formal memorandum of understanding had to be signed (Hemmingway and Rebstock 2006). A lack of coordination and confused roles do not add to the sustainable governance of the electricity sector.

2.5.2.3 Potential barriers to improving the electricity sector

The government set up the Electricity Commission as an independent body to improve the electricity sector's situation and perform regulatory changes, but the contract for Roy Hemingway, the previous Electricity Commissioner, was not renewed at the end of his three-year term. There is speculation that his departure was due to political interference as seen in his statement given prior to his departure that the government is "politicizing electricity decisions" which will hurt investor confidence and is not "for the benefit of consumers" and that in the past the government has built projects that are "wasteful and unnecessary" (NZPA 2006). New Zealand's politicised governance mode of the electricity sector may be politically correct but it may not contribute positively to its sustainability (James 2004).

2.5.2.4 The doubts surrounding the usefulness of modeling

To allow better planning of resources, power forecasts were made using models and scenarios for better planning (Taylor and Eng 2000; Audet, Heiskanen et al. 2002; Smith, Fairclough et al. 2003; Potter, McAuley et al. 2005) but after a review, their accuracy has been put in doubt (Kang, Cheng et al. 2003).

2.5.2.5 Potential unsustainable experiences of the NZ electricity sector

Besides the events described in section 2.4.2 that interrupted the New Zealand electricity sector's operation, there are other historical events that will be discussed below.

As seen in Figure 9, the main sources of generation are hydro and gas. Reservoir level and water inflow affects the hydro lakes' capacity, therefore, the main generation source in New Zealand does not have a constant power reserve. It has in the past dropped below a comfort level numerous times. Also the country's dependency on gas from local gas fields may also cause anxiety as seen in the example of the threat of the Maui field running out (Blakeley, Goldthorpe et al. 2003) but was alleviated later by the discovery of a new gas field in Taranaki (Stokes 2006). Overall fuel supply in the long term is still not stable.

The transmission structure has been pointed out to be insufficient for future demand. Both the transmission and the distribution system are known to have bottlenecks and have weaknesses in their design, such as the vulnerability of the North Island to South

Island (NI-SI) High Voltage Direct Current (HVDC) link and the single backbone line along the North Island. Little has been done to alleviate that situation even today although various proposals are in place. Incidents of transmission such as the 2004 HVDC outage creates price spikes where the price at Haywards, in the North Island, jumped from an average $80/MWh to $627.12 /MWh on 9th Jan 2004 and $1037.13/MWh on 12th Jan 2004 (Baker and Sise 2004). Since the establishment of the Electricity Commission, it has set plans to improve the transmission system such as the plan for spot price intervention where at $200/MWh (M-co 2003) reserve generation will be brought in to minimise the chances of price extremes.

The Resource Management Act (RMA) has hindered numerous power plant proposals such as Project Aqua in March 2004. Even though the government has been making suggestions to improve the RMA, as reported in Bennett (2007), it still needs to demonstrate how the amendments to the Act can speed up and simplify the application and review process for power projects while still maintaining the Act's principles.

From the point of view of investing in the sector, the issues that New Zealand faces, like fuel supply uncertainty and regulatory uncertainty, deter investors from investing in the market (Charles River Associates (Asia Pacific) Ltd. 2005) but investment is what the sector needs. It is up to the government and the stakeholders to improve the investment environment to attract more funds for expansion.

The government is an effective instrument to make nationwide improvements in the electricity sector but the effectiveness of their plans and policies has been put in doubt in the case where the target of improving overall energy efficiency cannot be met (NZPA 2006). In fact, the four-week Auckland Central power cut in 1998, which was in the middle of the sector's re-organization as described in 2.5.1, makes consumers wonder if the sector is more concerned with business takeovers and mergers than focusing on providing the service and products these companies are supposed to deliver.

A number of events also show the conflicting views between the government and the businesses which puts in doubt whether being politically correct or getting business results is of higher priority. The Electricity Commission first blocked Transpower from building a new 400kV transmission line to meet expanding demands but upon the changing of the Electricity Commissioner, it was subsequently approved. The

Electricity Commissioner ruled that the South Island operators (Meridian) should cover the cost of expanding the HVDC link to the North Island (both reported in Inder (2006)). The Commerce Commission threatened to take over the distribution company Vector due to discovering the details of their pricing schemes (Commerce Commission New Zealand 2006). The carbon tax plan was found to have underestimated the cost to the country by $1billion (Fallow 2005; Woodham 2005) and was finally scrapped (Hodgson 2005).

With a list of events that affect the sustainability of the electricity sector, some of the underlying causes have been identified, and it is found to be all the more important to derive a methodology to measure and report on the "state of health" of the sector which is addressed in Chapter 4.

2.5.3 Critiques on New Zealand Sustainable Development studies

The reporting styles of the general sustainability reports are limiting in quantifying sustainability and pinpointing corrective actions. A review of them shows the following findings. The Infrastructure Stock report (PriceWaterhouseCoopers 2004) summarises data from a number of existing external reports and analyzes historical data with projections and recommendations, but it does not quantify the results with respect to sustainability. It makes proposal from a planning point of view on what could be done to improve the situation but targets are rarely set. These are also the criticism from the report Monitoring Progress Towards a Sustainable New Zealand (Pink 2002). Another report, the Ecological Footprint report of New Zealand (McDonald and Patterson 2003), has sector analysis but the concept is criticised as limiting because out of all the dimensions in SD, only land use was singled out as the limiting factor (Costanza 2000; Moffatt 2000). Even a more seemingly focused report, Melhuish (2002), is also limited in the scope of the indicators it uses and it suffers from the same shortfall of being mostly descriptive and not quantitative.

New Zealand has no official quantitative sustainability study of the electricity sector. There are general county-wide SD reports on the society in general such as McDonald & Patterson (2003), Pink (2002) and PriceWaterhouseCoopers (2004) which include the electricity sector. There are also reports that give an outlook of the electricity sector either by modeling (Smith, Fairclough et al. 2003) or by making scenarios (Potter, McAuley et al. 2005) and there are reports that analyze the past power usage such as Dang (2004) but these reports do not give metrics in quantifying the sustainability of the sector.

Numerous studies and proposals in SD policy and strategy were made by the government such as Patterson (2002), EECA (2005) and Hemmingway (2004) but despite having a more than ten-years period to put them into practice since Agenda 21, the government is still trying to clarify its policies and trying to rephrase the same principles in numerous reports such as Williams (2000), Hobbs (2002) and the Parliamentary Commissioner for the Environment (2002). Even the Prime Minister's address to the nation at the opening of the Parliament 2007 was seen as a talk without a comprehensive program using a "precise yardstick by which to measure" targets and results (NZ Herald Editor 2007). Local proposals from independent bodies and academics such as Patterson & Jollands (2004), Boyle (2004), Donnelly & Boyle (2004) and reports from the industry such as Barrett (2004), Peat (2000), Halliburton (2002) and Elder (2004) and also research papers on sustainability frameworks, indicators and methodologies such as Peet (2003), Williams (2000) and Williams (2003) are still focused on the philosophical and strategic aspect of SD rather than quantitative methods that can measure and report sustainability numerically and analytically. The latest review of the literature shows there is no quantitative research indicating to what extent the principles and philosophy from these proposals have been implemented and how much these have contributed in making the society and its sectors more sustainable.

2.5.4 Conclusion on the New Zealand electricity sector

Sustainability of the electricity sector in NZ has been a matter of concern especially due to the unique electricity generation mix, the geographical situation and the politics of the country. There have been various attempts to measure its sustainability, but they are deemed to be either not comprehensive enough, short of methodology, or lacking in quantifying targets. What is needed is a methodology that performs solid and intensive analysis of the electricity sector and can identify and measure effective indicators. It would enable the project team to recommend remedies, perform corrective actions and take following-up actions. These are the feature in the method that this thesis will propose in Chapter 4.

2.6 Conclusion

Chapter 2 has reviewed the definitions and the frameworks of general sustainable development and the sustainability of industry sectors. Focus was put on the electricity sector and especially for the one in New Zealand which was reviewed in detail.

Areas for improvement have been identified and concepts that need to be included in sustainability measurements pointed out. These form the basis for designing the proposed methodology in Chapter 4.

This thesis acknowledges that there are sustainability issues of the electricity sector in New Zealand ─ the main ones being the forecast accuracy for future electricity demand levels and the predictability of price spikes in the wholesale electricity market. These two issues are further investigated in Chapter 3.

Chapter 3 Modeling of the electricity sector

3.1 Introduction

This chapter starts off with an introduction of system types and different frameworks for modeling. The accuracy of their application to modeling electricity demand is discussed with examples from the electricity sector of New Zealand and emphasis was placed on chaotic systems. The electricity sector of New Zealand was tested for chaotic characteristics and the results and their implications are discussed.

3.2 System types and their suitability for modelling

An industry sector such as electricity can be analyzed as a system and the characteristics of a system can be briefly summarised as one of the following types: deterministic, stochastic and chaotic. Their accuracy is negatively affected by imperfect information such as on model structure and parameters (for deterministic and chaotic systems), or initial conditions (for chaotic), and well as the future inputs (for all types).

If a system is deterministic, that means the outcome can be precisely predicted by knowing the inputs and the input-output relationships. On the other hand, if a system is stochastic, meaning the output is random and there is little that can be done to influence it, there is then little incentive in assessing the sustainability of such a system since it is already known that it can never be improved. On the other hand if a system is chaotic, small changes in the input will have an undue influence on the output especially in the medium to long term.

In analyzing the nature of a system, however, if the result of analyzing the system shows that an industry has periods of chaotic behaviour but they are short term, what then would be productive is to try to establish how one can drive a chaotic system into a deterministic regime. This technological issue is not further addressed in this thesis although it may well prove a productive research area. While this chapter was deliberately industry specific, it may well be that other industries experience periods of different behaviour of which some may be chaotic.

Drawing from the above information, conclusion can be made that predictions are only useful when a system is reasonably deterministic or if the statistics of a stochastic system is known, and that effective changes can only be made if the system is mostly deterministic.

3.3 Background of the electricity sector in New Zealand

This section on the modeling of the electricity sector in New Zealand is clearly specific to one industry due to the sector's unique combination of conditions such as its development history and generation mix. While the concepts here on modeling the electricity sector may not be directly applicable to other sectors, this chapter illustrates some interesting and potential sustainable issues of the electricity power industry.

In the electricity sector of New Zealand, due to the nature of the spot electricity price market, the spot price has at times experienced spikes of more than ten times the average price as shown in Figure 14. This puts immense financial pressure on the industry consumers and it has been seen as a factor that affects the sustainability of the electricity sector but as it only happens occasionally, its importance has sometimes been over-emphasised but its nature is definitely worth investigating.

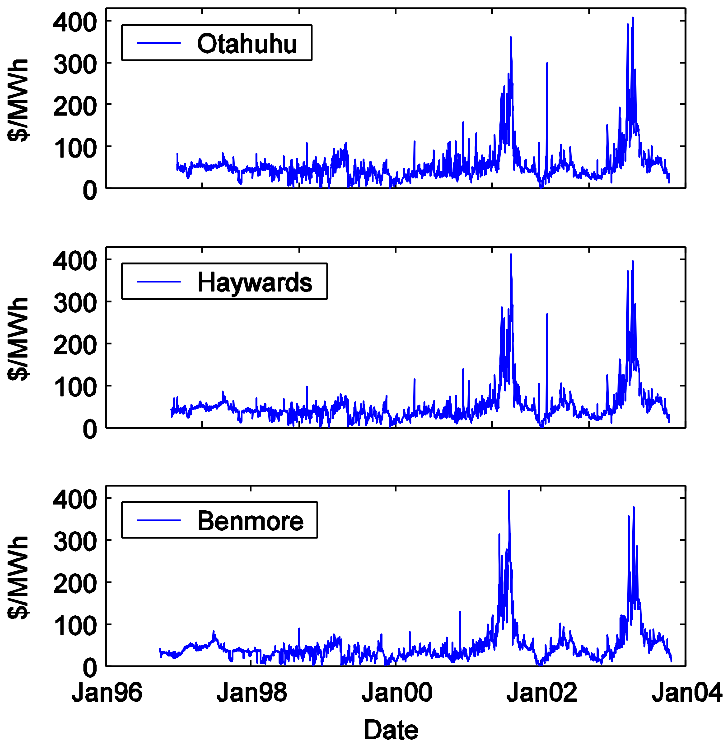


Figure 14 Electricity spot price for 3 grid termination points in New Zealand since deregulation, from 1996 to early 2004. Data from (Stevenson, 2003).

If the nature of the spot electricity price in New Zealand is deterministic, that means this spot price follows some pattern and can at least be modeled and is predictable in principle. And if the spot price is predictable, that means customers can proactively avoid price spikes before they happen by taking measures such as buying hedge contracts, re-scheduling production, or by carrying out demand side management. On the other hand, if the spot electricity price is not deterministic, spot price may then have a chaotic nature, meaning power users cannot accurately predict the price spikes' occurrence and have to be subjected to extreme price variations. That may put them in a difficult financial position because they have to pay the sudden elevated cost or, in the case that they cannot afford the price, may have to interrupt production until the price lowers to an affordable level. Power supply of this nature is concluded to be unsustainable as it is not consistently secure, reliable and affordable. In such a case, this would imply that modeling may not be the best option to predict and control the power market, instead, other methods need to be derived to improve the sustainability of the sector and a suggestion will be made at the end of the chapter. The hypothesis that the spot electricity price is deterministic will be tested in section 3.3.3.

Some of the factors that may be accountable for the decrease in the sustainability of the electricity sector in New Zealand are described as follow: New Zealanders, at least for the industry sector, have been used to relatively cheap electricity given the historical abundance of hydro-generation capability and cheap gas for generation from the offshore Maui gas field. The demand has been increasing by around 1.8 percent to 2 percent per year (as shown in Figure 15), but cheap electricity is threatened as the electricity price is predicted to go up 30 percent between 2007 and 2010 (Ministry of Economic Development 2006). Also, New Zealand's present dependence on non-renewable fossil fuels ─ natural gas 21.3 percent, coal 13.1 percent (Ministry of Economic Development 2006), and the degradation to the environment from large scale hydro, notwithstanding counter arguments (Klimpt, Rivero et al. 2002), is not sustainable.

New Zealand's heavy reliant on hydro-power, which generates 56% of total electricity (Ministry of Economic Development 2006), was the cause of the three "dry years" in the last seven years where the availability of hydro power supply was limited and the affordability for electricity decreased as shortage caused spot price spikes for short periods as can be seen in Figure 14. Given the extreme inelasticity of the short-term price for electricity, this situation nearly caused catastrophic consequences to consumers, to industries and to society as a whole. Some industries had to stop production because of the high electricity price and the economy suffered an estimated $200 million loss (Leyland 2002) due to a decrease in industry production and economic activities. The GDP growth in New Zealand slowed to 0.2 percent for the 2001 September quarter compared with 2.3 percent the year previously (Weir 2001) due to the high electricity prices in this dry year.

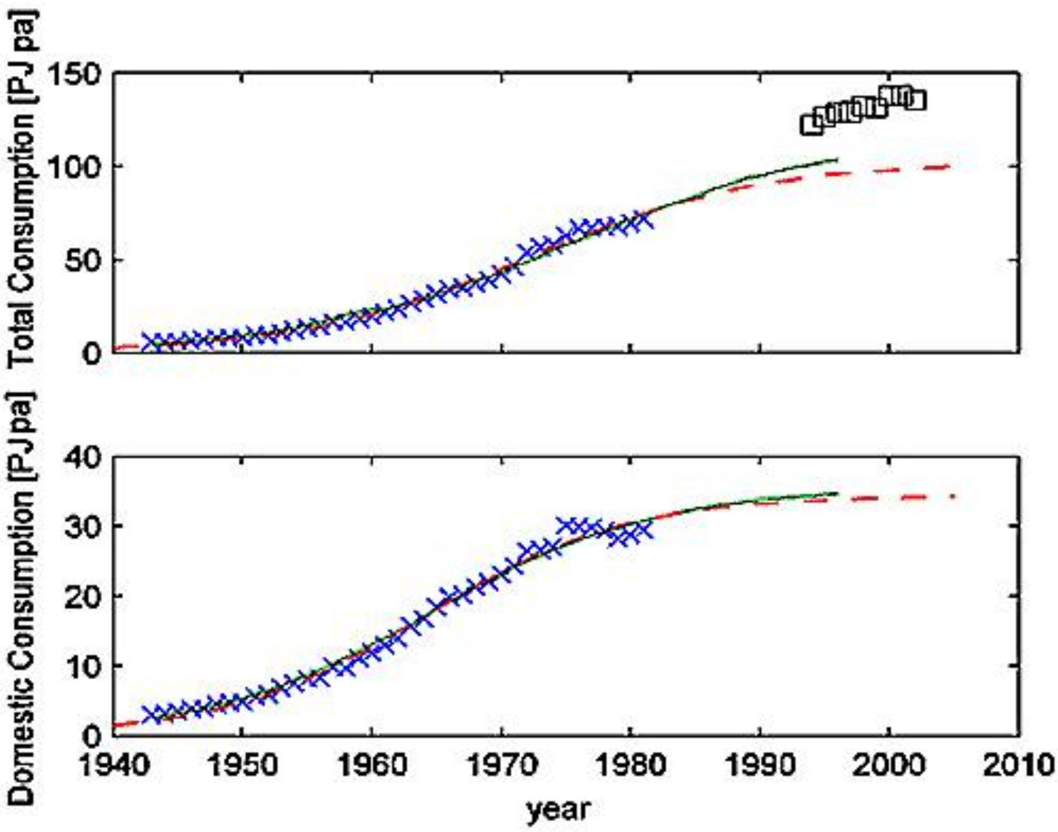


Figure 15 Total electricity consumption predictions for New Zealand (dashed from original paper, solid re-regressed) from (Bolder & Tay, 1987) compared to actual data, (x). Recent validation data not used for the original fitting is given as □ .

While the government took the initiative to perform a “Post Winter Electricity Review” and received 47 submissions aimed at reducing the likelihood of a repeat, this seemed to have minimal effect on the electricity sector as two years later the same scenario repeated itself causing a ten fold increase in spot price and the government had to call for another power saving campaign. As a result, these events gave the public the perception that dry years significantly and repeatedly threatened the sustainability of the electricity sector. This then raise the question of what is an effective methodology for increasing sustainability for the electricity sector.

This chapter on reviewing the feasibility of the electricity sector to be modeled is based on the following two observations: (1) the performance of models for predicting electric power usage have historically been, at best modest, and (2) a system exhibiting chaotic behaviour cannot, even in theory, be predicted over medium time ranges.

3.4 Modelling frameworks for sustainability

Three types of relevant modeling for the power market are defined in this context: (1) engineering/technological models of the generation hardware, (2) country-wide technological models such as those concerning transmission and climate, and (3) market models of supply and demand, culminating in a model of the spot price for electricity (Kang, Cheng et al. 2003).

Type 1 and 2 models enable planners to weigh the various techniques and costs of generation alternatives. Due to the extreme inelasticity of the short-term electricity price, it is the lack of viable generation alternatives that caused the price fluctuations exhibited in Figure 14. The type 1 and 2 models are specific to the technology considered, and will not be further discussed in this thesis except to note that better models give an optimization potential within a generating industry, and a degree of choice across industries to reduce the vulnerability to rainfall, for example. Level 3 models are concerned with the electricity market in general and the spot price in particular. The modeling of the electricity market has been reported as unique in economic terms as it regularly exhibits characteristics such as jump diffusion and regime switching (Weron, Bierbrauer et al. 2004).

3.5 Predictive models for electricity in New Zealand

Estimates for the long term future electricity demand, if they can be accurately done, are crucial for SD planning as indicated in Electricity Commission (2007). These models span from simple blackbox models that combined smoothing and extrapolation of past time series data, to complex econometric models.

3.5.1 Blackbox models

The oft-cited disadvantages of black-box models, such as their expected poor performance in extrapolation to conditions not seen earlier in the fitting stage are, to a degree, addressed in more mechanistic models such as system dynamic models or econometric models. However Price & Sharp (1986) find little correlation between model complexity and predictive performance. Using historical data of electricity consumption from 1943 to 1981, Boldger & Tay (1987) fitted simple logistic curves of the form as in equation (1) for consumption *c* where:

$$c = F/(1 + e^{\theta_0 + \theta_1 t}) \tag{1}$$

and where the saturation factor *F* and scaling parameters θ_0, θ_1 were regressed. The authors then make a brave, but hedged, prediction for the long term trend of electricity consumption in 1987. The logistic model predicts a saturation around 2000 (for the total), while the alternative energy substitution model predicts a decline. With the benefit of hindsight, these predictions can be validated as in Figure 15, and in fact, the logistic model under-predicts the demand by around 36 percent (Kang, Cheng et al. 2003). It puts doubt on whether complex models have a significant benefit in terms of increased accuracy.

3.5.2 Econometric medium-term models

Two families of medium-term econometric models, one from each organization, the Centre for Advanced Engineering (CAE), and the Ministry for Economic Development (MED), are summarised in Table 7. In both cases, the basic model was subsequently updated. The predictions for total electricity used compared to the actual data from

Dang (2003) are given in Figure 16. The prediction for hydro generation is in Figure 17 (a). The significant difference between actual and predicted is in part due to variation in rainfall volume and in the times of the year it falls. This reinforces the role climate plays in the current electricity market of New Zealand, but the detailed discussion of long-term climate change and its potential causes and effects will not be covered here as it is beyond the scope of this thesis.

Predictions for eelectricity generation by gas are given in Figure 17(b) and coal in Figure 17(c). The accuracy is also relatively low because of the near-impossibility to predict dry years during which more gas and coal will be needed to supplement hydro generation.

Table 7 Predictive electricity models, for legend in Figure 16

Organization	Predictive electricity models
CAE	Leyland Consultants Ltd (1994) Leyland & Mountain (2002)
MED	Ministry of Commerce (1994) Smith et al. (2003)

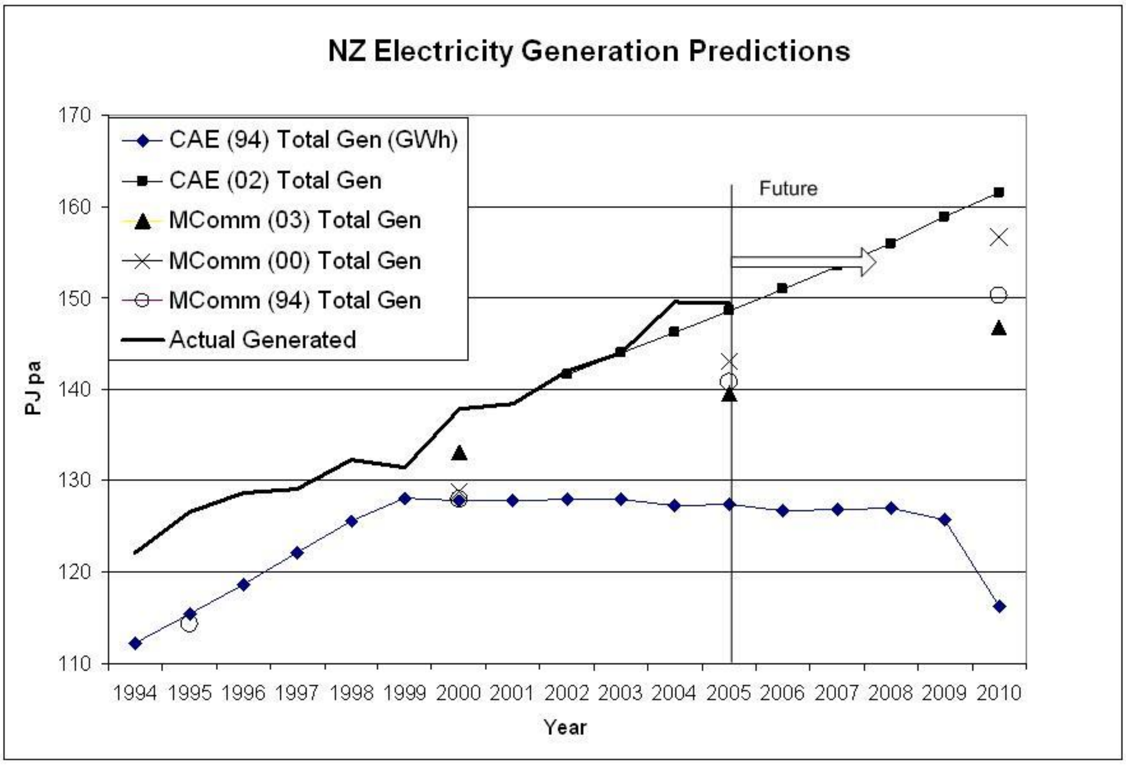
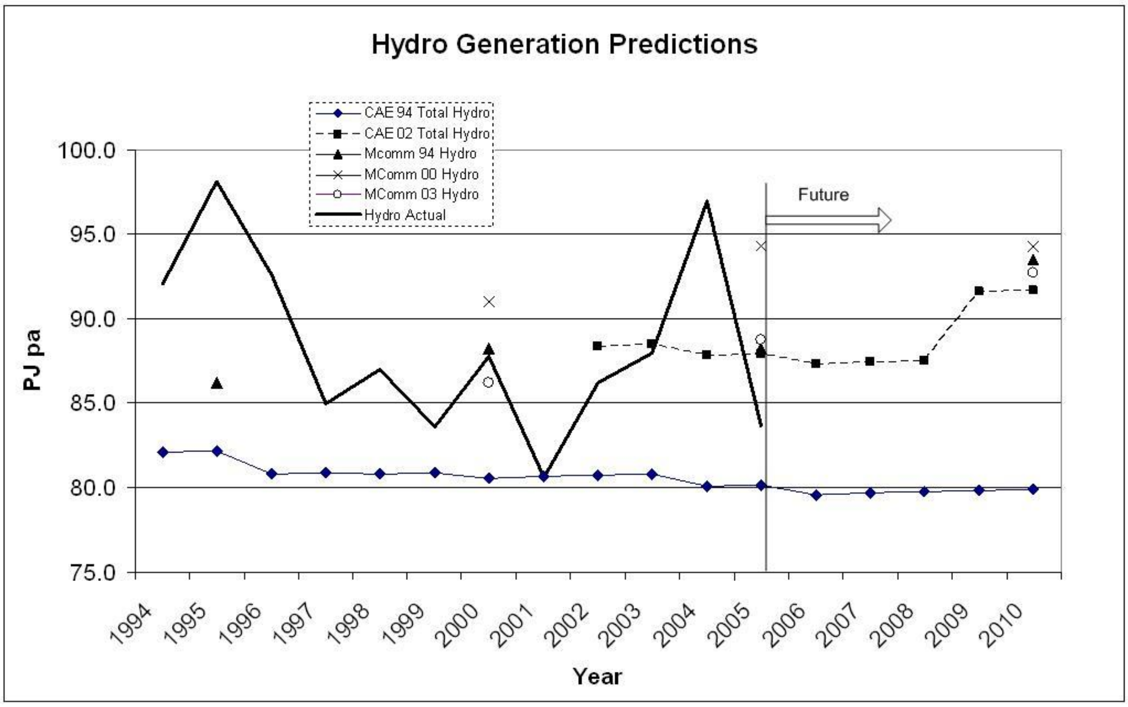


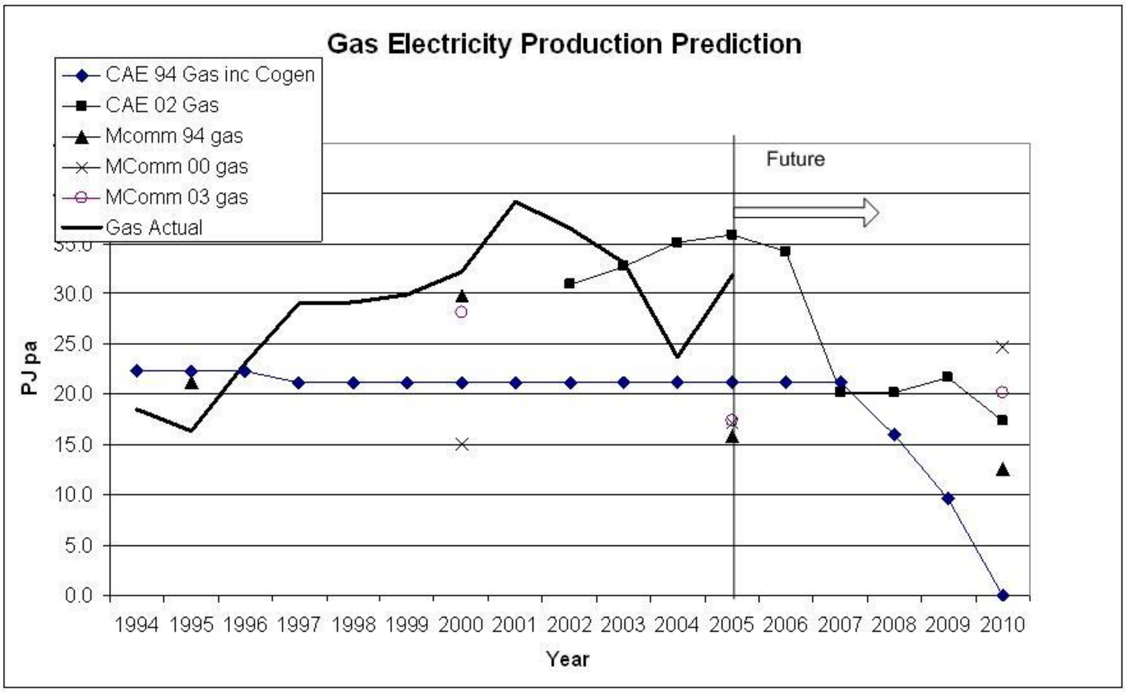
Figure 16 Total electricity use predictions compared to actual
(Craig, Gadgil, & Koomey, 2002; Leyland & Mountain, 2002; Leyland Consultants Ltd., 1994; Taylot & Eng, 2000)

In conclusion, if complex econometric or system dynamic models fail to produce reliable predictions, or those at least on a par with simple extrapolating trends, then one must question the purpose of trying to make such predictions. Similar sentiments about the inability of existing models to make accurate predictions are also expressed in Craig, Gadgil et al (2002).

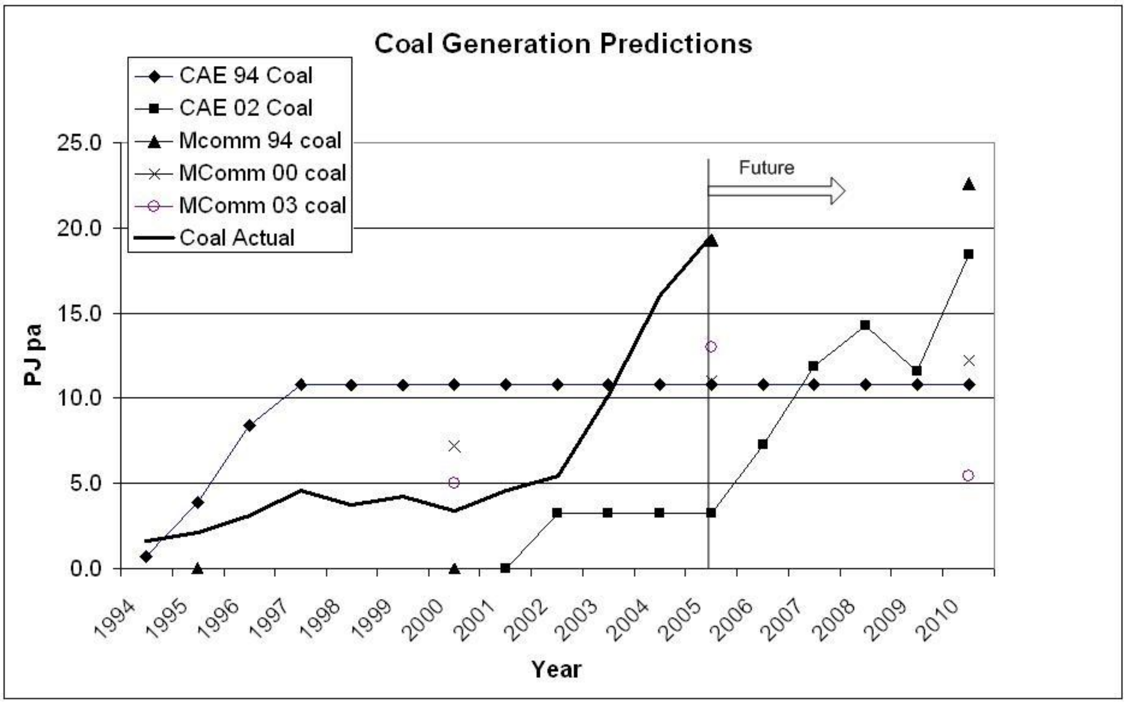
As there is unresolved controversy on the accuracy of overall electricity sector demand modeling, the focus of the research will then be changed to a smaller but essential character of the power market, the spot price, and investigate its ability to be modeled.



(a) New Zealand hydro generation in energy output per annum. Actual (solid line) and prediction from various sources. See Table 7.



(b) New Zealand gas generation in energy output per annum. Actual (solid line) and prediction from various sources. See Table 7.



c) New Zealand coal generation actual in energy output per annum. Actual (solid line) and prediction from various sources. See Table 7.

Figure 17 Model predictions for hydro 4(a), gas 4(b) and coal 4c).
(Craig, Gadgil, & Koomey, 2002; Leyland & Mountain, 2002; Leyland Consultants Ltd., 1994; Taylot & Eng, 2000)

3.5.3 Short term chaotic models

Given the deregulation of the electricity industry, ideally electricity users would like to predict the spot price and currently certain companies provide that service. The question is not whether an accurate prediction is reasonable, but if it is even theoretically possible. Cases where the prediction is likely to be unsuccessful are where the underlying time series is random or chaotic. However, chaos is an elusive concept, but it can be detected by an indicator, the dominant Lyapunov exponent, λ. For a bounded system, a positive λ implies that neighbouring trajectories exponentially diverge, leading to chaos. While it is one thing to reliably compute Lyapunov exponents for deterministic dynamic systems using numerical experiments, it is quite another to extract λ from an experimental time series, possibly corrupted with a stochastic input.

Some analysis work on the chaotic nature of energy resources are Chwee (1998), which concludes that the natural gas futures data is nonlinear but not chaotic, and Serletis and Gogas (1999) which holds a contrasting view that the natural gas liquid markets are chaotic. The problems to quantify λ are of a practical nature. To adequately estimate indicators of chaotic behaviour such as Lyapunov exponents, embedded dimensions etc., a large amount of regularly spaced time series data is needed. The freely available public data concerning electricity in New Zealand are spot price and reservoir levels in hydro dams. However, restricting ourselves only to a data-driven approach means that this must be identified from a single one-dimensional time series of data. However the embedding theorem, if applicable, means that this single time series contains all the necessary information to establish chaos, (Golovko, Savitsky et al. 2001).

One estimate of the dominant Lyapunov exponent given N values is given in equation (2).

$$\lambda = \frac{\lim}{N \to \infty} \frac{1}{N} \log \|\boldsymbol{T}_N\| \tag{2}$$

where the matrix $\boldsymbol{T_N = J_N \cdot J_{N-1} \cdots J_1}$ is built from a series of Jacobian matrices of the underlying nonlinear map. As in this case, the underlying nonlinear function is unknown, Nychka, Ellner, Gallant, & McCaffrey (1992) suggest using neural network models as they appear to be less sensitive to noise (compared to direct methods), and are well suited to capture the nonlinear behavior inherent in chaotic systems. This work uses the LENNS (Lyapunov Exponent of Noisy Nonlinear Systems) routines adapted by Nychka, Ellner, & RonaldGallant (1992), and subsequently redeveloped in Cheng and Wilson (2004).

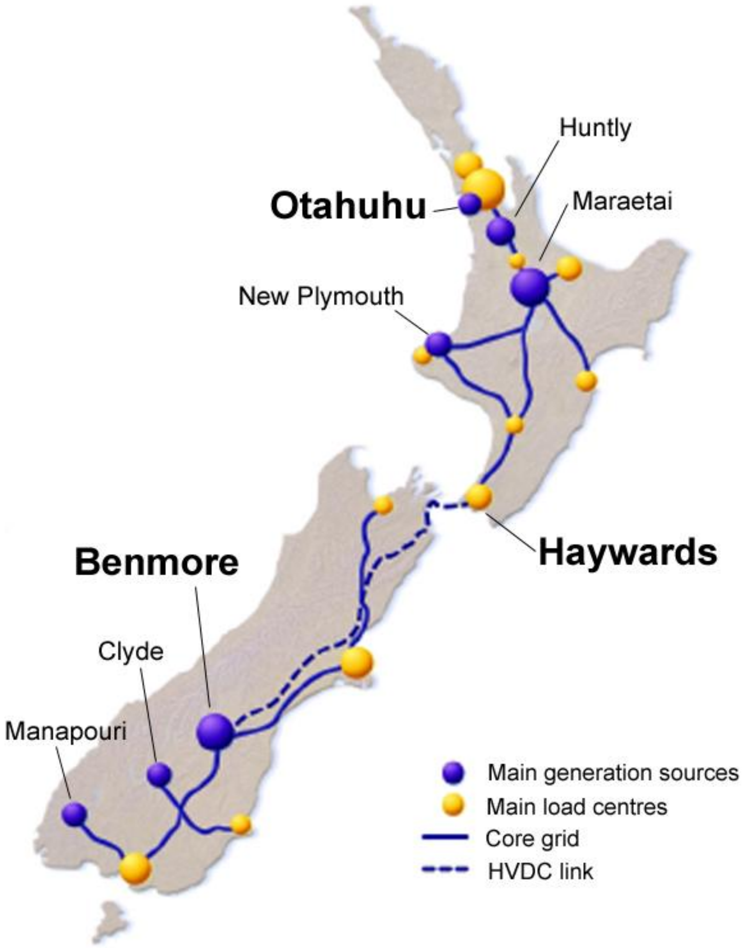


Figure 18 Location of grid termination points Benmore, Haywards and Otahuhu (Gould 2007; Transpower 2007)

Figure 19 shows the trend of the dominant Lyapunov exponent over time for the spot price at the grid exit point at Benmore. Benmore was deliberately chosen as it is closest to a significant hydro generating station, and it is less influenced by outside factors such as transmission limitations (see Figure 18). Nonetheless, at times the estimated Lyapunov exponent is positive, indicating that the time series exhibits chaos (Kang, Cheng et al. 2003). The trend to chaos is, not surprisingly, highly correlated to the periods where there was intense activity in the electricity market.

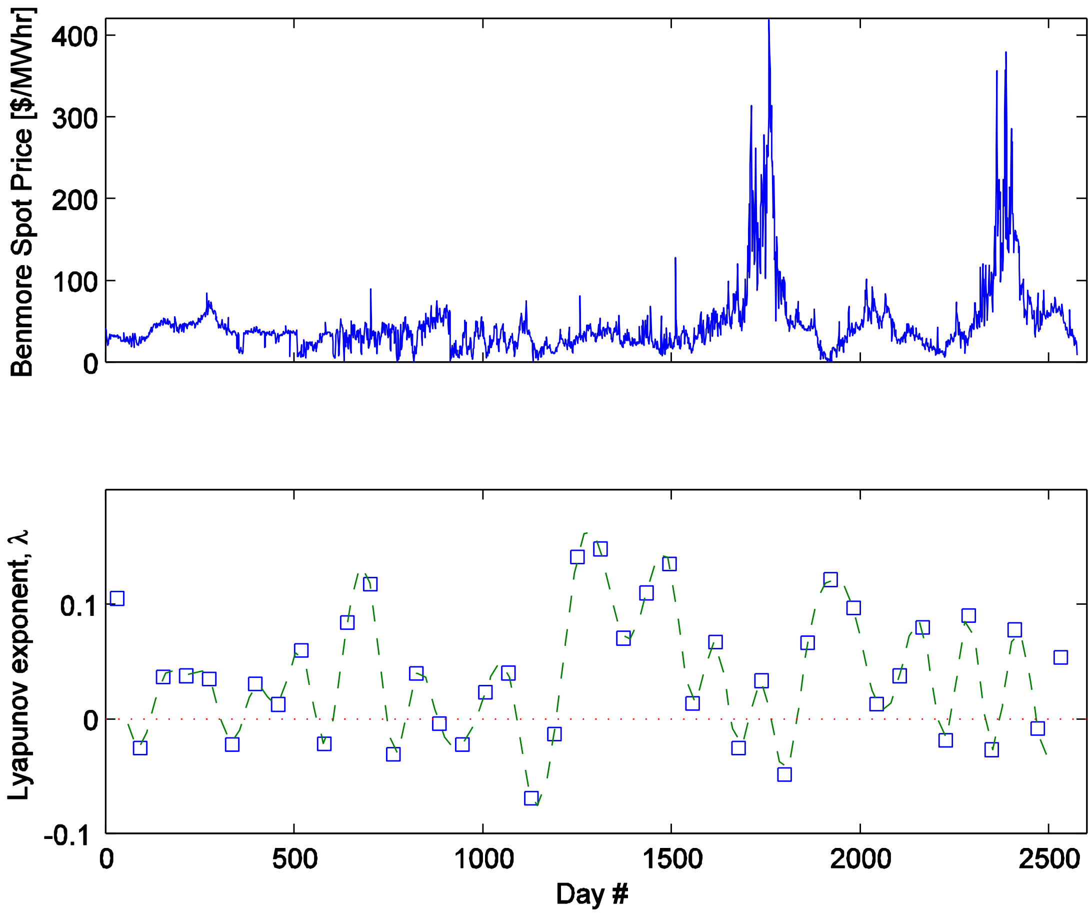


Figure 19 An estimate of the dominant Lyapunov exponent, λ, as a function of time for the Benmore spot price.

The fact that the spot price is sporadically chaotic has some significant consequences. The first is that chaotic trends are unpredictable in the medium and long terms, although some may argue that workable predictions are possible in the short term. (The magnitude of 'short' depends on λ.) The second consequence is that the chaos, which adversely affects the market, needs no significant external input – stochastic, chaotic or otherwise. It is often simply a non-trivial function of the underlying nonlinearities in the dynamics, and the current parameters. This means that future chaos in the electricity market need not be triggered by concerns in early autumn regarding lake levels, or that the triggering concern is disproportionately small. However it should noted that the computation to estimate λ is a delicate one, and one that requires considerable computing resources. λ is an estimate obtained by looping over model predictions derived using different values of embedding dimensions, delays, and different numbers of parameters in a neural network model. Furthermore, due to the nature of the computation, it is difficult to derive reliable uncertainty estimates for λ.

3.6 Conclusion

In this chapter, the characteristics of the three system types have been discussed, they are namely: deterministic, stochastic and chaotic. It also identified three levels of models for the power market and argued that the quality of predictions was modest for all the models being reviewed, thus supporting the claim that modeling alone does not provide sufficiently accurate, or feasible solutions, for improving the sustainability of the electricity sector. Secondly, the thesis tested the hypothesis that the spot electricity price in New Zealand is deterministic and found that it is not always so within the range of data tested ─ in fact it, at times, showed a chaotic tendency. Any unsustainable sub-system will render the whole system unsustainable, similarly, if a crucial element of a system is chaotic, it may render the whole system chaotic, making it impossible to make accurate predictions, especially in the medium and long term, not withstanding the fact that it may swing out of the chaotic state at a later time. The nature of chaotic systems is a delicate function of their parameters. Minor changes in model parameters or subtle changes in model structure can flip a system into, and out of, chaos. The key point is that the chaos can be triggered by disproportionately small events, either in structure such as an addition of an extra feedback loop, or in parameters, or even in operating point which can make the result unpredictable and un-modelable.

Deterministic models are attractive to policy makers because they are precise, but these cannot be expected to be the panacea for the electricity sector. Indeed when justifying the recent investment for the upgrade to the transmission line from Whakamaru to Otahuhu, Transpower used only very simple linear or near linear demand curves for the prediction of next 50 years' (or more) demand (Electricity Commission 2007). However, stochastic models are still useful for assessing risks. It may seem that a minor weather fluctuation alone, such as a dry year, can cause major changes in electricity price and may imply that the key problem to sustainability is to reduce dependency on hydro generation. While that is to some degree true, other stochastic events such as mechanical failure and line fault can have a deterministic effect on power supply shortages, but the mechanism by which the market absorbs these events, and the resulting level of spot price determined by the supply and demand level, is distinctively chaotic.

A sustainable electricity supply is a secure and affordable one where there is confidence that the spot price is constant or predictable as opposed to what has happened recently in New Zealand. Large excursions in spot price disrupt the economy, causing financial difficulties to the industry and the economy, and encourage the consuming of non-renewable resources to generate power during the crises. The generally accepted reasons for the recent periods of elevated spot prices have been attributed to the low levels in the hydro reservoirs in the early autumn of 2001 and 2003. However, now, there is in fact another interpretation based on the fact that the spot price market is chaotic.

The whole system has not been tested for chaos but this provides an element of doubt of how predictable the sustainability of an industry sector is. If a system is truly chaotic, (but not many systems are constantly chaotic) one would hesitate to apply the methodology proposed in Chapter 4 or any methodology to assess and attempt to improve the system, but as the spot price of the electricity sector of New Zealand is only sporadically chaotic, this thesis concludes that it would be more productive to focus on performing a sensitivity study by deriving a management oriented methodology as will be described in Chapter 4, instead of modeling the power market or its elements for sustainability. The proposed methodology can be used to monitor sustainability by selecting significant indicators and defining the sustainability threshold and putting indicators on a scalar so that sustainability of a sector can be represented by an index or indices, which are objectively calculated and used for the identification of areas for sustainability improvements.

Chapter 4 Methodology

4.1 Introduction

Chapter 1 and 2 has established a need to quantify sustainability and concluded that such a resource did not sufficiently exist. This chapter develops the tools required to make this quantification.

In the process of analyzing and quantifying sustainability indicators and indices, the method produced should have four key attributes, namely: transparent, scale invariant, recursive and robust. The process should be transparent so that users can understand the procedure and the assumptions made and could offer suggestions and improvements. It should be (as far as possible) scale invariant so the procedure is applicable to a wide variety of organisations varying from an industry to a nation. The procedure should also be recursive, meaning that different people can focus on different levels of sustainability by following a similar procedure and robust, meaning the results cannot be manipulated easily by biased inputs.

In this methodology, the personnel involved would include a project coordinator, and an investigation team that is carefully selected to represent, as equally as possible, the stakeholders, with a voice for the environment and the future generations. Representatives from stakeholders should then take the responsibility of making improvements within an agreed time frame.

4.2 Summary of the methodology

This approach to quantify sustainability, believed to be novel by the author, has a built-in feature to backtrack to the sources of the problems. It also includes a continuous improvement loop and is summarised in the flow chart in Figure 20.

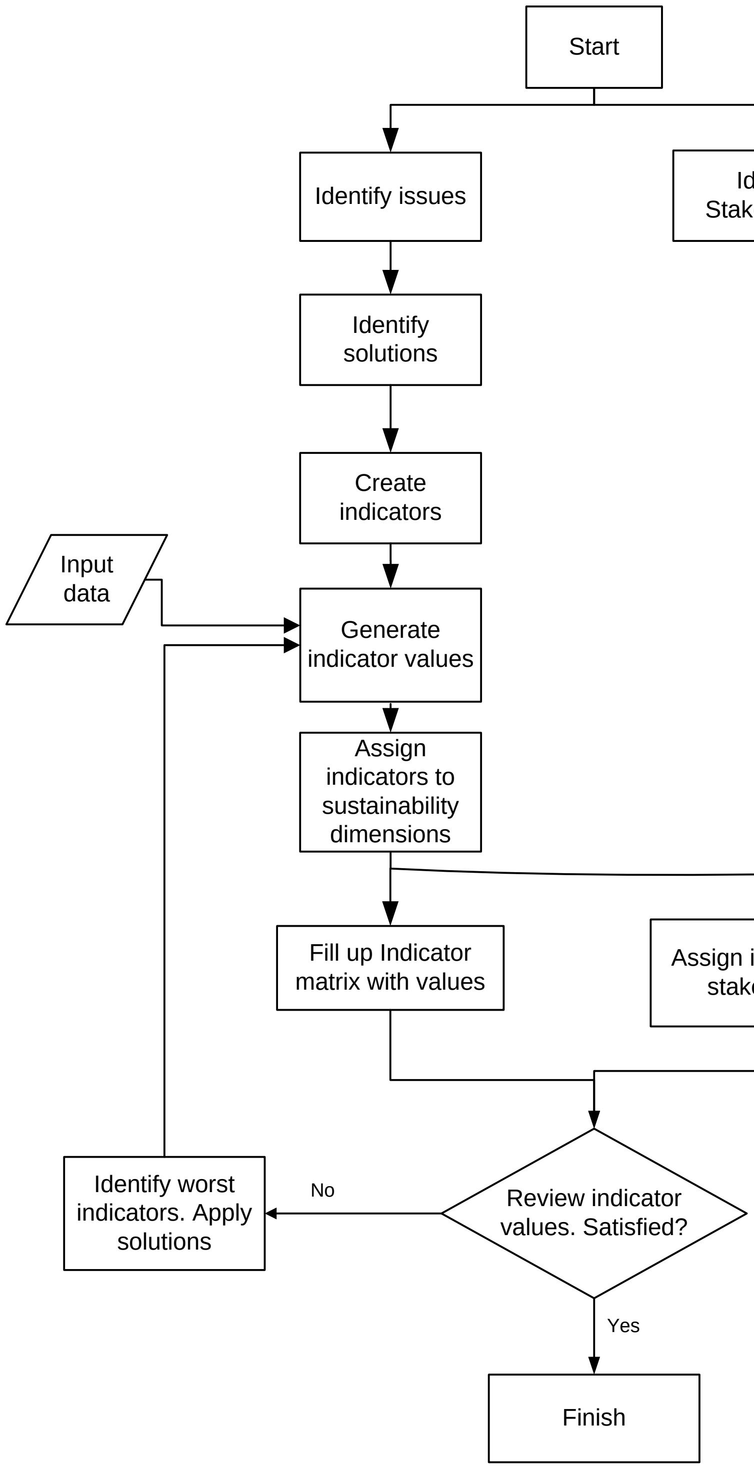


Figure 20 Flow chart outlining the methodology to generate quantitative sustainability indices in industry sectors.

In developing a quantitative measure for sustainability, the first step is to identify the areas that pose sustainability problems for the industry sector under analysis (details of the step are in section 4.5.1) and where possible, a summary of the solutions are proposed (see section 4.5.3). The next step is to identify the major players or stakeholders in the sector and their relationships (details in section 4.5.2).

Armed with this information, the attributes that best represent the sustainability problems of the industry can be chosen and the methods to measure and grade them into indicators (see section 4.5.4) can be decided. Data is then categorised according to its relevance which includes being mapped to the six dimensions of sustainability and to different stakeholders (see section 4.5.8). The data for the attributes is obtained and transformed into indicators (see section 4.5.6) and summarised in a three-level pyramid of indices, to provide different details at different levels of the index.

This proposed methodology eventuates in a number of sustainability indices. The top level, with just one index number, is for users that are concerned with the overall result where a singular scalar performance figure is sufficient. Moreover, in many cases where such an approach is overly simplistic, Level 2 indices in this methodology supplies six attributes which can be succinctly described in a spider diagram. Level 3 has the intrinsic details of each index and is only meaningful to the users who wish to look into the details of the areas that need improvement. Aspects of low sustainability are identified (described in section 4.5.10) and plans for improvements are created (details see section 4.5.12). These plans are then implemented and the results are monitored and checked for further improvement opportunities.

The proposed strategy outlined in this chapter is intended to be generic, as far as possible, for those who want to monitor and identify the sustainability issues of an industry sector. For adaptation to be used in other sectors, the same framework can be used and the only different elements are the issues for the specific sectors, the stakeholders, and the analysis that follows.

Although the case study used in this thesis is for the electricity sector, the methodology is also considered to be transportable in measuring sustainability of any industry sector involving engineering issues and societal problems. These include the energy sector, transportation sector, agriculture, fresh-water management and waste water management. On a much larger scale, this method may also be applied to a nationwide study, albeit on a large scale, it would involve bigger teams and handle more issues but the strategy as mentioned in section 4.1, is the same.

An effective methodology should be robust, meaning it should be able to handle extreme variation of input data and that the results could not be easily manipulated by persons deliberately altering the input values. In order to test the robustness of this method, input from three evaluators with different views were obtained. The standard view is from the author looking at the sector from a researcher's point while the second view comes from an environmentally biased source and the third one has his focus on commercial interests.

The combination of tools and concepts proposed in this thesis stands out from the traditional methods in that it involves the use of management tools from Total Quality Management (hereafter abbreviated to TQM), following the philosophy of "Continuous Improvement" advocated in modern management. Before describing the methodology, some of the basic concepts of TQM is first described.

4.3 Total Quality Management (TQM) management tool concept.

4.3.1 Background on TQM

Classic or traditional management styles are rarely in the preventive mode but often address issues after events have happened, working in the "fire fighting" mode (Dale and Bunney 1999). That often is the case for the electricity sector in New Zealand (Atkinson 2006; Parliamentary Commissioner for the Environment 2006), where often improvements and consultations are intensified only after serious incidences such as the power outage in June 2006 (Connell Wagner Pty Ltd. 2006), HVDC breakdown in January 2004 (Baker and Sise 2004), winter power shortage in November 2001 (Ministry of Economic Development 2001) and the Auckland power supply failure (Rennie 1998). This type of management can be argued to stifle creative solutions and lacks systematic analysis, resulting in little future planning and improvements. When problems are handled this way, their causes are often just contained and not removed (Dale and Bunney 1999), and problems may reappear in another form. That is because the poor quality is mainly caused by the process itself and any major improvements can only be achieved after a fundamental change in the process.

Ironically TQM, developed in America and proven effective in Japan, did not get recognised and accepted in the USA until the 1980's when the USA industries felt threatened by the quality of Japanese goods (Cole and Scot 2000). In order to compete, the American industry had to create a trend to improve quality by applying TQM concepts and to use a group of techniques developed under the title of TQM Management and Quality Tools (see section 4.3.3). One of the consequences was the establishment of the Malcolm Baldrige National Quality Award of USA in 1987 and the details of this award's concept can be seen in Evans (2005). There are numerous case studies indicating, with evidence, that TQM creates effective improvements in organizations (Evans 2005).

Deming (1994) stated that "a product or a service possesses quality if it helps somebody and enjoys a good and sustainable market." From this the link can be clearly seen between the quality of a service (in our case, it is the management of an industry sector), and the sustainability of it. Since TQM has proven to be an effective method to identify and solve problems, some of its concepts and tools will be adopted in a unique way to analyze, improve and solve some of the issues in the New Zealand Power industry.

4.3.2 The concepts of TQM.

TQM is the philosophy of a management approach that focuses on three main principles: "customer focus, continuous improvement, and team work", and is characterised by its principles, practices and techniques (Cole and Scot 2000). Although the framework for improving quality is based on the understanding and improvement of processes, at the core of this is "a total change in thinking and not a new collection of tools" (Evans 2005). From the criteria of the Malcolm Baldrige National Quality Award of USA, an indication of what is considered "quality" in a broader sense can be obtained which might be applicable to sustainable development works. These involve: leadership, strategic planning, customer and market focus, measurement, analysis, knowledge management, workforce focus, process management, and business results. (Evans 2005) As a contrast, traditional Sustainable Development concepts only focus on a relatively narrow scope, namely the Triple Bottom Line (TBL), which includes economic, environmental and social aspects. This thesis suggests that by integrating the concepts of these two disciplines, a powerful methodology can be developed to measure and improve sustainability in a broader and more practical sense.

In the application of TQM concepts to our methodology, TQM's emphasis on "Customer focus" is interpreted as looking into the stakeholders' interest and is addressed by the fact that sustainability is being considered from the point of view of the stakeholders in the industry. As a result, the stakeholders and the relationships between them are identified in a Systems Diagram (section 4.5.2), indicators are selected to describe the sustainability situation of each stakeholder (section 4.5.4) and a set of sustainability indices is calculated for each of them.

Secondly, the concept of "Continuous Improvement" is applied at the end of this solution-finding methodology. Improvement results will be reviewed and further improvements will be identified in the next cycle of the exercise.

"Team work" is organised at different stages: the investigation team will identify the major issues in the industry, decide on how to allocate the indicators to different stakeholders and to set the rating methods for the indicators and a team of managers from the stakeholders is needed to make commitments to carrying out the corrective actions according to the agreed time frame.

Having discussed the concepts of TQM, the next section will point out the TQM Tools adopted in this thesis and will investigate how they may be applied to our methodology.

4.3.3 The Seven Management Tools and Seven Quality Tools

A selection of the Seven Management Tools are adopted in this thesis to clarify, group and analyze ideas, they are: Affinity Diagram, Systems Diagram, Tree Diagram, Matrix Diagram and Matrix Data Analysis. One of the Seven Quality Tools that are used to analyze data in this thesis is the Flow Chart, but other Quality Tools, such as Check Chart, Histogram, Pareto Diagram, Cause and Effect Diagram, Control Chart and Scatter Diagram, may be used at a later stage for analyzing and grading indicators but they will not be covered here. A brief overview of the tools used is described below, and further details on the application of these management tools are evident later in section 4.5.

4.3.3.1 Management tools:

Affinity Diagram

An Affinity Diagram is used to organise a large number of ideas logically into smaller numbers of categories for easy understanding. The ideas are first generated in a brain storming session, they are then rearranged and grouped with those belonging to a similar idea (or with "affinity" to each other) and put under a main topic, thus called an Affinity Diagram (see section 4.5.1 for more details). Often this is carried out with a cross-discipline team in order to get ideas from a wide perspective and obtain a well represented range of ideas. In this study it is used in identifying issues threatening sustainability of the New Zealand's electricity sector (section 5.2) and in sorting out and categorizing the sustainability indicators (section 5.5).

Systems Diagram

This is a way to layout the elements in a system (stakeholders and the environment in our case study) and to identify their relationships. Any material flow, information or service flows between them are marked on lines that are drawn between the parties to represent the relationship (see section 4.5.2 for more details). Although Systems Diagrams of great detail can be drawn, initially a brief one will be prepared and further details can be added on when needed.

Tree Diagram

The Tree Diagram's function is to break down a concept into its logical components. It starts off at the top or the basic level and becomes more specific at each level as it branches off (see section 4.5.7 for more details). It facilitates the analysis of the dimensions of sustainability and breaks them down into their components.

Matrix Diagram and Matrix Data Analysis

The function of matrix diagram is to show how two or more attributes relate to each other, irrespective of whether they have a Boolean relationship or one that is numeric (see section 4.5.3 for more details). Matrices are used in multiple instances: representing relationships between Issues and Solutions in section 4.5.3, Stakeholder and Dimension in section 4.5.8, and Stakeholder, Dimension and Indicator in section 4.5.9

4.3.3.2 Quality Tool used in methodology:

Flow Chart

It is a map showing the sequences of the process steps under study and gives a better understanding of complex procedures. An example is Figure 20 under section 4.2.

Having reviewed the concepts of TQM tools, the thesis will then proceed to discuss the framework of sustainability used in this paper.

4.4 Framework of the methodology

A number of basic sustainability concepts are proposed and assumptions made in this thesis, and they are reviewed below. They are the dimensions of sustainability, systems approach, the focus on significant issues, the scaling of indicators, index aggregation and the stakeholders' interests.

4.4.1 Concept of dimensions of sustainability

The society considers many attributes as important for sustainable development. In order to organise them logically, they are grouped and categorised into what are called the "dimensions of sustainability". These are very high level concepts, usually numbering three to six. Traditionally the concerns are the Triple Bottom Line (TBL) involving social, environmental and economic aspects, but our methodology needs a more finely defined list of aspects/factors that affect the sustainability of the sector under study. Besides the three dimensions mentioned above, three more have been added in this thesis, namely technological, ethical and institutional.

In industry sectors, technology plays an important role in improving sustainability thus there is the need for a separate dimension. For example, new technologies can improve efficiency of energy use, or reduce pollution.

Having said that, the sustainability of an industry sector is also an economic/ ethical issue. An individual company considers its own sustainability as a commercial issue because if it is not viable economically, the company will close down, but for a sector, especially a commodity as fundamental to our modern way of life as electricity, it is in the society's interest, ethically, to ensure the sector is sustainable, to avoid the dire consequences of social and commercial chaos, as seen in the various cases of medium-duration supply interruptions in different countries. Thus an Ethical dimension is included.

It is worth noting that ethical issues, when taken to an excessive level in some cases, can in turn threaten the sustainability of an industry sector and this phenomenon can be called the Paradox of Sustainability. For example, excessive environmental rules and regulations aimed at increasing sustainability of the environment, extremist public opinion, complex appeal procedure, and inconsistent rulings in challenging a project's effect on the environment can instead slow down the development of an industry. These cost time and money and stakeholders will be deterred from making investment and may re-direct their funds into other types of investment with less risk and better return. Under such circumstances, the sector will decline and become more economically unsustainable, defying the objective of the environmental rules which is make the sector more sustainable (in an environmental sense). As a result, ethical issues need to gain a fine balance to maintain the sector's sustainability.

The Institution dimension also plays a crucial role in maintaining the sustainability of a sector. Government policy changes the directions in which society and investors puts their funds and attention, and regulations have direct effect on the operation and environment of specific industries. For example, many once-state-owned industries are now de-regulated and their operation and policies are still being fine-tuned to ensure the free market's operation is sustainable.

For the rigorous analysis used in this paper, there is the need to break each dimension down into its own list of sub-dimensions. The method to do so is described in section 4.5.7 and in Figure 30 to Figure 32 in this chapter.

4.4.2 Analysis using the Systems Approach

Wherever there is a group of stakeholder interacting with each other in a business system, complicated relationships are formed among themselves and the elements outside the system, such as the environment, and the most effective method to understand those relationships is through systems analysis. A single action in such a system often leads to a chain of reactions, ricocheting from one stakeholder to another and interacting with other elements such as the environment and sometimes resulting in unexpected consequences. It is through systems analysis that the stakeholders are listed out and the interactions flow among them and the environment identified, e.g. flows of material, information and service, identified as in section 4.5.2. Detailed systems analysis is often time consuming and can involve elaborate consultation with the stakeholders which in turn can be a major project in itself, but in the methodology proposed in this thesis, only a brief outline of the system is described which is fit for the purpose of this work.

4.4.3 Stakeholders

Different stakeholders in a sector have different concerns, therefore, one all-encompassing Sustainability Index, while providing an overall picture, does not relate the intricate details to each stakeholder. This is addressed by analyzing which indicators are relevant to each stakeholder and forming a group of sustainability indices for each of the stakeholders.

4.4.4 Focusing on issues causing problems in sustainability

A large number of attributes can be monitored in the study of sustainable development but to do so runs the risk of over-information – the investigation team may miss the few significant issues that are the crucial points causing un-sustainability but are hidden among the mountain of data. Here a framework is adopted to take on the view that in order for a system to be sustainable, it needs to eradicate un-sustainability issues, thus there is the need to identify these first. The process is described in section 4.5.1.

4.4.5 The use of indicators and their scaling

Having identified which sustainability issues to look into, such as those in section 4.5.1, the next step is to decide on how best to design the indicators. A dimensionless scale has been chosen from negative two to positive two to quantify an index.

While an indicator is often expressed in absolute terms such as units per annum or parts per million, that does not address the fact that sustainability has a yes/no nature and can best be expressed in relative terms. It needs to be converted into a scalar for comparison: zero being just sustainable, negative two being the minimum value of the range indicating it is the most unsustainable, and a positive two is the maximum value on the range meaning most sustainable – this idea is further demonstrated in section 4.5.5. The way to convert data into indicators by a data-indicator conversion function will be recorded in detail so that this scaling procedure is repeatable and is as objective as possible, although it is expected to cause vigorous debates among the various stakeholders. In fact just the debating exercise, even if it does not result in establishing a uniformly agreed recipe to establish the index measured, would still be a very valuable exercise.

4.4.6 The creation of indices.

Due to the complexity of the sustainability of an industry sector, a large number of indicators may be needed to give a comprehensive representation of its main sustainability issues. In order to get an overview of the situation, these indicators need to be summarised or aggregated into indices on different levels for different users. A choice of three normalizing methods are available, they are: the median, the minimum and the average and this thesis concluded that the median is the most appropriate method because it is less likely to be distorted by extreme input values (see Section 4.5.10). It can be argued that taking the minimum is more aligned with the sustainability concept since any unsustainable part of a system will render the whole system so, but to do so will erase too much detail in the normalization process that needs to be recovered at a later stage, for example, for use in the steps to trace back to the main causes of un-sustainability and for prioritizing corrective actions.

Any data compaction strategy such as taking the median does, as a natural consequence, suppress the outliers. This is the approach taken in this thesis, but if outliers are deemed important, for whatever reason, then since the raw data is always available, one could plot a spider diagram with uncertainty bands thereby indicating the extent of the outliers.

Having reviewed the sustainability concepts, the next section will be a description of our proposed methodology.

4.5 Steps in generating sustainability indices

4.5.1 Identification and categorizing of issues – Affinity Diagram

The first step in analyzing an industry's sustainability is to identify the major issues that are affecting its sustainability. The Affinity Diagram collects all these detailed issues, d, into logical groups, known as issue headings, s, as shown in Figure 21.

In order to get a comprehensive view of the issues, a wide range of stakeholders in the sector are invited to join the investigation team, aiming to give fair representation, in giving a list of the Detailed Issues, *d*, that affect the sector's sustainability. A large number of issues might be identified (say perhaps 100); in order to avoid duplication, issues of very similar nature are combined and Detailed Issues *d* of similar nature are grouped together and categorised into Issue Headings, *s*. If too many similar issues *d* come under one practical Issue Heading *s*, (say more than ten), the Detailed Issues *d* need to be further divided into two separate Issue Headings *s*. From this step, a list of sustainability Issues Headings *s*, are identified, such as those 12 in section 5.3, namely generation, fuel related problems, transmission, acts of God, environment, ethical, social reasons, technological, lack of in vestment, power market, industry structure and economics, each of which covering a list of sustainability Detailed Issues *d* (see Figure 22 and Figure 23).

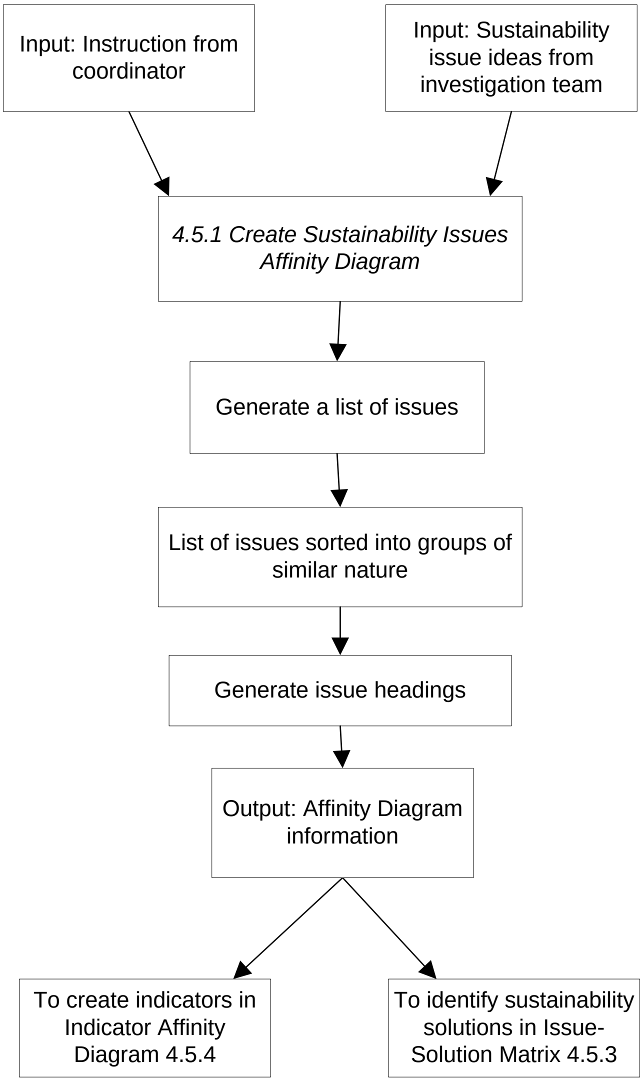


Figure 21 Flow chart for the Sustainability Issues Affinity Diagram.

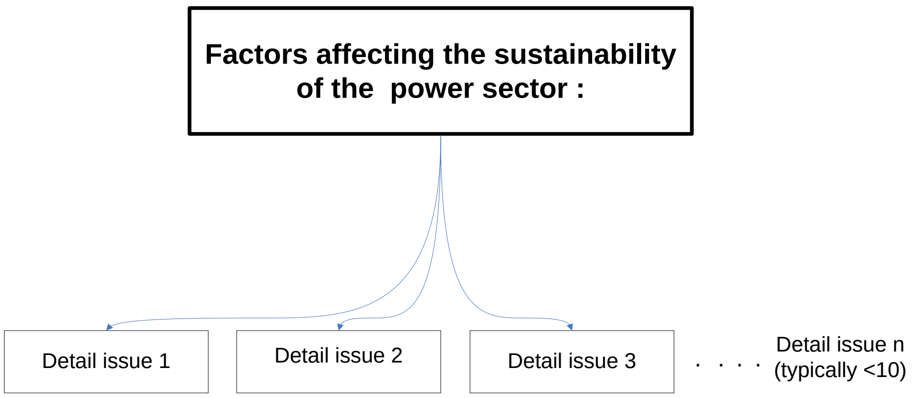


Figure 22 Step 1 of 2 in making an Affinity Diagram – showing ungrouped ideas

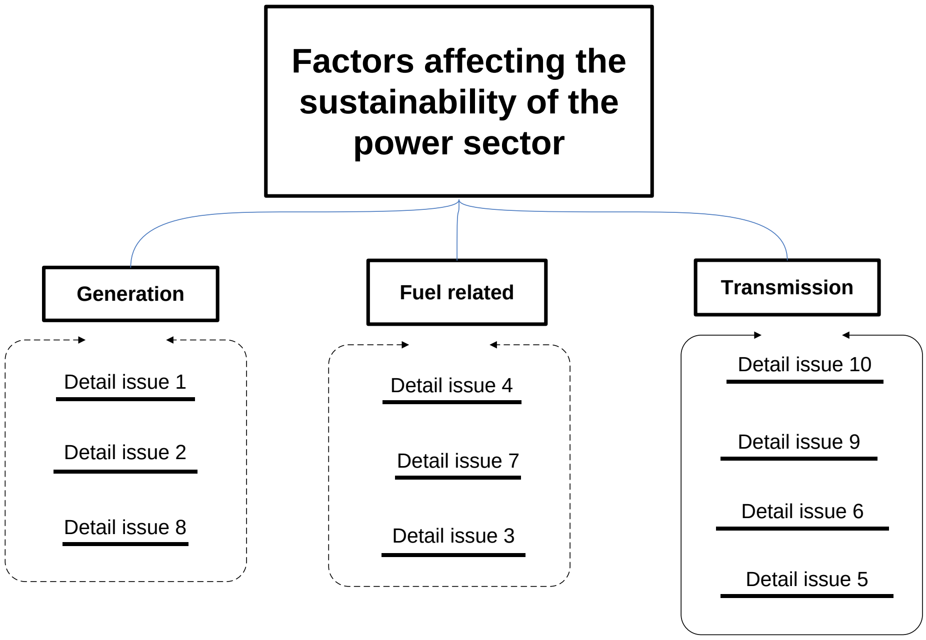


Figure 23 Step 2 of 2 in making an Affinity Diagram, example of grouping similar items under common headings.

4.5.2 Identification of Stakeholders and their relationships – Systems Diagram.

The second step is to get a comprehensive view of the sector by setting up a Systems Diagram as shown in Figure 24.

This is set up by the investigation team where the stakeholders, *t* are identified and the inter-relationship, material and service flow between them and the environment are listed out diagrammatically (example in Figure 25). The purpose of this is to gain a better understanding of how the system functions in order to facilitate the identification of solutions in section 4.5.3 and indicators in section 4.5.4.

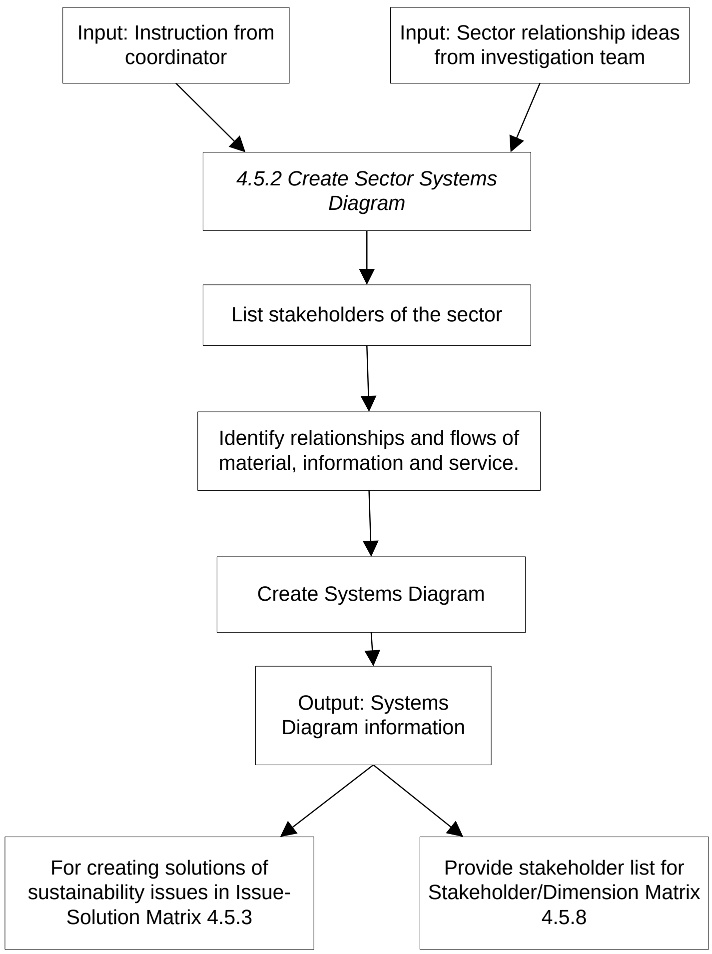


Figure 24 Flow chart for creating the sector systems diagram.

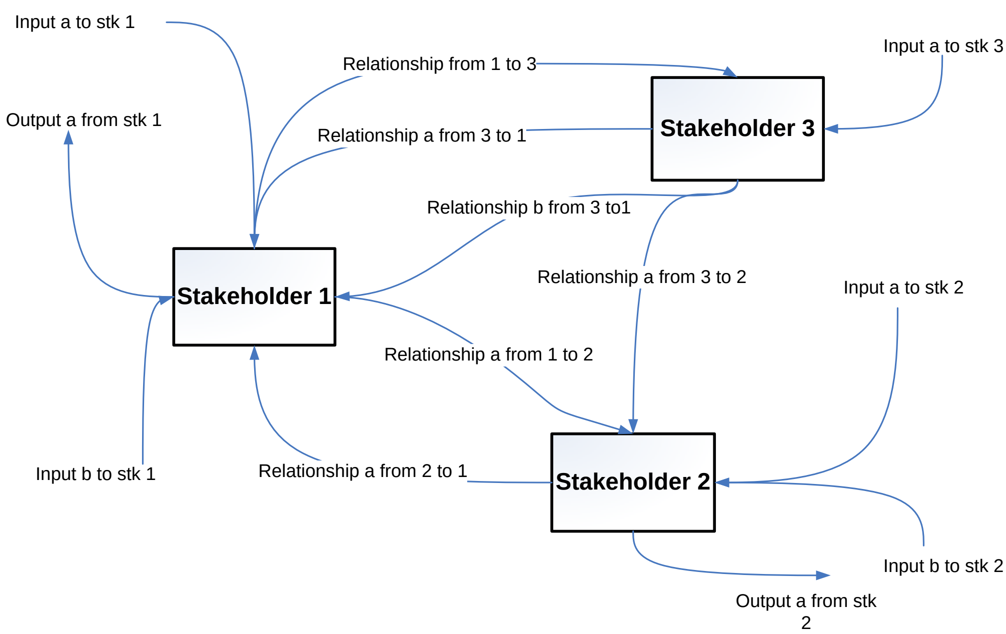


Figure 25 Systems Diagram with stakeholders, inputs, outputs and relationships.

4.5.3 Suggestion of possible solutions - Issue Solution Matrix

Solutions are suggested and matched to issues to assist the making of indicators (see Figure 26).

By referring to the sustainability issues identified in the Systems Diagram in section 4.5.1 and the systems relationships in 4.5.2, possible Solutions, *l,* are suggested for the Detailed Issues, *d*. These are represented in an Issue/Solution Matrix (see Figure 27) as one solution may address multiple issues. These solutions, combined with the issue details, form the basis for creating indicators in 4.5.4.

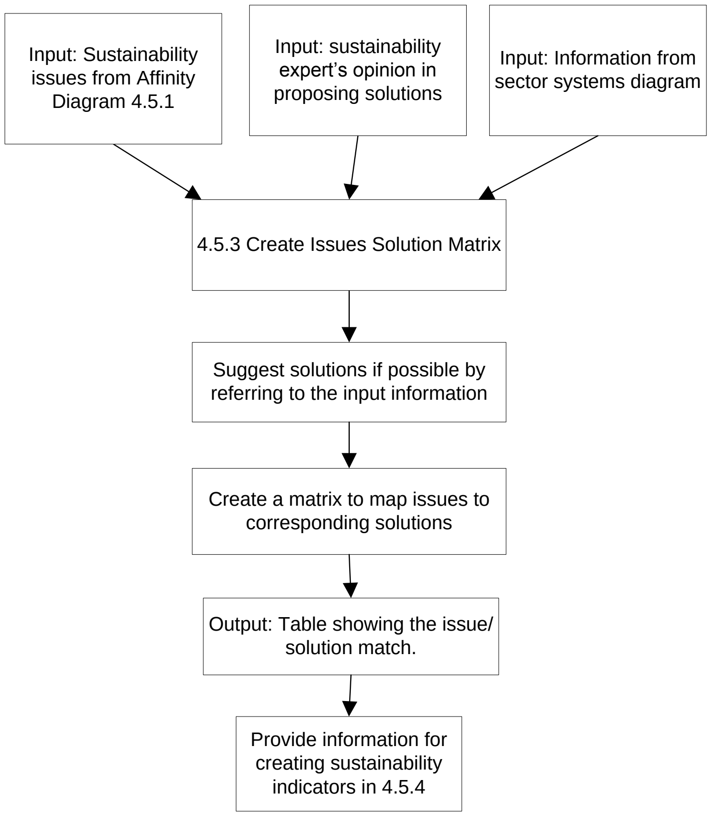


Figure 26 Flow chart for creating the Issue-Solution matrix.

Solution	A	B	C
Issue 1	■		■
2		■	
3		■	
4			■

■ = combination where an issue has a solution, blank = irrelevant

Figure 27 An example of an Issue-Solution matrix.

4.5.4 Creation of indicators & categorizing them ─ Affinity Diagram.

Indicators are created and grouped under consistent headings (see Figure 28).

With the recommendations from section 4.5.2, in the next brainstorming session, Ideas *e* on what areas to create indicators for are generated. That is facilitated by referring to the list of Detailed Issues *d* from section 4.5.1 and the Proposed Solution *l* in section 4.5.3.

These Ideas *e* are analyzed and combined to minimise duplication and then grouped together within an Affinity Diagram to form different levels of indicators: the newly created level 1 Indicator Main Headings *s*, level 2, Indicator Sub-Headings *r*, and level 3, the final set of Sustainability Indicators, *i*. The level 3 indicators are assigned according to stakeholders in the Stakeholder/Dimension matrix in section 4.5.9.

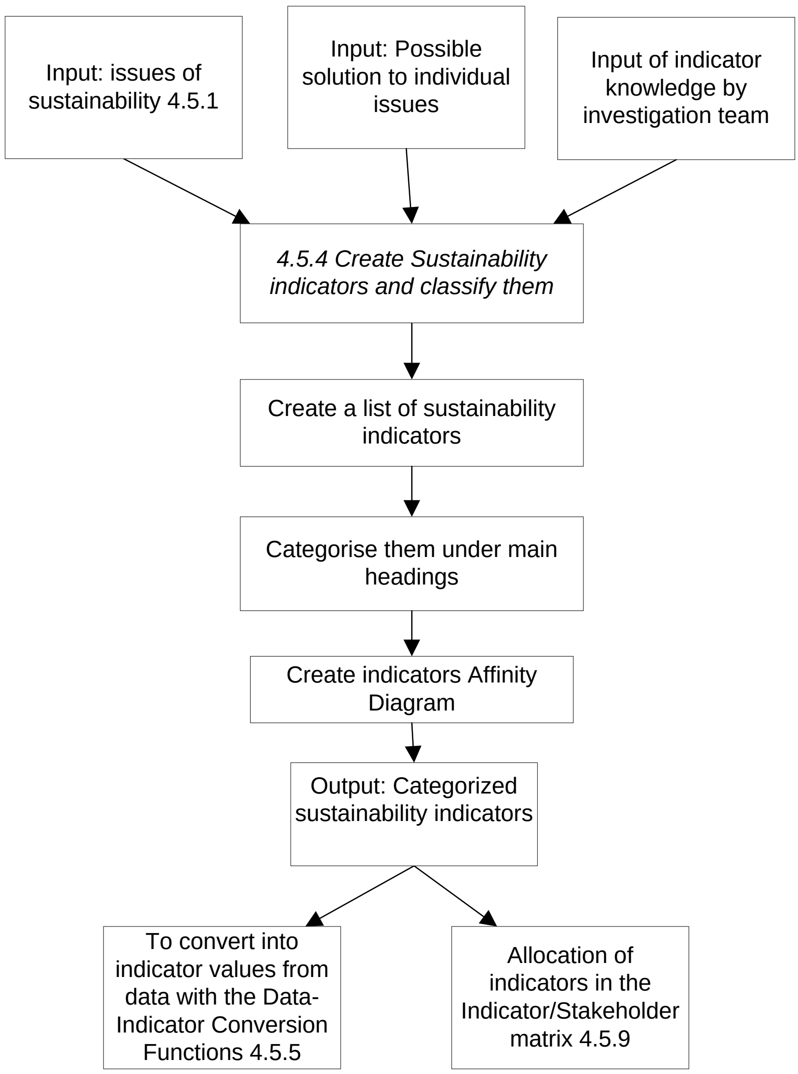


Figure 28 Flow chart for creating indicators and their Affinity Diagram

4.5.5 Defining the indicators – the quantitative Data-indicator conversion functions (DICF).

Arriving at a quantifiable index means that raw data must be changed from a plethora of interpretation possibilities to a scaled weight and that is done using a Data-indicator conversion function or DICF (see Figure 29).

The next step involves setting a Data-indicator conversion function (DICF) for each Indicator *i* to convert the raw data into an indicator metric. To perform this step well, the investigation team is required to provide a clear understanding of the particular sustainability issues and their related attributes, and to design a scaling method for each attribute.

This is probably the most crucial and delicate part of the entire procedure, as the DICFs are industry specific, need updating from time to time, and are debatable. The question is then "How to keep this exercise unbiased and reasonable?" While unavoidably subjective, the best the methodology can do is to keep a clear record of the details and make it transparent and open to conversation with the stakeholders.

Our proposal is to consider that each indicator metric has an integer value between −2 and 2 where −2 is the most unsustainable and zero and any positive values are sustainable. Clearly the investigation team must agree to what amounts to a large variety of conversion and weights here for this method to be feasible and a large amount of consultation is expected in this step. Once the rating methods of the indicators are defined and the evaluation of indicators are carried out according to these metrics on a regular basis, it then can be considered as objective since it can be repeated according to a set of criteria.

In this thesis, different rating inputs from three evaluators will be considered; one of which is from the author and may have a more academic view, one is with an environmental biased view and the last one is with a commercial focused view. The main difference among the three evaluators' input is in the scaling functions that convert data into indicators. For example a certain level of pollution may be considered acceptable by the commercial focused view and is rated 1 out of a scale of -2 to 2, but in the environmental biased view, that may be considered as a rather serious problem and may be rated -1 as unsustainable. The results from the three evaluators with different views were analysed to explore how robust the model is in handling views from different perspectives.

An important practical use of this methodology is sensitivity testing, meaning policy makers can test the effects of certain proposed changes and find out their overall impact on sustainability.

4.5.6 Obtaining data for the indicators

Attributes should be chosen so that the data can be accurate, assessable, up-to-date and can be verified and the data's source and limitations should be noted. It is worth noting that in practical cases, some needed data may be commercially sensitive and not readily available or may be obtained under special agreements or conditions. Some information may also be out-of-date and there may be data gaps. These need to be filled in using standard statistical methods such as interpolation or smoothing. If so, these conditions need to be recorded so that when the information is available in the future, it can be updated.

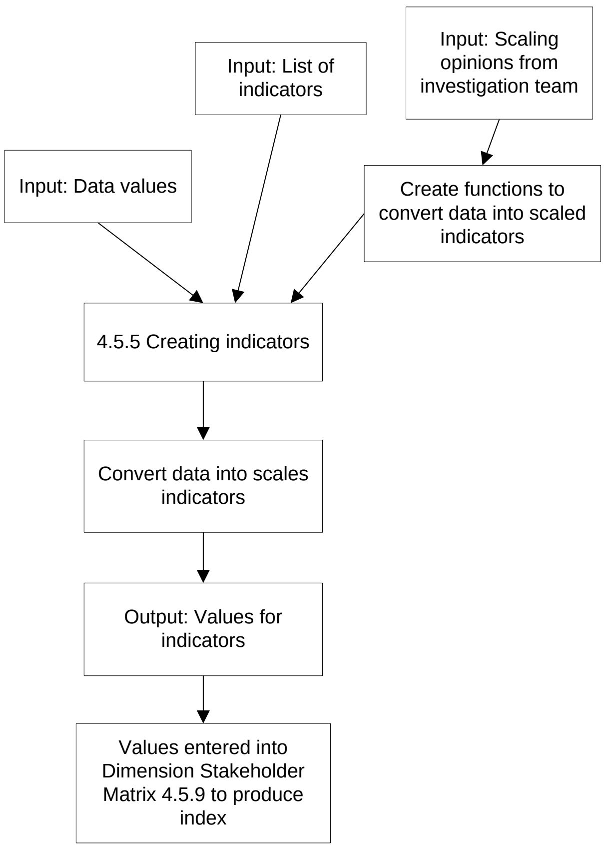


Figure 29 Flow chart for creating indices

4.5.7 Identification of Dimensions and sub-dimensions of sustainability development – Tree Diagram

The process of creating sustainability dimensions can be seen in Figure 30.

Policy makers and stakeholders are faced with a potentially large number of indicators (over 100 in our New Zealand case study given in section 5.4). For ease of understanding and interpretation of this volume of data they are best grouped under different aspects of sustainability called "dimensions of sustainability". On top of the Triple Bottom Line (TBL) that includes social, environmental and economic aspects, three more are added, they are: technological, ethical and institutional (also see section 4.3.1).

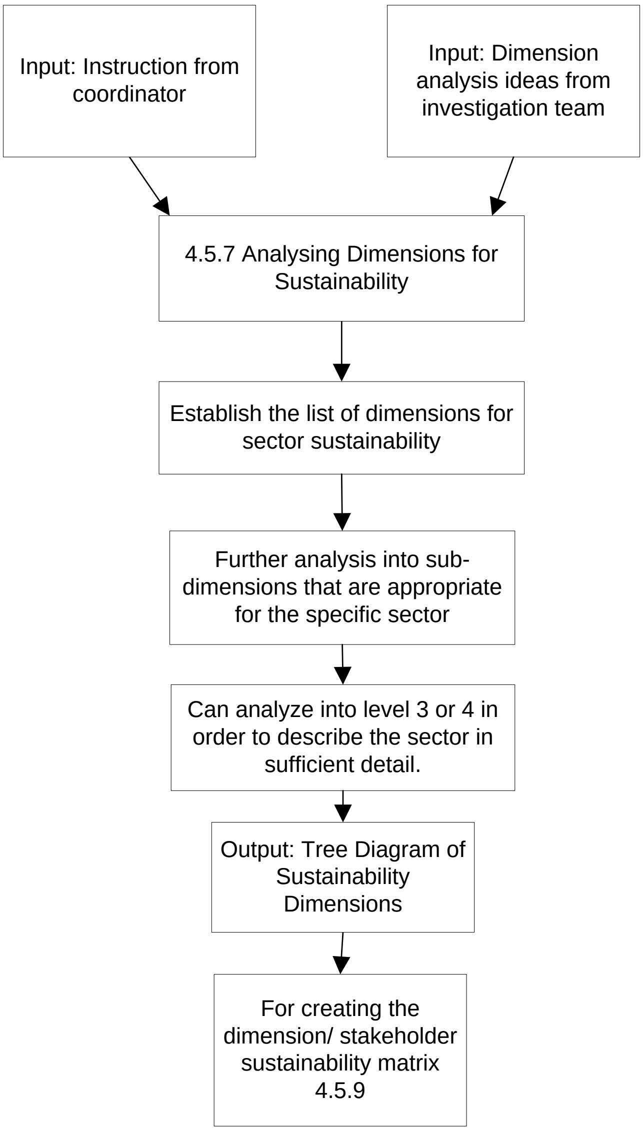


Figure 30 Flow chart for generating the Sustainability Dimension Tree

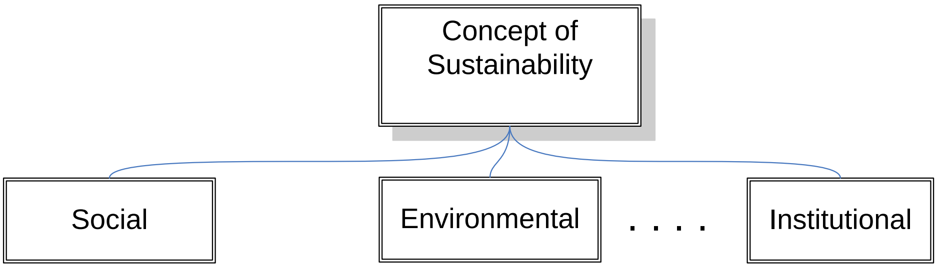


Figure 31 Tree Diagram starts off with examples of ideas or dimensions.

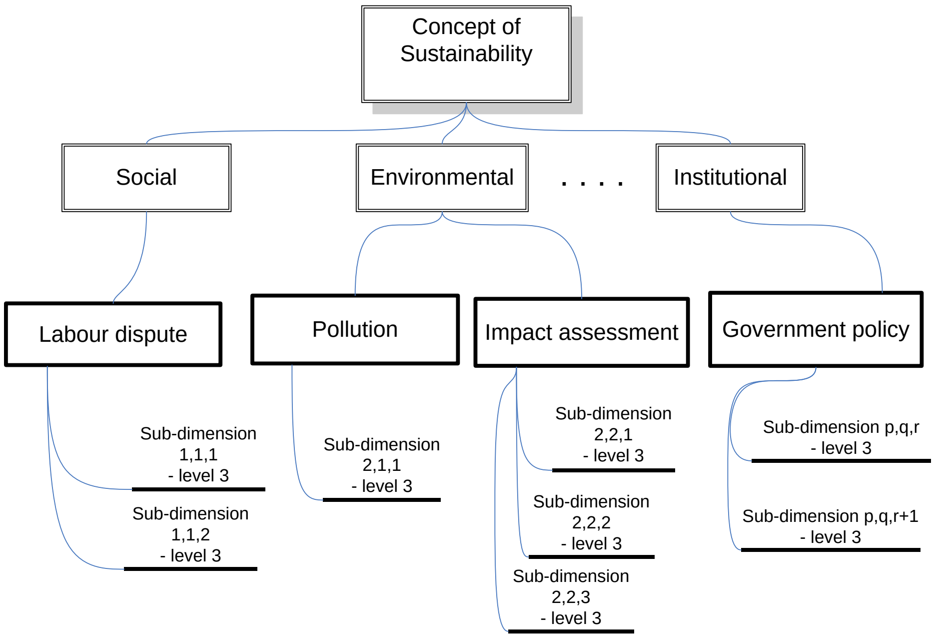


Figure 32 Tree Diagram showing examples of developing ideas into different dimension levels.

The method used in this thesis is to employ the Tree Diagram to analyze and breakdown the elements of the six “level 1” dimensions, p, to obtain “level 2” sub-dimensions, q, and “level 3” sub-dimensions, r, that describe the sustainability elements in more detail with regard to the industry being studied (see Figure 31 and Figure 32).

4.5.8 Setting up the Stakeholder/Dimension Matrix template.

This step creates a matrix where the stakeholders get a match for the dimensions and sub-dimensions of sustainability that affect them.

A two-dimensional Stakeholder/Dimension Sustainability matrix is set up to prepare for the allocation of indicators as described in section 4.5.9 (see steps in Figure 33).

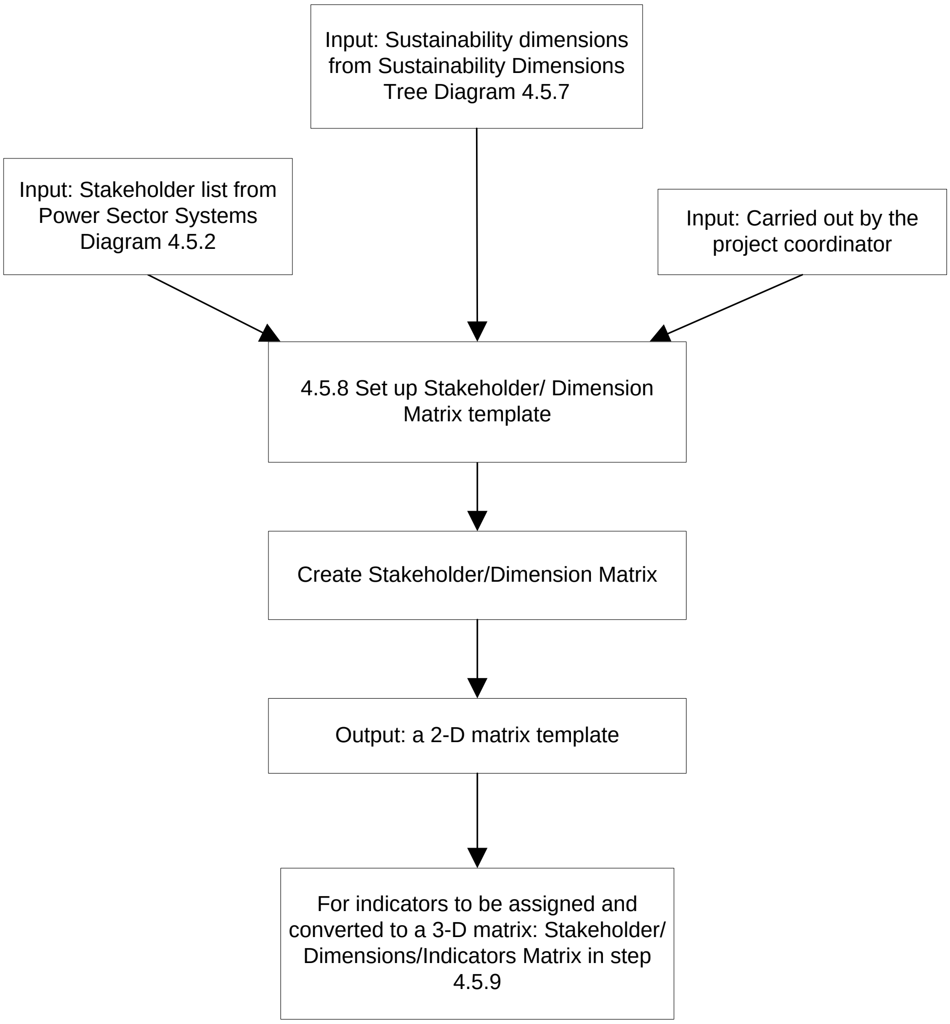


Figure 33 Creation of Stakeholder/Dimension matrix template

4.5.9 Setting up of the Stakeholder/Dimension/Indicator matrix and entering indicators into it.

This step completes the setting up of the sustainability matrix and data is entered to obtain indicator vales (see Figure 34).

In this process, indicators are allocated to measure each Stakeholder/Dimension combination. It has a three-dimension matrix and is best visualised as having Stakeholders t on the x-axis, Sustainability Sub-dimensions Level 3 r along the y-axis, and Sustainability Indicators *i* on the z-axis. Indicators *i*, where *i*=1 to n, where n is the total number of suitable indicators, are allocated to Stakeholders *t* in Sustainability Dimensions Level 3 *r*.

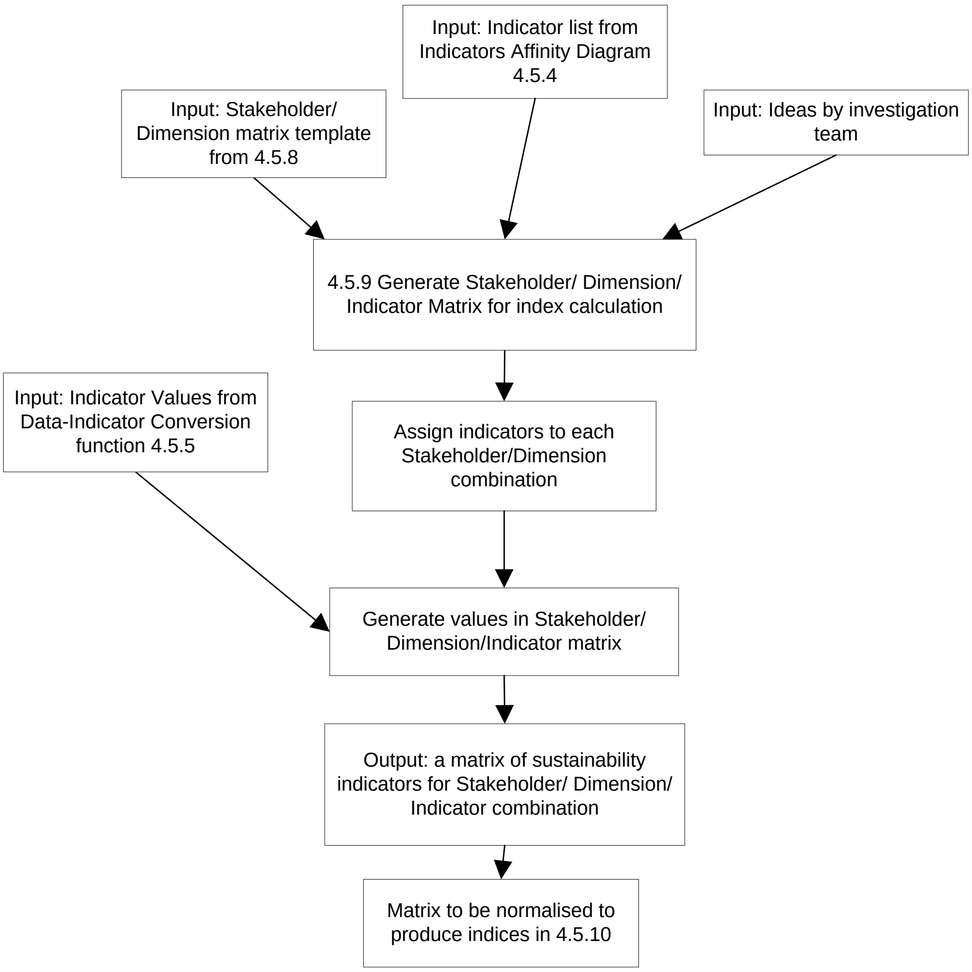


Figure 34 Setting up the Stakeholder/Dimension/Indicator matrix

With the values of the indicators obtained from the Data-Indicator conversion process in section 4.5.5, a multi-dimensional matrix of sustainability indicators is produced that represent the sustainability of the sector. The large number of indicators will be normalised with steps as described in section 4.5.10 to form indices.

4.5.10 Summarizing the index at different levels.

Normalizing the indicators to form indices at different levels (see Figure 35).

Numerous indicators may all represent the sustainability of a stakeholder under each sub-sector. To present it in an easily understood manner, the indicators are normalised to three levels of details (see Figure 35).

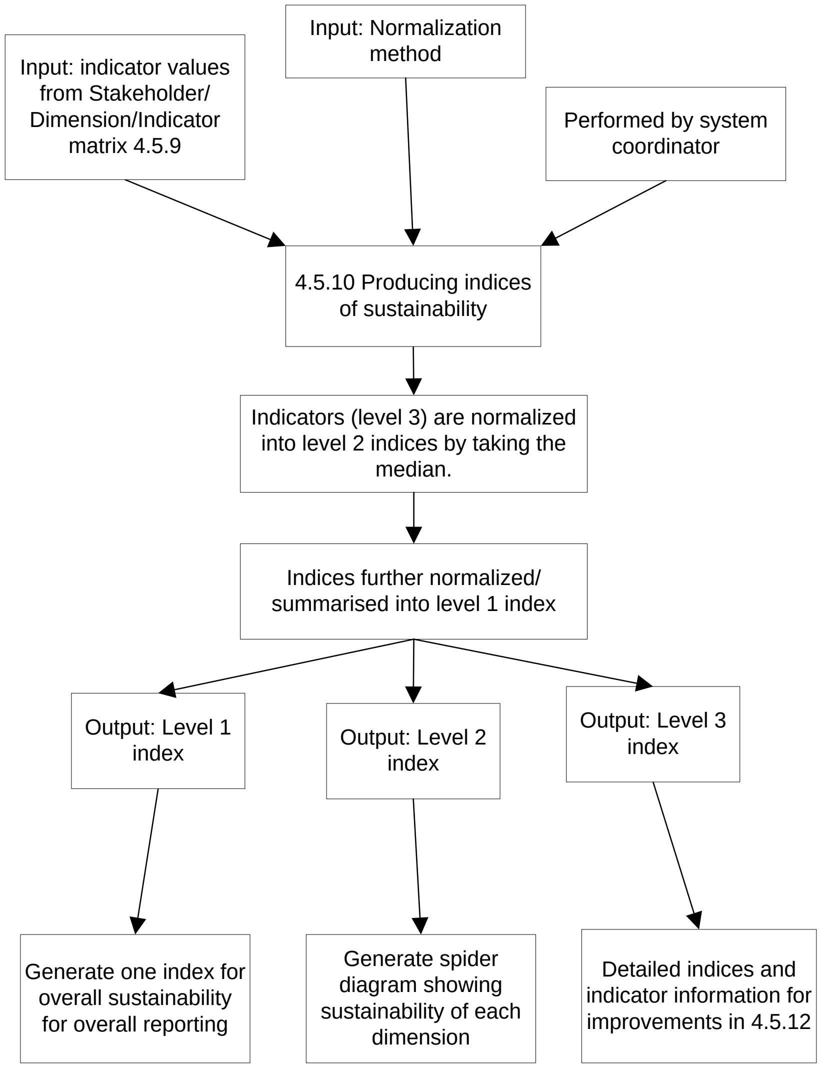


Figure 35 Normalizing the indices into different levels of complexity.

The Index *t,r* is normalised by taking the median value of the indicators *i*, where $i = 1$ to n, to obtain a single Index for *t,r*, where we have stakeholder *t* and sustainability dimensions Level 3 *r*. These are then further normalised, by taking the median, to obtain the Level 2 sustainability indices for each dimension by stakeholder. Furthermore, each dimension's overall sustainability index is the median of all the stakeholders' indices for it. The final Level 1 sustainability index is the median of the Level 2 overall sustainability indices for the different dimensions.

4.5.11 Presentation of sustainability indices on a spider diagram.

Presenting indices visually on a chart (see Figure 36).

The overall Level 2 sustainability indices, and the indices by stakeholders, are mapped onto a spider diagram with dimensions on the axis, placing sustainability dimensions of contrasting natures opposite each other and ones of similar natures next to each other. As shown in section 5.13.2, Ethical is placed opposite Technological, Social next to Ethical but opposite Institutional, and Environmental next to Ethical but opposite Economic. The dimensions that are based more on hard data are grouped and termed "hard dimensions" and they are located at the lower half of the spider diagram, they are namely: the Economic, Technological and Institutional dimensions. The top three, Ethical, Social and Environmental, are described as the "soft dimensions". Their scale is -2 to 2 with -2 forming the centre point of the diagram.

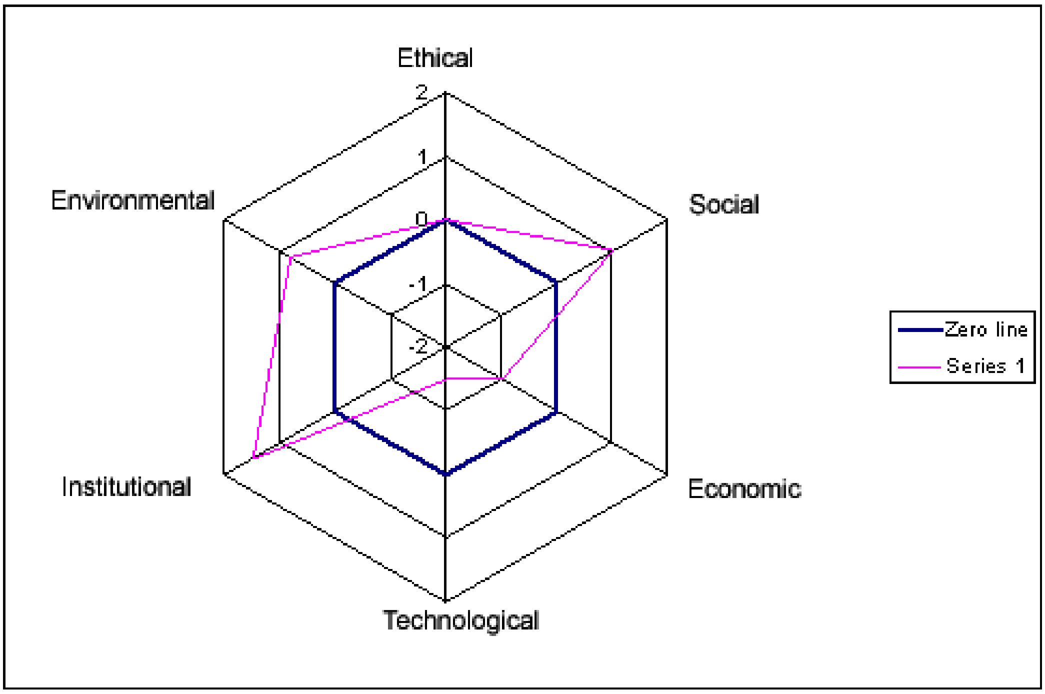


Figure 36 An example of spider diagram with values shown on each axis representing different dimensions of sustainability.

4.5.12 Identification of significant issues, their causes and solutions.

Selecting the significant few problem areas of sustainability for improvements.

With the least sustainable dimensions, the next step is to identify their most un-sustainable sub-dimensions elements (see section 4.5.9) and then find out the sustainable indicators for sub-dimensions with the lowest value. By selecting these and backtracking through the normalization steps, the significant sustainability issues are tracked down. From here, solutions are identified for their ability to solve most of such issues. If a large list of significant issues and solutions are identified, a method then has to be derived to prioritise them and select the cut-off point for selecting corrective actions. For example, only the issues that address more than two indicators are selected, or to select a solution that can solve more than three issues. The decision on what criteria to base on in choosing the issues and solutions is to be made by the investigation team.

Management from the Stakeholders needs to take on the responsibility of implementing these solutions and to follow up on their effectiveness as described in section 4.5.13.

4.5.13 Completion of the TQM Plan-Do-Check-Act cycle.

After the corrective actions are identified and implemented in section 4.5.12, the state of the indicators needs to be periodically reviewed by the stakeholders or monitoring bodies, and regularly reported to the coordinator of the exercise. At regular intervals, may be annually or more frequently under special request, this sustainability quantification exercise (hereby after called assessment) should be carried out again, taking notice of any indices that had a significant decrease in their sustainability. Projects are then created with the aim to improve these weak areas. The components of the methodology also need to be reviewed regularly, perhaps once every three years, to identify new sustainability issues and incorporate them into the measurement. Also, the current validity of the DICFs' needs to be reviewed. With changing perceptions and new insights and knowledge in the society, the scales in some of the DICFs may change. For example, the level of an attribute that may be considered as sustainable and was rated 1 on the scale may be considered as fairly unsustainable three years late and rated -1 on the new scale. Constant conversation with the stakeholders is crucial in keeping the scale up-to-date, so is the continuous improvement of sustainability in the sector which is expressed in the annual assessment exercise.

4.5.14 Contextual nature of the indices

Sustainability indices calculated from this methodology serve a specific purpose of finding solutions to sustainability problems that have been identified previously and they must be read in this context. An index quoted without referring to its specific details may risk having its significance misinterpreted.

4.6 Conclusion

In this chapter, a methodology has been proposed to quantify sustainability for an industry sector. First, the concepts and the tools of the management tools from Total Quality Management (TQM) were described and then the framework of sustainability used in this methodology spelled out. That was followed by a detailed description of the proposed methodology. Emphasis was put on the concept of continuously improving the sector in terms of regular reviews to identify new sustainability issues and updates to the scalar functions.

To illustrate the proposed methodology, a case study on the electricity sector of New Zealand has been chosen and it is presented in Chapter 5.

Chapter 5 Case study – Quantitative Sustainability Index for New Zealand's power market

5.1 Introduction

This chapter performs two functions. Firstly, by the use of a case study, the methodology, which was outlined in Chapter 4 and summarised in Figure 20, is illustrated through the electricity sector of New Zealand, filling in the specifics of the templates to produce a set of quantitative sustainability indices. Secondly, the sustainability of the industry will be looked at from three perspectives, the reason being that any proposed method faces the inherent risk of being "hijacked" by special interest group and produce a biased result, so the methodology needs to be robust. In order to explore the robustness of our methodology, a spectrum of viewpoints will be taken, one where the investigating team, or the evaluator, is heavily sympathetic to environmental issues, the second is where the team is dominated by a bias for commercial interest and a standard view for this thesis from the author.

From these three viewpoints, the results from three different evaluators will be compared and the model's robustness will be commented on in the face of potentially extreme inputs. This strategy is designed to dampen any excessive entries so that the chance of users of the method knowingly affecting the final results is minimised and the results will be more representative of the real situation. However the method equally needs to be ensured that it is sensitive enough to pick up legitimate changes in sustainability through a congruent set of indicator changes.

This quantification process involves multiple stages of decision making, classification and clarification. While it is possible that this process can be automated, that would require programming resource that is beyond the immediate scope of this thesis and has the possibility to be a follow-up research project.

5.2 The identification of stakeholders and their relationships

The first step in this methodology is to analyse the electricity industry and identify the stakeholders and their relationships through the establishment of a Systems Diagram of the electricity sector, as proposed in Figure 37. The main players are identified to be the international and local fuel suppliers, power generating companies, wholesales market, transmission and distributors, retailers, consumers and government, and their relationships are described in the sections below. Such a model of course is complex, and different groups of stakeholders in the evaluation team will, most likely, arrive at different systems diagrams. It also should be noted that, while it is impractical to establish if the model is correct, the author believes it is a suitable working model for the purposes of this thesis.

5.2.1 International and local fuel suppliers

International and local fuel suppliers (shortened to fuel suppliers hereafter), or those providing generating source such as hydro/wind, clearly play a crucial role in the sector. The input factors they receive that affect their performance are: economical, physical, environmental and institutional. Economical factors include international fuel prices, reserve of fossil fuel (locally and internationally at their generation source and at local storage for immediate generation), reserve of other generating resources (e.g. hydro lake level), and government Sustainable Development guidelines and regulations that may control the use of a certain fuel (such as minimum amount of wind power) or extraction.

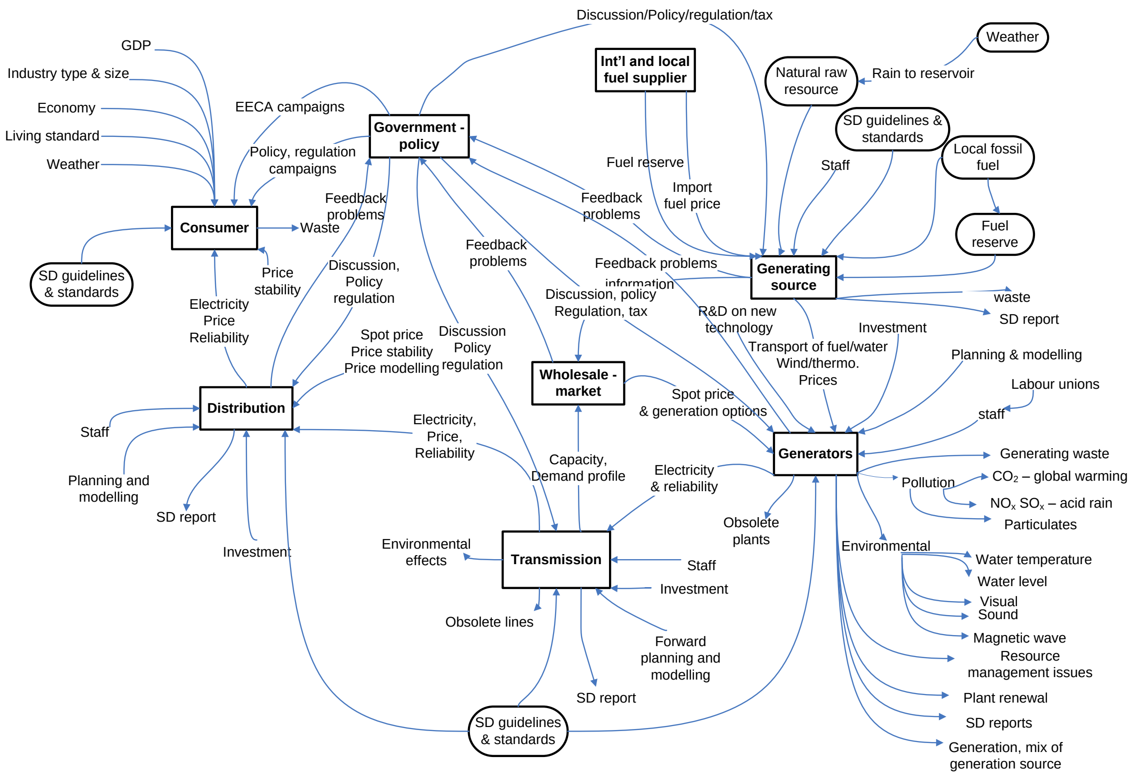


Figure 37 Systems diagram of the electricity sector for New Zealand

The physical outputs of fuel suppliers are: fuels that are transported to generators and for export and indirectly, and the byproducts associated with the extraction, refining and transportation. For hydro, the output may also involve water that is allocated for other purposes such as irrigation or recreation. Non-physical outputs are the prices of the fuel and supply conditions that get passed onto the wholesale market. These outputs affect the wholesale price of electricity since fuel shortages will cause increase in the wholesale spot price. In terms of SD, companies emphasizing their efforts on sustainability, and producing sustainability reports, attract investors who wish to invest in a socially responsible way, as echoed by the Dow Jones Sustainability Indexes (SAM Indexes GmbH 2007). The major interactions with other stakeholders are shown in the systems diagram in Figure 37.

5.2.2 Power Generating Companies

The main physical inputs to the power generating companies (shortened to generators supply hereafter) as seen in fig Figure 37 are fuels and staff (who operate and maintain the machines). On the operation side, the indirect input is the amount of R&D that improves generation efficiency and safety, and investigates new generation schemes such as wind and solar. In economic terms, the inputs are fuel prices and investments for expansion and maintenance. Government policy, SD related guidelines and regulations and public pressure are also non-physical inputs that affect the generators' operation. An example of public pressure stopping the development of a power project is the opposition to the proposal of building dams by Mighty River (Mighty River Power 2001). Data of power demand projection from government or private sources is also an important input for their production and expansion planning.

The power generators' direct product is electricity transmitted over the grid, and by-products are, for example, physical solid and liquid waste, exhaust gases, particulates and heat. The generators affect the environment mainly through exhaust gases, and depending on the method used for cooling, it can affect the environment through cooling tower or cooling water that affects the ecology of streams, visual effect, sound, and, arguably, magnetic waves. For hydro generation, it also affects the level of water which is used for irrigation or recreational purposes in the rivers and lakes both upstream and downstream, through the damming of rivers. One more consideration on the planning side is the obsolete generation plants that need to be decommissioned properly to minimise environmental impacts. Life-cycle analysis of generation plants will consider that. One other output by the generators would be their sustainability reports.

In its relation with the wholesale market, information on the mix of generation methods affects the wholesale price but there is also a feedback mechanism that the price also affects the operational decision of which source is to be used for generation at any given moment.

5.2.3 Wholesale market

The electricity wholesale market (shortened to wholesaler hereafter) is the exchange centre of a “free” market where electricity is traded according to the supply and demand principle and the spot prices are set at different nodes, or points at which electricity is sold. While in a normal goods market with limited supply, an increase in demand will drive up the price and thus slow down supply via a phenomenon called the elasticity of demand, electricity hardly exhibits these characteristics as it is a utility and a necessity. Demand is difficult to decrease even with a steep price rise, and it classified as an inelastic good.

Wholesalers receive inputs such as power supply information on fuel levels, and the amount of generating and transmission reserve, and demand levels from customers where this information is used to establish the wholesale price.

The wholesale market’s non-physical output is the wholesale price level referred to by the generators, distributors and end-users.

The inputs that control its operation are rules, regulations and policies from the government. The planning side of it is affected by the modeling of demand and supply by the government and other parties, such as the Ministry of Economic Development and the Centre of Advanced Engineering in Christchurch. In return, it may generate SD reports as an output to inform the public of the sustainability approaches it takes for its operations.

As an issue common to all stakeholders, recruitment of quality staff is an important input as well as the attraction of sufficient investment for growth and expansion.

5.2.4 Transmission and Distribution

There is a unique situation for the transmission and distribution system in New Zealand because of its geographical layout. Transmission and distribution (shortened to transmission hereafter) are crucial elements of the sector (Inder 2006), but New Zealand has been affected by a number of breakdowns such as the one in Auckland in June 2006, Cook Strait in 2005 and Auckland Centre in 1996. Recently in New Zealand, these have been the centre of attention as extra transmission capacity is needed to meet expanding demand in the Auckland region and the approval of its expansion plan has been met with opposition from various organizations and from the public. As a contrast there is a line over-capacity on the east coast of the North Island. Issues relating to the expansion and upgrading of the lines and creation of new lines are affected by environmental and ethical issues and they have to abide with the SD guidelines and standards, such as the Resource Management Act, and go through the resource consent process.

Currently in New Zealand, there is a monopoly for the high voltage long-distance transmission National Grid by Transpower, but there are numerous distribution companies that have entered this competitive market for local low voltage distribution of electricity.

For physical inputs, this stakeholder needs skilled operators for line and station maintenance as well as non-physical ones like demand forecast including planning and modeling. As an output, they transmit and distribute power in a reliable and fair manner to the consumers. The operation is under the input influence of government policy and regulations, guidelines and standards. The expansion plans of the transmission and distribution network depends on the input of accurate demand and supply modeling. Any potential of reaching a bottle neck in its network is an output signal to the wholesale spot market which may affect the spot price. In fact, pricing is a function of the load carried. As an output to inform the public of their operation, transmission companies may also produce sustainability reports.

5.2.5 Retailers

Retailers are in a competitive market. They buy electricity at the wholesale market and sell it to the consumers after it has been distributed. The retailers' cost of electricity includes the wholesale price, transmission cost and line charges from distributors. Example of retailers are Contact Energy Ltd, Empower Ltd., Genesis Power Ltd., Meridian Energy Ltd., Mercury Energy Ltd., Bay of Plenty Electricity, King Country Energy, and TrustPower Ltd. (Electricity Commission 2007).

5.2.6 Consumers

New Zealand's power market consists of nine large users that are directly connected to the National Grid (Wilson 2007) and a large number of small users. For example, New Zealand Aluminium Smelters Limited is the single largest user, consuming 5,217GWh out of the total industrial usage of 16,190GWh (32% of total industrial use), paying an average of 4.89 c/kWh comparing with the industrial average of 7.56 c/kWh (Ministry of Economic Development 2006).

Although the direct inputs to the consumers seem to be just electricity and the price that they obtain through the grid, other indirect factors that also affect them are the GDP, the composition of user types, the economy trend, living standards, and the weather. Inputs like policy and regulations affect how consumers use the power as well as the SD guidelines and standards. At time of power reserve shortage, the demand is effectively affected by government campaigns and initiatives (NZPA 2003). The output they have for the sector is the price they pay the retailers for electricity and services. As a by-product, users produce waste heat and industrial users may utilise their "waste" heat in other facilities.

5.2.7 Government

In New Zealand currently there is not a single entity in charge of the electricity power. There was a Ministry of Energy that overlooked all energy issues but that was abolished in 1989 (1989), instead, New Zealand has a Minster of Energy but the control of the electricity sector is distributed among him, the Electricity Commission, Energy Efficiency and Conservation Authority, and Ministry of Economic Development.

The outputs from the government consist of plans for a country’s development and that of its power market such as the National Policy Statement, by designing policies and regulations as well as giving advice, running campaigns and giving guidelines to the public. Ideally the government should have long term plans and targets for the sake of creating stability thus providing a stable investment environment. However sometimes, in developed democratic countries, considerations such as strategies for winning the next election and being politically correct may take priority over these plans which may take more than one term of government to complete and harvest the benefit.

Having said that, one of the inputs the government takes is the feedback from the population and monitors the market with the intention of improving it. As mentioned in section 2.2.5.6, government plays the most important role in ensuring Sustainable Development in a society.

5.3 Issues threatening sustainability of New Zealand's electricity sector and proposed solutions.

The next step in this method is to identify issues that are perceived to affect the sustainability of New Zealand's electricity sector by using an Affinity Diagram. The issues are identified through a brainstorming session by the panel and grouped under main headings as shown in **Error! Reference source not found.**, the details of which will be discussed in section 5.3.1. The key points are described in the following sections.

For the ease of presenting information, the twelve main sustainability issues are arranged into four major groups. Group one has the power market "hard" issues, including issues in Generation, Fuel supply, Transmission and Acts of God. Group two has the "soft" issues including Environmental, Ethical and Social. Part three are the "sector support" issues, comprising of Technological, Investment and Power market issues. Part four has the "sector background" issues, including Industry structure and Economic ones.

The step after identifying the issues is to identify the existing and potential solutions that can address the issues pointed out above and obtain a matrix diagram representing the relationship between the solutions and the sustainability issues. This step is performed on all groups of issues.

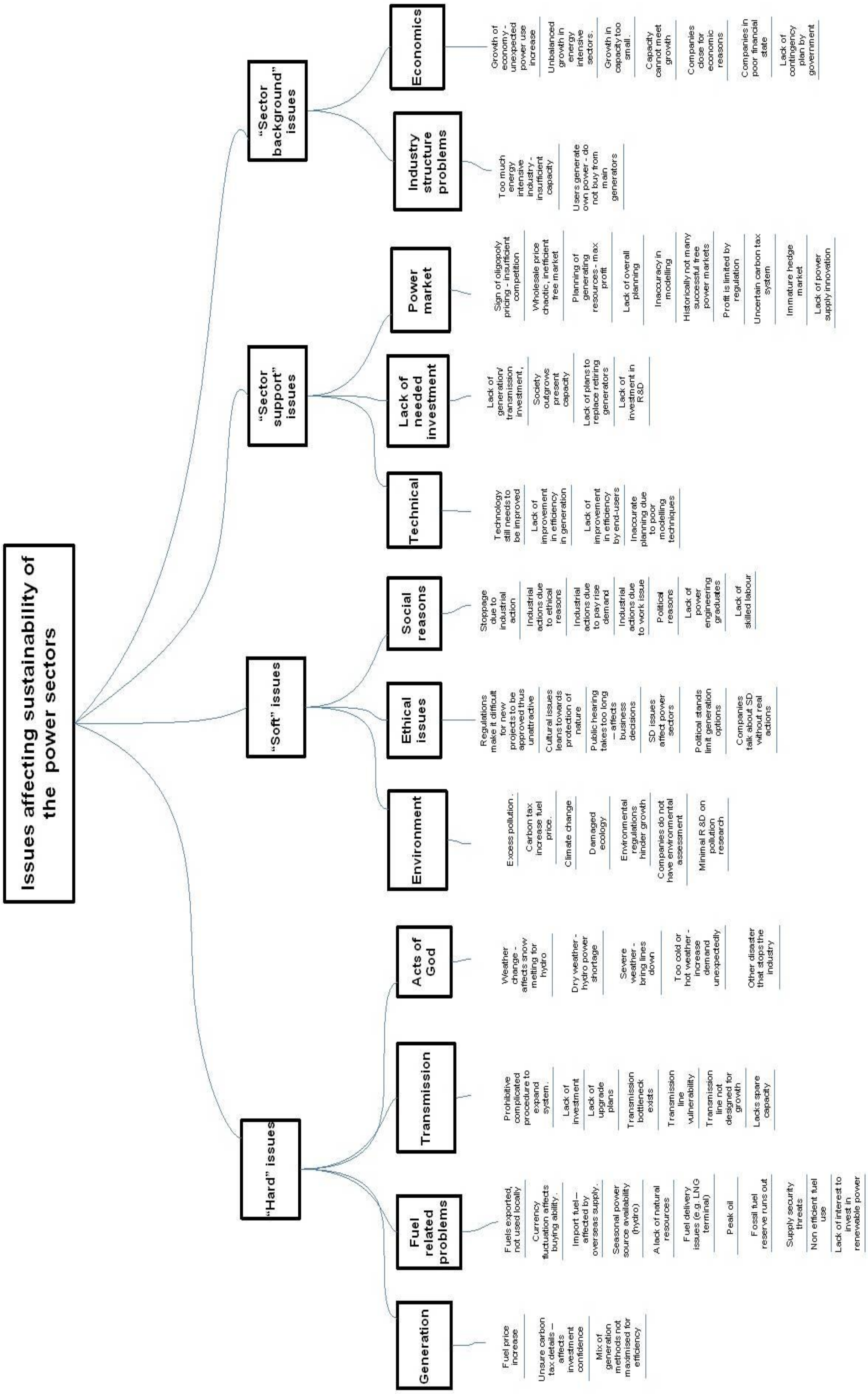


Figure 38 Tree diagram of sustainability issues in the New Zealand electricity sector

5.3.1 The sustainability “hard issues”: Generation, Fuel supply, Transmission and Acts of God.

5.3.1.1 Generation issues and solutions

Generation issues ─ issues faced by the electricity generators

As mentioned in section 5.1.1, New Zealand needs contribution from different generation sources to meet its demand. Problems arise when the mix of generation resources may be set to serve the purpose of profit maximization and not for improving the overall efficiency for the society. Also, any significant fuel price increase in the future will pose a threat to the sector’s sustainability. The unclear direction of a future fuel price increase due to a carbon tax works against the sustainability of the sector (see Figure 39 for a summary).

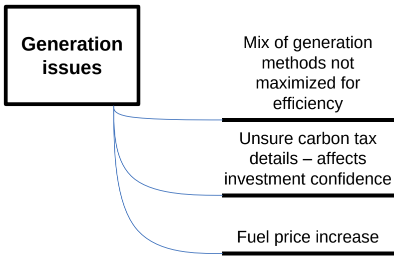


Figure 39 Generation sustainability issues

Existing and proposed solutions identified for Power Generation sustainability issues

From the generation side, fuel supply sustainability can be increased by having sufficient fuel reserve, better planning for the replacement of obsolete plants and better modeling of fuel usage and prices. Management strategies in the generation industry that focuses on generation efficiency and uses an appropriate generation mix of hydro, fossil and renewable generation to increase efficiency is important, especially for the New Zealand situation. The government can also play a role by having policy and regulations on generation efficiency. Improved generation plant efficiency also makes a contribution. The proposed solutions are summarised in Figure 40.

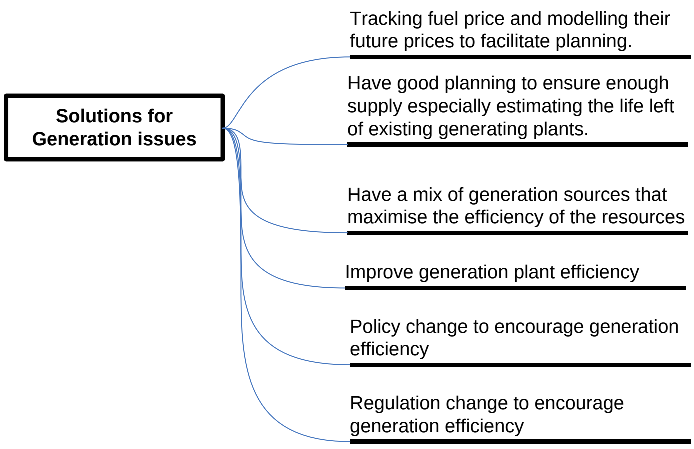


Figure 40 Proposed solutions for generation issues.

The relationship between the sustainability issues and proposed solutions (simplified as "solution" in the issue/solution charts that follows) can be seen in the matrix diagram Table 8. In this matrix, the solutions are matched with the sustainability issues which they are likely to improve. It is worth noting that more than one solution may be needed to improve a sustainability issue because of the issue's complexity and one solution may contribute in improving multiple sustainability issues.

Table 8 Generation issues/solution chart

	Solutions					
Generation issues	Monitor and modelling of fuel price	Have a mix of generating source to maximise efficiency of the resource	Better planning to anticipate end of life of old plants	Improve plant efficiency	Policy change to encourage generation efficiency	Regulation change to encourage generation efficiency
Fuel price increase	X	X		X	X	X
Unsure carbon tax details – affects investment confidence	X				X	X
Mix of generation methods not maximised for efficiency		X	X		X	X

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.1.2 Fuel supply issues and solutions

Fuel related issues – issues in fuel supply and pricing for generating electricity

While some fuel problems are global such as the threat of peak oil, some issues are more local. New Zealand has been depending on cheap Maui Gas for generation since the 1970s but in 2003 it was discovered that it will run out ahead of schedule, in about four year's time. With no significant gas find at that time, local gas supply security was threatened. That threat was lessened in 2006 when the discovery of the Taranaki gas field improved the situation (Stokes 2006), but again Taranaki will one day run out too. A summary of these issues can be seen in Figure 41.

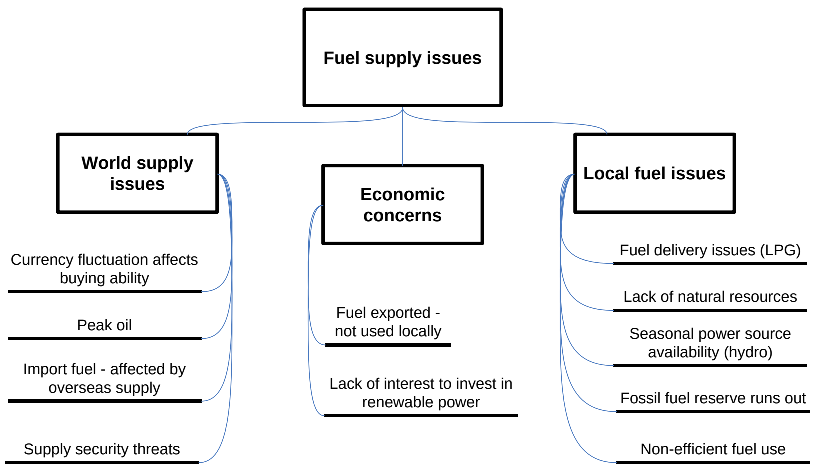


Figure 41 Fuel Supply sustainability issues

Despite the fact that the Huntly coal field and the coal fields in the South Island holds hundreds of years worth of coal supply for New Zealand electricity generation (Elder 2004), it remains uneconomical to be burnt currently, and it is not eco-friendly to release pollutants associated with burning coal of that grade into the atmosphere. Due to the increased awareness and concern for ecology and a lack of breakthrough technology to solve the related problems, new large scale coal plants are unlikely to be built in the near future.

Having an abundance of fuel does not automatically imply that the society will use it efficiently but it is more likely to work in the opposite way. In fact, fuel scarcity for power generation can be due to political/technological moves; examples are the cases where cheap Maui gas was diverted to make ethanol and the Aluminium smelter was attracted to New Zealand because of the cheap gas and hydro-generated electricity.

Coal is being exported by New Zealand but burning imported coal makes New Zealand exposed to the risk of supply shortage and currency fluctuation. Still on the economic side, the scale of investment in renewable power (besides hydro) is small in New Zealand compared with European countries like Germany, Spain and Greece (German Wind Energy Association (BWE) 2006), despite the fact that New Zealand has great potential in wind and wave power.

If the definition of "fuel" can be expanded to all generation resource, including hydro which supplies around 60 percent of New Zealand's electricity, our supply is then subjected to seasonal “fuel” availability because rain is seasonal and there were recent seasons where dry weather has caused power shortages.

Should New Zealand decide to import LPG, the selection of a suitable site for the LPG terminal and gasification plant would pose another Resource Management problem as it will take a long consultation period for that to materialise.

Existing and proposed solutions identified for Fuel related sustainability issues

Fuel supply problems (summarised in Figure 42) can be local (e.g. transportation limits) or international (e.g. elevating crude price) and some solutions can come from the government. For example, it can encourage research in renewable resources or it can have a policy for fuel self-sufficiency and a declaration that a certain portion of power needs to be generated from renewable sources as the Australian Government has done (Office of the Renewable Energy Regulator 2006). The government can also improve fuel availability by encouraging local fuel exploration, or, accepting a wider range of generation options, such as considering nuclear power, as in the direction pointed out by Australia in AAP (2007), but bearing in mind that there will be intense ethical and political debates. Even so, increasing research to develop and promote renewable energy is also a choice. The industry can improve planning to ensure future security of supply and may take on long term supply contracts to import fuel. Fuel availability can also be improved by improving the fuel transportation and handling system such as rail or ports.

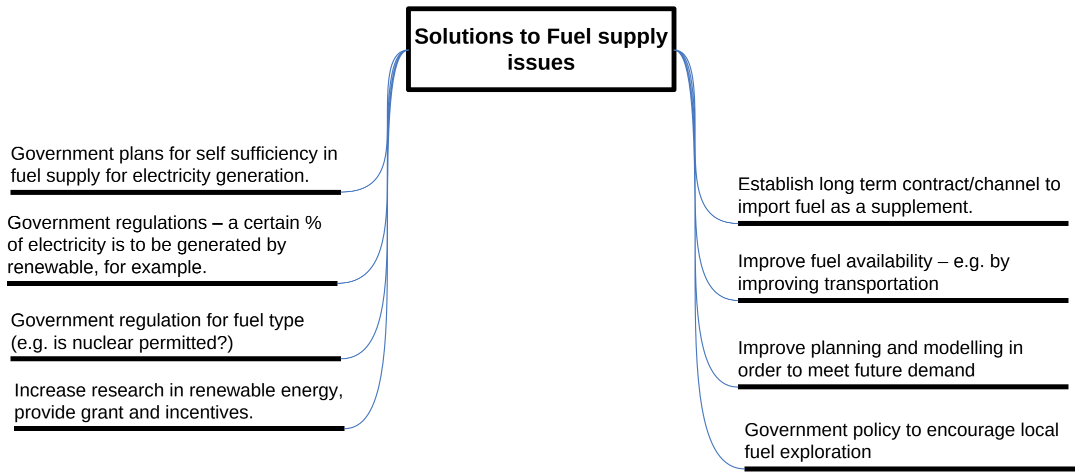


Figure 42 Proposed solutions for fuel related problems

The relationship between the sustainability issues and proposed solutions can be seen in the matrix diagram Table 9.

Table 9 Fuel related issues/ solution chart

	Solutions							
Fuel supply problems	Government policy – fuel self sufficiency	Government regulations – fixed % from renewable	Government fuel type policy	Increase R&D in renewable energy	Setup long term supply contract for security of supply.	Improve local fuel availability	Improve planning and modelling	Govt policy – encourage local fuel exploration
Fuels exported, not used locally	X		X		X			
Currency fluctuation affects buying ability.	X	X		X	X		X	X
Import fuel – affected by overseas supply.	X		X	X	X	X		X
Seasonal power source availability (hydro)		X		X			X	
A lack of natural resources								
Fuel delivery issues (e.g. LNG terminal)	X		X	X		X		X
Peak oil supply			X	X	X		X	
Fossil fuel reserve runs out			X	X				
Threats from supply security	X	X		X	X			X
Non efficient fuel use		X					X	
Lack of interest to invest in renewable power	X	X	X	X				

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.1.3 Transmission issues and solutions

Transmission issues – insufficient capacity and hurdles in expansion.

Electricity has specific transmission limitations and the electricity transmission system in New Zealand faces a number of sustainability issues, as summarised in Figure 43

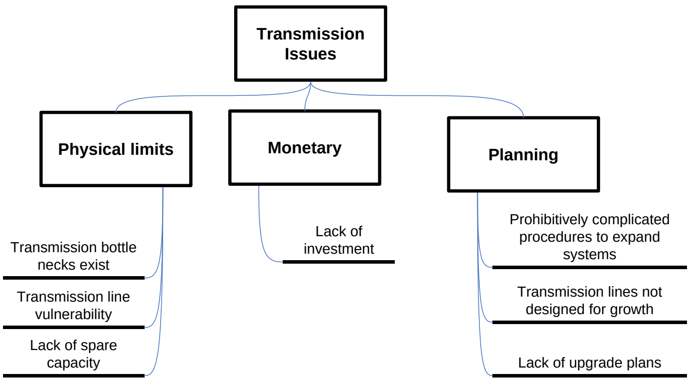


Figure 43 Transmission sustainability issues

First, it is reported to lack spare capacity to allow for growth in demand and is predicted not to be able to cope by the year 2009 (Craven 2004). That is partly due to lack of planning for the geographic layout for New Zealand which is of a long and narrow shape and is separated in two islands. The South Island is where the majority of the hydro generation is and the North Island is where most of the consumers (including industrial consumers) are. The original design has one line going into the cities such as Auckland, and should a fault happen as in Auckland in 1996, the city does not have a back up line. The other major issue is, New Zealand, being two islands, poses the problem that power has to be transmitted often from the South to the North Island via an undersea HVDC link. That line was originally installed in 1965 and was upgraded once in 1992 (Civil 2005). Any significant problems with the HVDC line caused by a hardware fault or caused by weather damage have resulted in a shortage of supply in the North Island in the past.

Plans have been proposed to upgrade power lines but the process has been long in some cases, such as the Transpower plan that started in 2003 but is still not implemented in 2007 (Transpower 2007). Such plans were interrupted in various ways such as public opposition according to the procedures described in the Resource Management Act, and intervention by government bodies such as the Commerce and the Electricity Commission.

Unfortunately, transmission upgrading may work better in a “fire-fighting” mode. Only when a serious transmission problem happens will the public realise the significance and urgency of the problem and will have sympathy and motivation for solving the problems. The government can then possibly pass regulation with less opposition. This uncertainty and the long time lag in these processes are the main factors that deterred investors from the New Zealand electricity market.

Local power distribution is the low voltage short distance transmission of power, and issues that apply to transmission may also apply to power distribution. The free market principle has not achieved the result desired by the government, with the result that at the time of writing this paper, the government body, the Commerce Commission, has announced that due to pricing issues by the distribution company Vector, it cannot rule out the possibility of taking it over (Commerce Commission New Zealand 2006) and to impose price control. Vector responded with a warning of future power cuts (Inder 2006).

Existing and proposed solutions identified for Transmission sustainability issues

Transmission problems (see Figure 44) include reliability problems and sufficiency problems. The overall capacity can be increased and the government can help by enforcing compulsory standards for transmission systems such as supply designs with backup systems. It can also put in a penalty system for non-performance. Government has the power to use economic instruments to encourage investments in transmission facilities. The situation can also be improved by simplifying the procedures for applying for expansion and having better expansion planning.

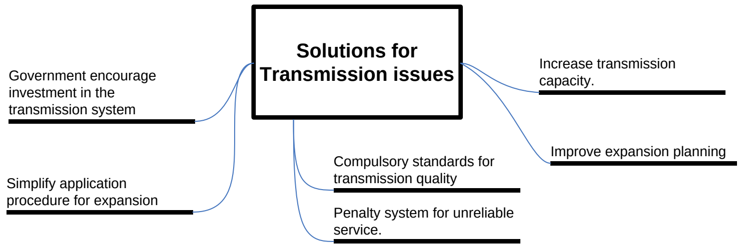


Figure 44 Proposed solutions for power market

The relationship between the sustainability issues and proposed solutions can be seen in the matrix diagram Table 10.

Table 10 Transmission issues/solution chart

	Solutions					
Transmission Problems	Government encourage investment	Simplify application procedure for expansion	Compulsory quality standards	Penalty system for unreliability	Increase transmission capacity	Improve expansion planning
Prohibitive complicated procedure to expand system.	X	X				
Lack of investment	X	X				
Lack of upgrade plans	X	X	X	X		X
Transmission bottleneck exists			X	X	X	X
Transmission line vulnerability			X	X		
Transmission line not designed for growth	X					X
Lacks spare capacity	X				X	X

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.1.4 Acts of God issues and solutions

Acts of God issues ─ preparing for the unexpected

Acts of God (AoG) is normally used as a collective term for all the events that are unexpected such as earthquake, or drought of unprecedented magnitude (refer to Figure

45 for a summary of the issues). Even so, some of the consequences of AoG are due to a lack of human foresight, or, if they are foreseeable, it might take an unpractical amount of resource to prevent it or to minimise their damages. An example of the latter is the option to build the control centre of a power station underground to prevent damage by meteor strike. For electricity supply security, it is only recently with the establishment of the Electricity Commission that the government aims to address a one-in-sixty-year dry season (Electricity Commission 2005). Situation such as that could be classified as AoG in the past, but with planning, the amount of damage can be minimised. Even so, New Zealand still faces a remote risk of dry years because of its heavy dependency on hydro power.

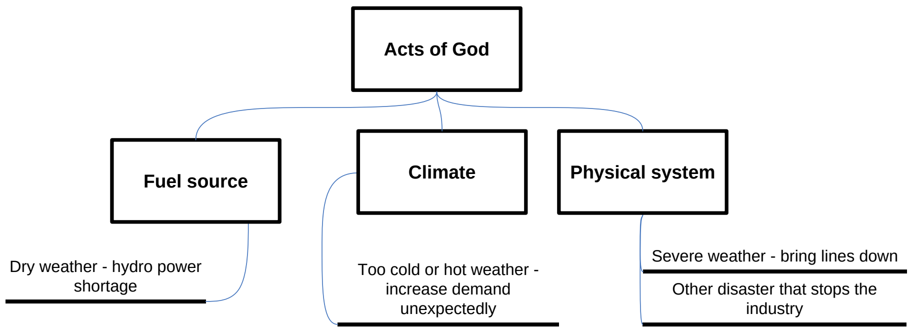


Figure 45 Acts of God sustainability issues

Power supply in NZ is vulnerable to storms and heavy snow conditions. The North Island / South Island HVDC link, when broken down, can affect half the country. This can be attributed to design that does not have back-up lines, or power poles that are not strong enough for the New Zealand's strong wind or heavy ice load that has occurred. While these events are foreseeable, they are not reasonably well prevented from happening, thus they should still be classify as AoG.

Excessively hot summers or cold winters result in excessive power consumption can be called an AoG which, when spare capacity is not available, can cause power shortages and wholesale price increase. General weather phenomena like climate change can bring on any of the above elements.

Another possible AoG is that New Zealand is in a volcanic zone. Although there have not been recent volcanic activities, any future activities will bring major interruption to power supply.

Existing and proposed solutions identified for Acts of God sustainability issues

For Acts of God, the potential damage can be minimised by setting up and promoting a suitable civil defence program through education and having sufficient reserve power as well as backup power for essential services in unexpected events. The proposed solutions are summarised in Figure 46.

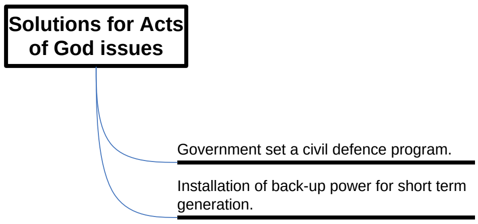


Figure 46 Proposed solutions for Acts of God issues

The relationship between the sustainability issues and proposed solutions can be seen in the matrix diagram Table 11.

Table 11 Acts of God issues/solution chart

	Solutions	
Acts of God	Govt review civil defence program	Install back up power for additional short term generation
Weather change - affects snow melting for hydro	X	X
Dry weather - hydro power shortage	X	X
Severe weather - bring lines down	X	X
Too cold or hot weather - increase demand unexpectedly	X	X
Other disaster that stops the industry	X	X

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.2 The sustainability “soft issues”: Environment, Ethical and social

5.3.2.1 Environmental issues and solutions

Environmental issues ─ environmental effects

Electricity generation by combustion produces air pollution in the form of combustion exhaust, or water ecological pollution by overheating streams by its cooling water. Also, increasing international pressure is being put on controlling the emission of green house gas in the face of the proposed climate change threats. From the business side, there are companies that still do not perform routine Environment Assessments (see Figure 47 for a summary).

Despite the best of intentions, some actions that protect the environment work against the sustainability of the sector as a whole, such is the paradox of sustainability improvements. An example is that consultation with the environmental protection regulations hinders or halts the necessary expansion of the much needed power facilities such as Transpower's transmission expansion plan. As a result, despite having environmental protection, potential future power shortages still exist. Also, initiatives such as carbon tax, are intended to protect the environment, but their implementation will add cost to the electricity sector thus work against the sustainability concept.

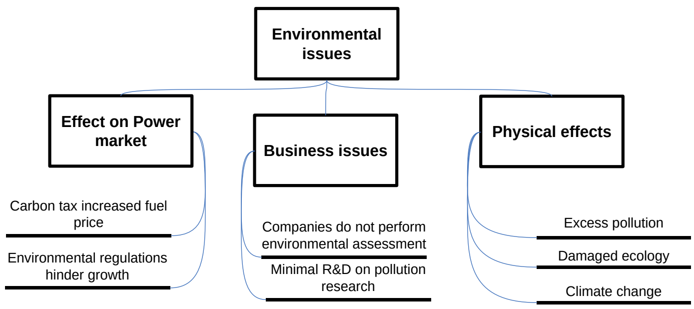


Figure 47 Environmental sustainability issues

Existing and proposed solutions identified for Environmental sustainability issues

Environmental issues can be solved mainly by pollution control policies and regulations, and increased research and development in pollution control technologies such as carbon sequestration. The proposed solutions are summarised in Figure 48.

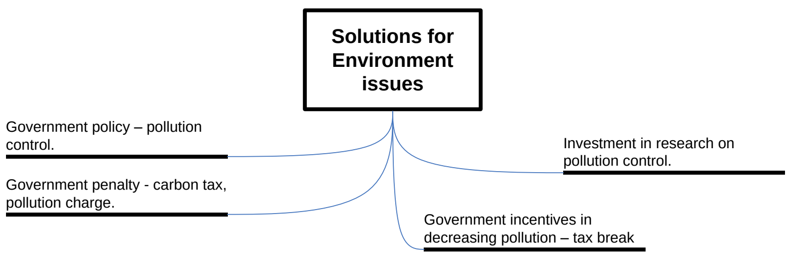


Figure 48 Proposed solutions for environmental issues

The relationship between the sustainability issues and proposed solutions can be seen in the matrix diagram Table 12.

Table 12 Environmental issues/solution chart

	Solutions			
Environmental issues	Government review policy – pollution control.	Government incentives to decrease pollution	Government penalty system – Carbon tax, pollution charge.	Increase investment in R&D for pollution control.
Excess pollution	X	X	X	X
Carbon tax increases fuel price.	X		X	X
Climate change	X	X	X	X
Damaged ecology	X	X	X	X
Environmental regulations hinder growth	X			
Company does not perform environmental assessment	X	X		
Minimal R&D on pollution research		X		X

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.2.2 Ethical issues and solutions

Ethical issues ─ limiting choices in the electricity industry

Ethical issues as summarised in Figure 49 are crucial in the electricity sector because this sector affects certain aspects of the society which are partly protected by the legal system in New Zealand. Ethical issues have become one of the major factors that hinder the development of the electricity sector.

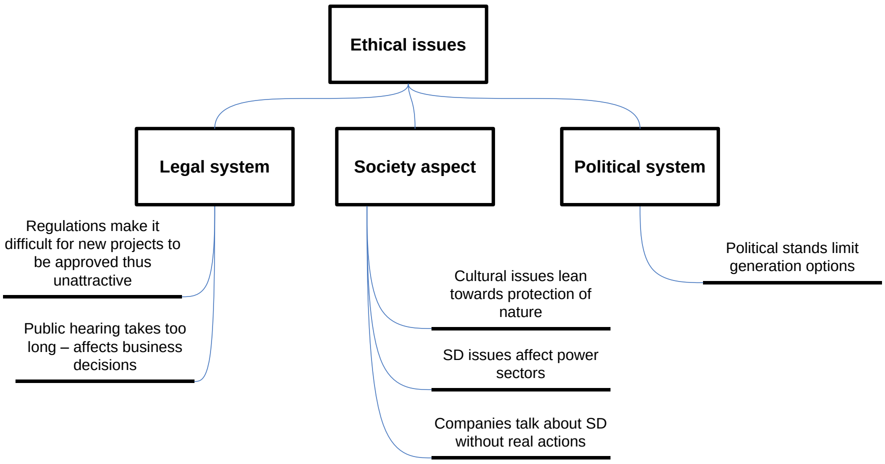


Figure 49 Ethical sustainability issues

Due to historical reasons that partly lead to the Treaty of Waitangi and the Resource Management Act, the law has to respect the will and the tradition of the native Maori as well as that of the general public. What that means is that any proposed project needs to be presented to the public for scrutiny, placing special priority on views from the Maori culture. The public will give submissions listing their objections and the project's proposer will need to compromise with the objecting parties until these parties are satisfied before the project can proceed.

Although the Maori culture originates from legends and myths, it has been serving the important purpose of ensuring man is living in harmony with nature. With changes in time, the traditions should still serve their purposes but the objections from Maori to some use of land to improve and expand the electricity sector, along with that from the general public, have been causing problems in electricity project development because public hearings has been taking too long and this poses as risks in business decision making. Business prefers certainty and if delays or regulatory barriers are likely to hinder or even prohibit their projects, and if the return on them is not attractive enough to overcome the associated risks, business investors will divert their funds and efforts to other projects that have less risk and uncertainty with higher returns. Unfortunately, the nature of these regulations makes it difficult to predict whether a project will be approved or not. Besides these, the ethical view the New Zealand government has taken up of not using nuclear power, although it may benefit New Zealand in other ways, limits its choice of power source. Having pointed out these areas, it is worth noting that recently New Zealand has coped fairly adequately with the current energy policy.

Existing and proposed solutions identified for Ethical sustainability issues

On the ethical side, the government needs to update the relevant regulations and policies to reflect the needs of today's society. It needs to have constructive negotiation and workable procedures with native groups on land rights involving electricity facilities, which is an issue of national importance. A balance needs to be strike on the importance between matters of national interest and the views of one interest group in a democratic way. The proposed solutions are summarised in Figure 50.

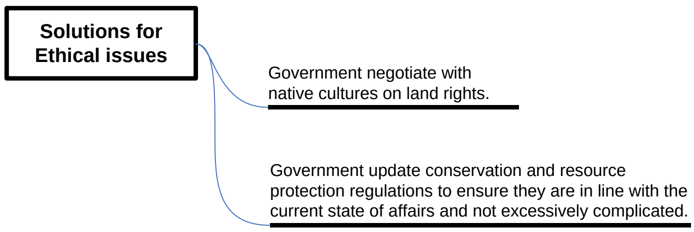


Figure 50 Proposed solutions for ethical issues

The relationship between the sustainability issues and proposed solutions can be seen in the matrix diagram Table 13.

Table 13 Ethical issues/solution chart

Ethical issues	Solutions: Govt update regulation to meet today's needs	Solutions: Govt negotiate on land right
Regulations make it difficult for new projects to be approved thus unattractive	X	
Cultural issues lean towards protection of nature	X	X
Public hearing takes too long – affects business decisions	X	
SD issues affect electricity sectors	X	X
Political stands limit generation options	X	
Companies only talk about SD without real actions	X	

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.2.3 Social issues and solutions

Social issues – skill shortage and union relationship

For industry, one of the major social problems (as summarised in Figure 51) can be work stoppages due to industrial actions. These can affect generation, transmission, fuel delivery and production. These, at least in other countries, often are due to collective bargaining for a pay rise, improvement of working conditions or for ethical issues. Historically it has not been a major factor that affects the industry in New Zealand nor does the industry have a strong record of political link.

Another social issue is the shortage of skill labour and dropping numbers of graduates from power engineering courses as local students rate engineering as a less attractive area to study (Career Services - New Zealand Government 2007). Skilled workers often head for overseas due to better pay and career prospect.

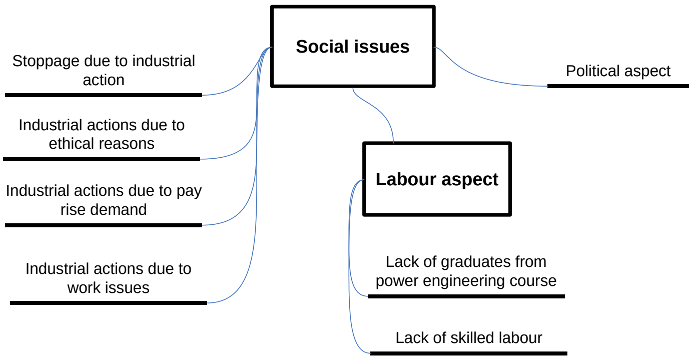


Figure 51 Social sustainability issues

Existing and proposed solutions identified for Social sustainability issues

Social problems can be improved by the government and employers having talks with the unions. The labour market aspect is less controllable as it has a complex relationship with factors such as education and lifestyle change and it is beyond the scope of this paper to make recommendations. The proposed solution is shown in Figure 52.

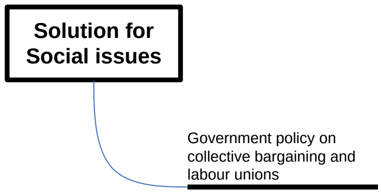


Figure 52 Proposed solutions for social issue

The relationship between the sustainability issues and the proposed solution can be seen in the matrix diagram Table 14.

Table 14 Social issues/solution chart

	Solutions
Social issues	Govt policy on solving these issues.
Stoppage due to industrial action	X
Industrial actions due to ethical reasons	X
Industrial actions due to pay rise demand	X
Industrial actions due to work issues	X
Political reasons	X
No graduates from power engineering course	X
Lack of skilled labour	X

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.3 The Power sector's "supporting issues": Technological, Investment, Power market

5.3.3.1 Technological issues and solutions

Technological issues ─ the need to increase efficiency

Improvements in the efficiency of power generation and in power usage by end-users remain the main technological issues that, if improved, can contribute to the sustainability of the electricity sector (see Figure 53). Also the technology of modeling supply and demand can be improved to increase the accuracy of supply and demand predictions.

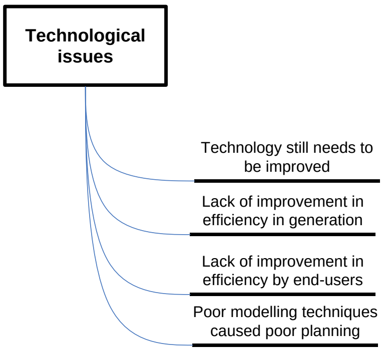


Figure 53 Technological sustainability issues

Existing and proposed solutions identified for Technological sustainability issues

The proposed solutions are summarised in Figure 54. One cannot really be expected to foresee future technological developments, but they are likely to be incremental as opposite to revolutionary. Technology problems often can be solved by economic incentives, insights and an entrepreneurial approach. Government policies on creating a culture to encourage creativity and entrepreneurship, will improve the situation, such as promoting research, creating incentives for innovation, investing in energy efficiency improvements, creating campaigns in improving energy efficiency, and implementing energy labeling programs are effective measures. The culture needs also to eradicate the "Tall poppy syndrome" where exceptional achievers are picked on to be criticised excessively thus deterring most from speaking out with potentially good ideas. Users can also be encouraged to adopt alternative energy efficiency enhancement methods such as distributed generation, demand management and combined heat and power. Resource and emphasis also need to be put on the more sophisticated modeling techniques and computing hardware to run it.

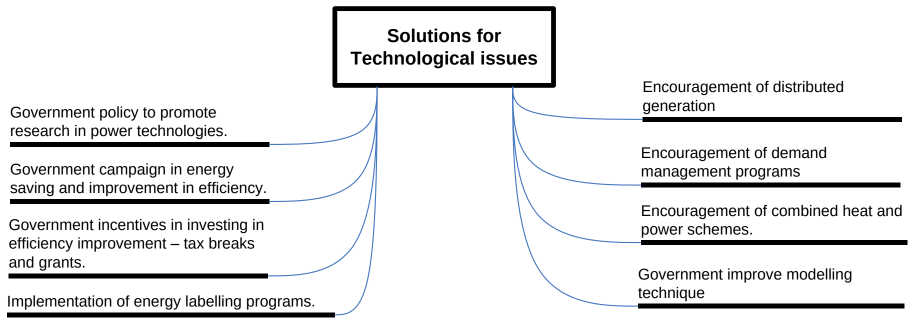


Figure 54 Proposed solutions for technological issues

The relationship between the sustainability issues and proposed solutions can be seen in the matrix diagram Table 15.

Table 15 Technological issues/solution chart

	Solutions							
Technological issues	Govt policy to encourage research in power technology	Govt incentive to improve user/generator efficiency	Govt campaign – to conserve power & to improve efficiency	Implement energy labelling	Govt. encourage distributed generation	Govt encourage demand management programs	Govt encourage combined heat and power schemes	Govt improve modelling technique
Technology still needs to be improved	X	X			X			
Lack of improvement in efficiency in generation		X	X	X	X	X	X	
Lack of improvement in efficiency by end-users		X	X	X		X		
Poor modelling technique causes poor planning			X					X

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.3.2 Investment issues and solutions

Investment issues – lack of investment in the sector

As the electricity demand in New Zealand is approaching the generation capacity, there still seems to be a lack of interest to invest in upgrading the transmission network, in increasing generation capacity or replacing retiring plants and in encouraging R&D in related areas (Inder 2006) (see Figure 55). The main reason is the barrier caused by regulations that hinder the progress of power projects. An example is the current Resource Management Act. The associated procedures often delay projects or cause them to be cancelled such as the proposed project such as Project Aqua, a proposed hydro generation scheme (Fallow and Young 2004; Taylor 2004) that was scrapped because of the long and expensive delay in obtaining approval to start. Unfortunate to the electricity sector, PriceWaterhouseCoopers (2005) pointed out that investors can make more return and have less risk by investing elsewhere.

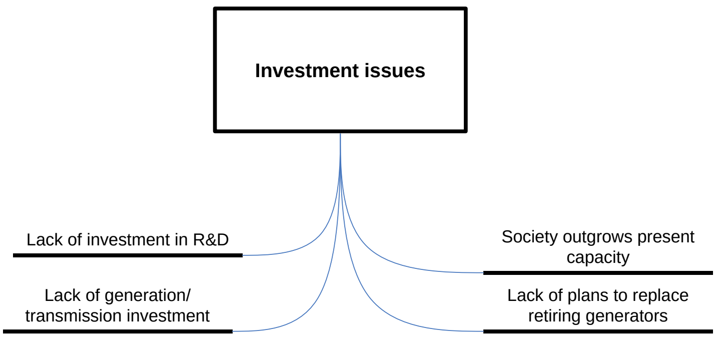


Figure 55 Electricity sector sustainability investment issues

Existing and proposed solutions identified for Investment sustainability issues

To solve the issue of a lack of investment in the electricity sector, the government can help by introducing economic mechanisms such as tax breaks, grants, and giving fuel supply contracts on special terms (see Figure 56).

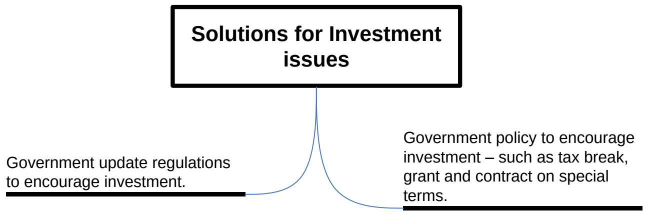


Figure 56 Proposed solutions for a lack of investment

The relationship between the sustainability issues and proposed solutions can be seen in the matrix diagram Table 16.

Table 16 Lack of Investment issues/solution chart

	Solutions	
Investment shortage	Government regulation change to encourage investment	Government policy change to encourage investment
Lack of generation/transmission investment,	X	X
Society outgrows present capacity	X	X
Lack of plans to replace retiring generators	X	X
Lack of investment in R&D	X	X

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.3.3 Power market issues and solutions

Power market issues ─ the unsure efficiency of a free market

New Zealand has a "free" or liberated electricity market meaning its wholesale price is subjected to market volatility. The first problem is that historically not many free markets have been successful in terms of achieving the objective of promoting competition and lowering prices ─ prices went up instead of down after the introduction of the free market (see Figure 57 for New Zealand data). Because of the huge investment involved in infrastructure projects, these are barriers of entry and in numerous countries, it has turned into an oligopoly market where firms make above normal profits (Rudkevich, Duckworth et al. 1998) thus the original intention of liberalizing electricity markets in order to introduce perfect competition and lower electricity prices has not significantly materialised. These issues are summarised in Figure 58.

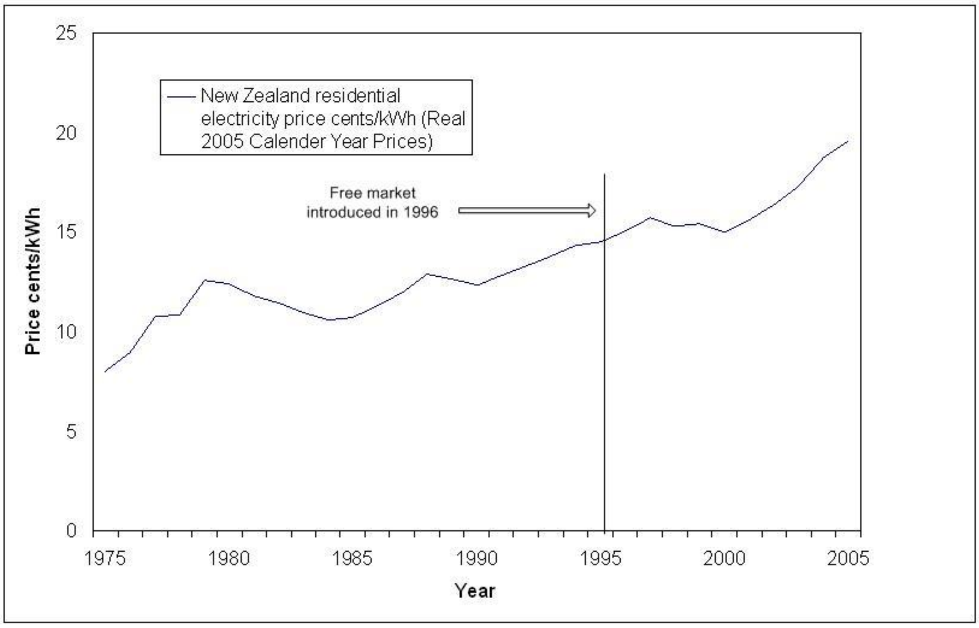


Figure 57 New Zealand residential electricity real prices.(MED 2006)

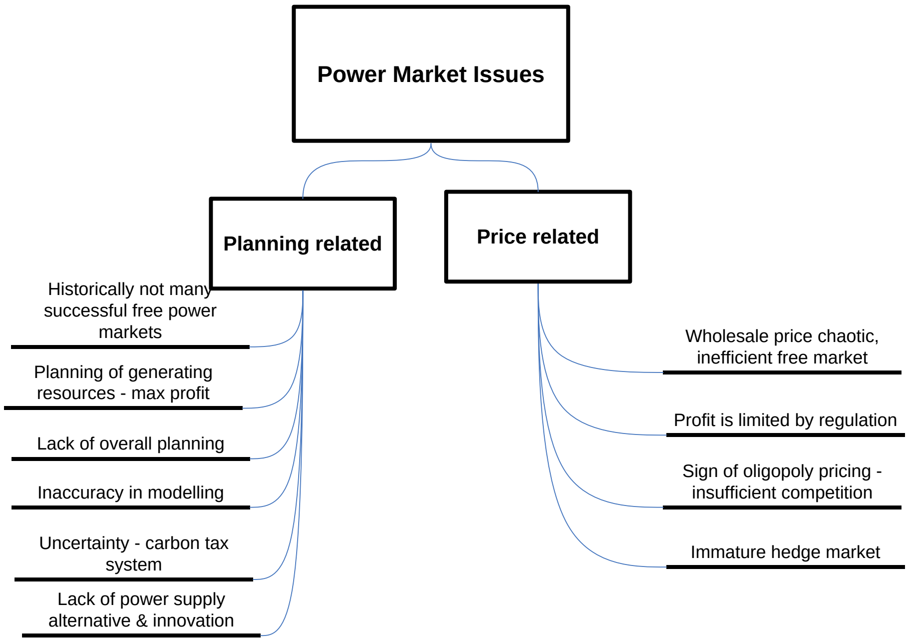


Figure 58 Power market sustainability issues

In case of New Zealand, the planning of generating resources is crucial — hydro generation contributes up to 65 percent of total generation, and the source of hydro is mainly rainfall. While thermal or hydro generation alone cannot supply the country's demand, generators have the freedom to decide on their generation source mix, using a combination of hydro, gas or coal, and there is an area of expertise called Reservoir Management where the amount of generation by hydro is managed so that a sufficient head of water is kept for the periods of high demand. Unfortunately, in an electricity market where the price elasticity of demand is low, producers can make more profit when there is a scarcity of generating resources, and the generators are not under legal obligation to stop that from happening. As a result, there is a risk that generators end up with insufficient power supply for the country at peak demand periods (because the reservoir level has been run down) and power-saving campaigns have to be launched as in 2001 and 2003. During these times, wholesale prices increased ten fold and the generators' profit increased significantly (see Table 17) while users, mainly industrial, suffered high power costs. This thesis is not proposing that power supply shortages were created artificially but it appears that the intrinsic nature of the New Zealand power market, with its over-dependency on the varying hydro supply, a lack of reserve generation and a transmission system that creates supply bottle necks, makes it an attractive business move.

Table 17 Genesis Power 2003 Financial Report (Genesis Power, 2003)

STATEMENT OF FINANCIAL PERFORMANCE		
	Group 2002 $000	Group 2003 $000
Operating Revenue	1,093,743	1,430,148
Operating Expense	1,023,592	1,324,694
Operating Surplus before Income Tax	70,151	105,454
Less Income Tax	22,088	44,340
Net SURPLUS	48,063	61,114

On the point of supply and consumption, there appears to be a lack of incentive to introduce innovative measures such as demand side management, distributed generation and combined heat and power (Cullen 2004), even though these are well known for overall energy savings in other countries.

Some studies, such as Cheng and Wilson (2004), which is summarised in Chapter 4, also show that the wholesale price indicates chaotic characteristics sometimes. What that means is that a small change in the conditions that affect the free market may cause a large fluctuation in the wholesale price. As a result, customers who are subjected to the wholesale price fluctuation, such as the ones not protected by hedged contracts or who do not have alternative power supply, are subjected to the risk of unpredictably high power bills. Although these periods of high price may last for a relatively short term, ranging from a few minutes to a few weeks, it may adversely affect some companies to the extent that they cannot financially survive that period.

Demand modeling provides the important data needed for the decision of building new generating facilities to ensure power shortages do not happen. But the logic of it remains controversial from the point of the generators because, while wanting to meet demand, generation companies have made more profits, which is what they want, from short-term power shortages which results in higher wholesale electricity spot price.

A free market, at least as a concept, is not supposed to be planned or instructed on supply, demand and pricing, and its daily running will be a consequence of the market force, but reality sometimes show otherwise. Problems did arise when the electricity wholesale market in New Zealand was left to its own devices, and a certain amount of central governance was needed to introduce order. That being said, New Zealand has moved through the stages from a centrally-planned market to a free market, but when significant issues arose, the government intervened and introduced rules and regulations, such as the recent introduction of the Electricity Commission in 2003 which is still experimenting with various degrees of planning (Electricity Commission 2003; Hodgson 2003). Also, despite being a free power market, the profit margin made by the transmission company is capped by regulations. Such limitations are not classified as an attraction for infrastructure investors.

The political climate in New Zealand gives a sense of uncertainty to the investors in the electricity sector because policies have changed within a short period. An example is the scrapping of the carbon tax. Also while the carbon trading system was proposed by the current Labour government, the opposition party, National, declared that the proposed carbon trading system will be scrapped if National gets into power (The National Party 2005).

Existing and proposed solutions identified for Power Market sustainability issues

The proposed solutions are summarised in Figure 59. Regarding Power Market issues, the government has reviewed market reform effectiveness and has policies to change market structure, improving it according to the lessons learnt and have a provision that, as a last resource, it has the authority to interrupt the market if necessary, which is actions it has done. The government also has created reserve power outside the free market and it can give incentives to encourage innovative solutions. The market may also be improved if minimum power supply standards and performance standards are enforced by regulations. Improvements in the accuracy of market supply and demand modeling could also make planning more accurate.

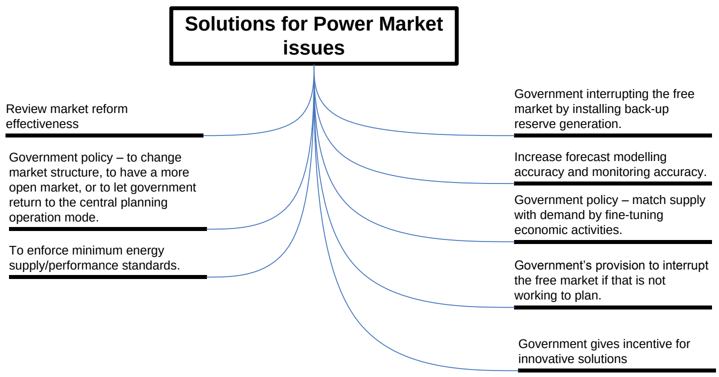


Figure 59 Proposed solutions for power market

The relationship between the sustainability issues and solutions are summarised in the matrix diagram Table 18.

Table 18 Electricity market issues/ solution chart

	Solutions							
Electricity market issues	Review reform effectiveness	Refine market structure	Enforce minimum quality standards	Government install own reserve power	Improve model accuracy	Govt fine tune economic activities	Govt authority to interrupt power market if needed	Government gives incentive for innovative solutions
Sign of oligopoly pricing - insufficient competition	X	X					X	
Wholesale price chaotic, inefficient free market	X	X			X			
Planning of generating resources – max profit		X	X				X	
Lack of overall planning	X	X	X	X		X	X	
Inaccuracy in modelling					X			
Historically not many successful free power markets	X							
Profit is limited by regulation		X				X	X	
Uncertainty – carbon tax system	X	X					X	
Immature hedge market		X					X	
Lack of power supply alternative and innovation				X			X	

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.4 The “industry background” issues: Industry structure and Economic

5.3.4.1 Industry structure issues and solutions

Industry structure issues ─ existence of energy intensive industries

The New Zealand government, in planning the development of the economic structure, has used its cheap industrial electricity price, generated from cheap Maui gas and hydro source, to attract energy intensive industries to New Zealand, such as an aluminium smelter and a steelwork. An excessive number of these industries will be in direct competition with the domestic market for electricity supply, bearing in mind the electricity price for the domestic market is more than double that for the average industrial user.

It should be noted that if too many users produce their own electricity with, for example, wind generation or combined heat and power plants, the demand of electricity from the grid and major generators will decrease which, in turn, will discourage further development and investment in the national grid. While it seems beneficial to the society in the sort term, a national grid has its advantages in being more reliable and has the ability of sharing resources if one of the generating elements fail. These issues are presented in Figure 60.

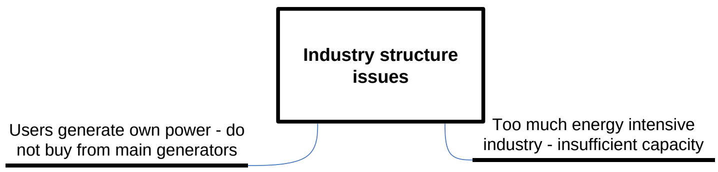


Figure 60 Industry structure sustainability issues

Existing and proposed solutions identified for Industry structure sustainability issues

In terms of industry structure where there may be an over-focus on power intensive industries, the government can adjust policy that maximises the benefit of the society by promoting a certain group of industries strategically and balancing the industry mix. The proposed solutions can be seen in Figure 61.

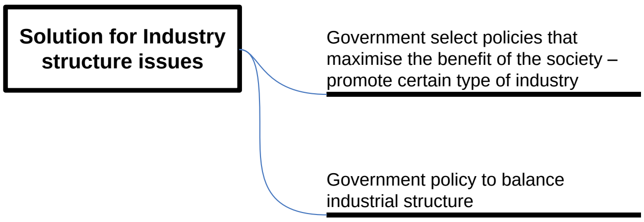


Figure 61 Proposed solutions for industry structure issue

The relationship between the sustainability issues and proposed solutions can be seen in the matrix diagram Table 19.

Table 19 Industry structure issues/solution chart

	Solutions	
Industry structure issues	Govt assists sector by selecting best policy	Govt policy to balance industrial structure
Too much energy intensive industry - insufficient capacity	X	X
Users generate own power - do not buy from main generators		X

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.4.2 Economic issues and solutions

Economic issues

The issues are summarised in Figure 62. When the growth in the economy results in an unexpected large growth in power usage and the capacity cannot meet demand, that poses a threat in a country with little spare generation and transmission capacity. In the case of New Zealand, because of the availability of cheap Maui gas for generation in the 1970s, New Zealand has attracted some power intensive investments like an ethanol plant which uses natural gas as raw material for manufacturing, and these are in direct competition with gas power generators.

Although not so obvious in New Zealand, power utilities need to be monitored if they are not performing well financially and may close down, affecting the market's supply.

There is no evidence to the public that the government has a contingency plan for generation in case of economic collapse or natural disaster.

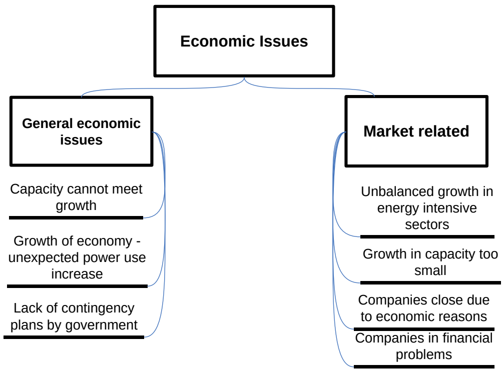


Figure 62 Economic sustainability issues

Existing and proposed solutions identified for Economic sustainability issues

The general economic environment affects the electricity sector so that in cases when the economy is in trouble, the government can actively help the generating companies by using economic instruments. Increasing capacity is important so is better planning of the sector that can be achieved by improving accuracy in modeling and prediction of supply and demand, using economic policy to prevent potential problems e.g. to select and encourage growth in less energy-intensive areas, and running campaigns on power conservation. The proposed solutions are summarised in Figure 63.

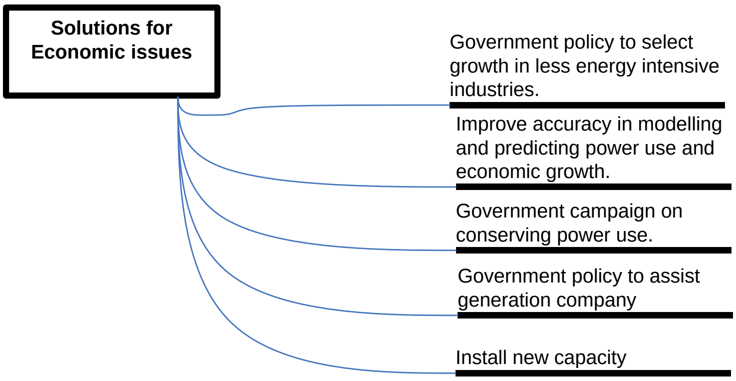


Figure 63 Proposed solutions for economic issues

The relationship between the sustainability issues and proposed solutions can be seen in the matrix diagram Table 20.

Table 20 Economics issues/solution chart

Economic Issues	Solutions				
	Government select growth in less energy intensive industries	Improve modelling accuracy & scenario analysis	Government campaign on power conservation.	Government policy to assist generation company	Install new capacity
Growth of economy - unexpected power use increase	X	X	X		
Unbalanced growth in energy intensive sectors.	X	X	X		X
Growth in capacity too small.		X			X
capacity cannot meet growth	X		X		
Power companies close due to economical reasons		X		X	
Power companies with financial problems		X		X	
Lack of contingency plan by government				X	

X = a matching relationship that the solution may be able to solve the sustainability issue.

5.3.5 Conclusion

Having analysed the main issues that have been causing sustainability problems in the electricity sector of New Zealand and learnt about the interactions between the stakeholders, existing or potential solutions were identified, where possible, with the intention of deriving indicators from these ideas. The existing and proposed solutions mentioned are listed out in Figure 64.

The issues faced by the electricity sector of New Zealand were classified into four main groups – the “hard” issues (including the dimensions of Generation, Fuel related, Transmission, Acts of God), the “soft” issues (including Environment, Ethical and Social), the “sector support” issues (including Technology, Investment and Power market) and the “sector background” issues (including Industry structure and Economics). For each group existing or potential solutions were identified. This information and their relationships will be useful at the latter stage of the methodology when the significant unsustainable issues are traced back from the indices and solutions are to be identified for carrying out improvements.

As a statement of caution, for practical reasons, the issues are not weighted in this methodology. It can be argued that it could have been implemented as in reliability or security analysis, the weakest link, or the most unsustainable area, should receive the most attention and that the total risks faced by a system should be the multiplication of all the risks in it. To take this into account would involve rigorous risk analysis beyond the scope of this thesis and could be the topic for a follow-up research project.

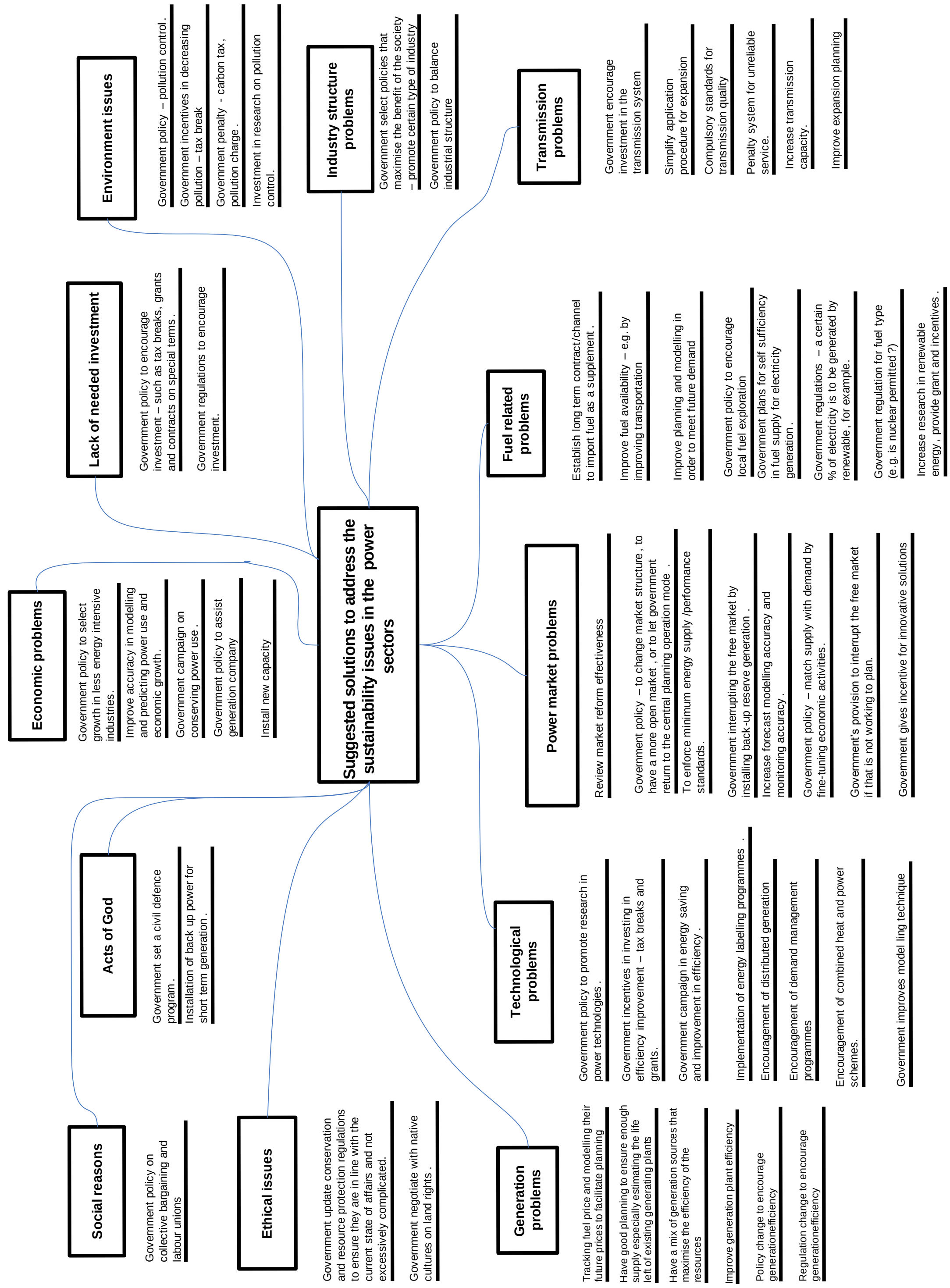


Figure 64 Proposed solutions of sustainability

5.4 Identification of the details of the dimensions of sustainability development.

The major aspects of sustainability are termed “dimensions of sustainability”. In this thesis six sustainability dimensions are being used by adding Technological, Ethical and Institutional to the traditional Triple-Bottom-Line Dimensions of Social, Environmental and Economic. The rationale for choosing these dimensions has been discussed in Chapter 2 and in this section the dimensions are further divided into sub-dimensions for a more refined analysis of the electricity sector. Because of the diversity of the sustainability concept, the sub-dimensions should be individually developed for each case study and they can assist users to focus on the specific issues of the sector under study. The detail of each dimension is described below and the overall sub-dimension grouping is shown in Figure 69.

5.4.1 Environmental dimension

Because of the relatively long history of environmental concerns and the highly visible nature of its impacts, the environmental aspect is one of the dimensions most exposed to public scrutiny. This aspect has been described in a number of ways but they have virtually the same message: a concern regarding SD, including the environmental and ecological conditions for species to live, especially human, and our obligation to maintain the gene pool on earth. Climate change, pollution, change of sea level, loss of species, lack of environmental conditions to grow food for human consumption, are all examples of unsustainable environments.

This case study has identified Pollution and Impact Assessment to be the aspects in this dimension that concern the public most (see Figure 65). Pollution is broken down into trend of pollution and the number of pollution complaints. Increasing pollution will cause more complaints but there is also the possibility that an increase in complaints received may be caused by an increase in the awareness of environmental issues and a simpler procedure for reporting. The management side also needs to be investigated, such as to monitor the number of new pollution control policies and the number of effective corrective actions. To be prepared for environmental disasters, Impact

Assessment (IA) needs to be made for power projects to demonstrate the readiness of the sector for unexpected events.

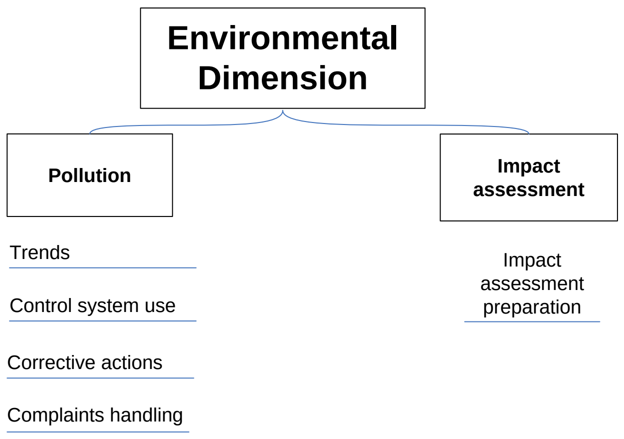


Figure 65 Environmental dimension analysis

5.4.2 Economic dimension.

Economic sustainability generally means having a reasonable annual increase in GDP, low unemployment, an expanding economy and growing industry and service sector. Economic unsustainability shows signs such as hyper-inflation, devaluated currency, high unemployment and a drop in economic activities. In this case, the economic aspects that affect the electricity sector's sustainability are: Market Control, Power Market conditions, Market Modeling and Power Market Economics.

This thesis considers the extent to which government imposes market control to be a major aspect here, as the government often has an overview of the economy, and is in a better position to make long term decisions that rise above short term commercial interest philosophy, and aim for longer term results (like 30 years). Having said that, it is also unfortunately true that market control activities, that do not give long term benefits, are sometimes used only to win elections. Under the Power Market Economics dimension, country-wide economy trends are considered as well as the sufficiency of new power plant planning and the sector's business performance.

In Power Market conditions, the aspects of the wholesale and consumer market are being looked into, as well as the power supply market, the fuel market and the transmission system's performance. The effectiveness of the planning for new generation plants will also be looked at, as well as the availability of market initiatives and the effects of any environmental conservation regulations on the industry. The number of companies that carry out sustainability reporting is also important. The sub-dimensions are listed out in detail in Figure 66.

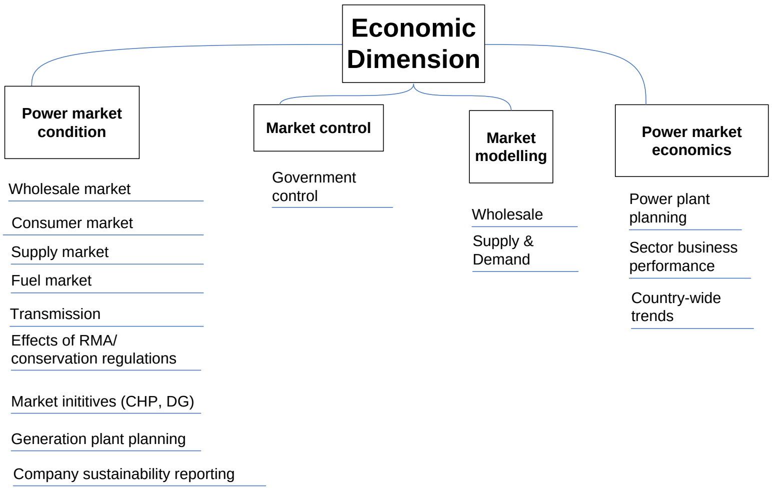


Figure 66 Economic Dimension analysis

5.4.3 Social dimension

SD covers a wide scope in this dimension – its meaning can range from having an expected life span not below the average, to fair treatment by international labour and human rights standards, to being physically and mentally healthy to live a productive and reproductive life. Admittedly, the judgment is subjective and the exact required conditions are opened for debate. These are complex issues and the solutions are beyond the scope of this thesis but bringing them up demonstrates the complexity of the SD issues. The sub-dimensions are listed out in Figure 67. The aspects chosen to investigate in this dimension are labour disputes and skill shortages.

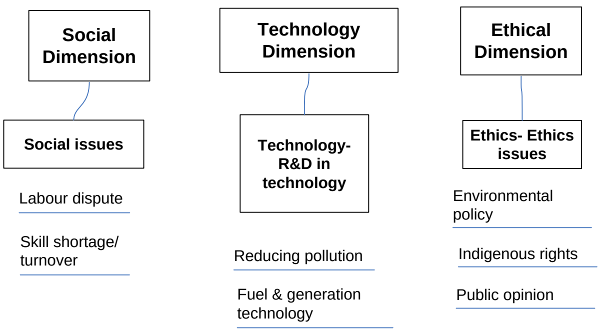


Figure 67 Dimension analysis for Social, Technological and Ethical dimensions

5.4.4 Technology Dimension.

Technologically sustainable means using technology to approach and solve today's problems. Examples are technology to reduce pollution and improved fuel and generation technology, having better energy efficiency, better ways to monitor SD projects and better modelling and simulation of the future. But as Albert Einstein once said, "*Unsere signifikanten Probleme können wir nicht auf der gleichen Ebene des Denkens lösen, auf der wir sie geschaffen haben,*" which translates to "Our most significant problems cannot be solved at the same level of thinking at which we produced them," (Flemings 2004), the sector should be looking for innovation and leap-frog improvements in technology that can solve today's and tomorrow's problems rather than the adaptation of today's technologies. The sub-dimensions are listed in Figure 67.

5.4.5 Ethical dimension

The world consists of different values and cultural views. When a country joins international agreements under international guidelines with economic or military pressure, the question is then whether or not the developed world is destroying the unique identity of the local cultures and local values it is trying to protect and preserve in the first place. Unsustainability in the ethical dimension would mean a gross disrespect of human life and a culture's customs and values.

Aspects under this category that affect New Zealanders most are the scope of indigenous rights ─ how they have affected the sector's development, the effect of the government's environmental policy and the influence public opinion has over developmental projects. The sub-dimensions are listed out in Figure 67.

5.4.6 Institution dimension

The importance of institutional influence is explained by Strong (2002) who asserts that "The systems of taxes, subsidies, regulations and policies through which our governments motivate the behaviour of individuals and corporations continues to incent unsustainable behaviours", and this sentiment is echoed by Brundtland Commission (1987) who emphasised that SD can only be achieved through political will. While many reports and studies can show the past and current sustainability conditions and recommend what institutional instruments could have been used, there is little methodology in the SD literature to help decision makers prioritise these projects. As a result, many projects solve the problems retroactively after they appeared, instead of taking a preventive approach. As many of these are on a national scale, the decisions often involve politics and political correctness, in a democratic society, especially if it is close to the end of the government's term and runs the risk of being only a short term solution to gain votes and win an election. While the society begins to realise the imminent and significant threats of sustainability, political parties need to have cross party talks and arrive at solutions that are good for New Zealand and not only for one political party, as proposed by the Prime Minister in Young (2007). The political decision making mechanism will not be covered here, but a simple methodology that can identify the crucial institutional problems using TQM methodologies is being proposed; it can also be designed to prioritise the problems according to the degrees to which they threaten sustainability.

The author suggests that unsustainability in the political dimension would mean the inability of the government to take political, economic or legal and legislative actions to improve the other five dimensions of sustainability.

Three areas under this dimension are being considered, they are: government policy, regulations and contingency planning. Under "policy", the effectiveness of the policies is measured in the following areas that are crucial to the sector's development: power market, transmission, energy investment, pollution control and economic instruments to encourage investment, power conservation, and ethical issues on industrial development. Under "regulations" aspects have been identified such as: minimum service quality, ability to interrupt the market, pollution laws, choice of fuel type (e.g. the non-nuclear policy in NZ), energy labeling of electrical appliances, free market control, and the proportion of renewable power generation. For "contingency planning", this thesis indicates how prepared the government is for the Acts of God (AoG). The sub-dimensions of this dimension are listed out in Figure 68.

All the dimensions and sub-dimensions of sustainability are presented in Figure 69.

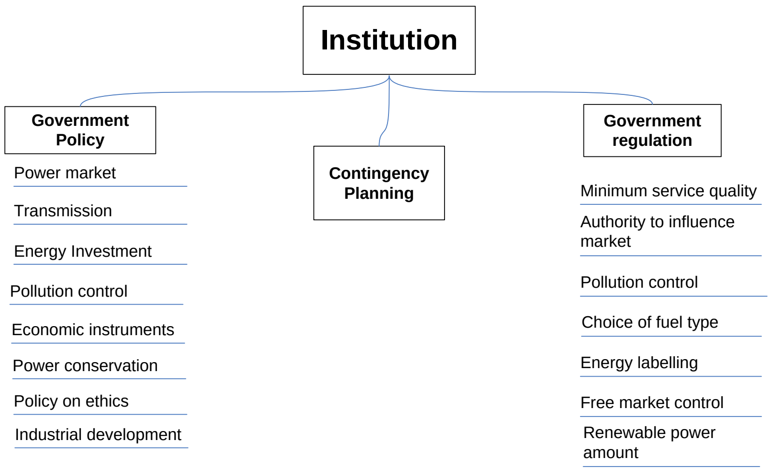


Figure 68 Analysis of Institution dimension

5.4.7 Conclusion

In this section, the electricity sector of New Zealand was analyzed under the six main dimensions ─ Social, Environment, Economy, Technology, Ethics and Institution. A number of sub-dimensions were identified that are relevant to the sector's current situation. At a later stage in this thesis, in section 5.7, indicators are assigned to each sub-dimension, the summary of which are the sustainability indices.

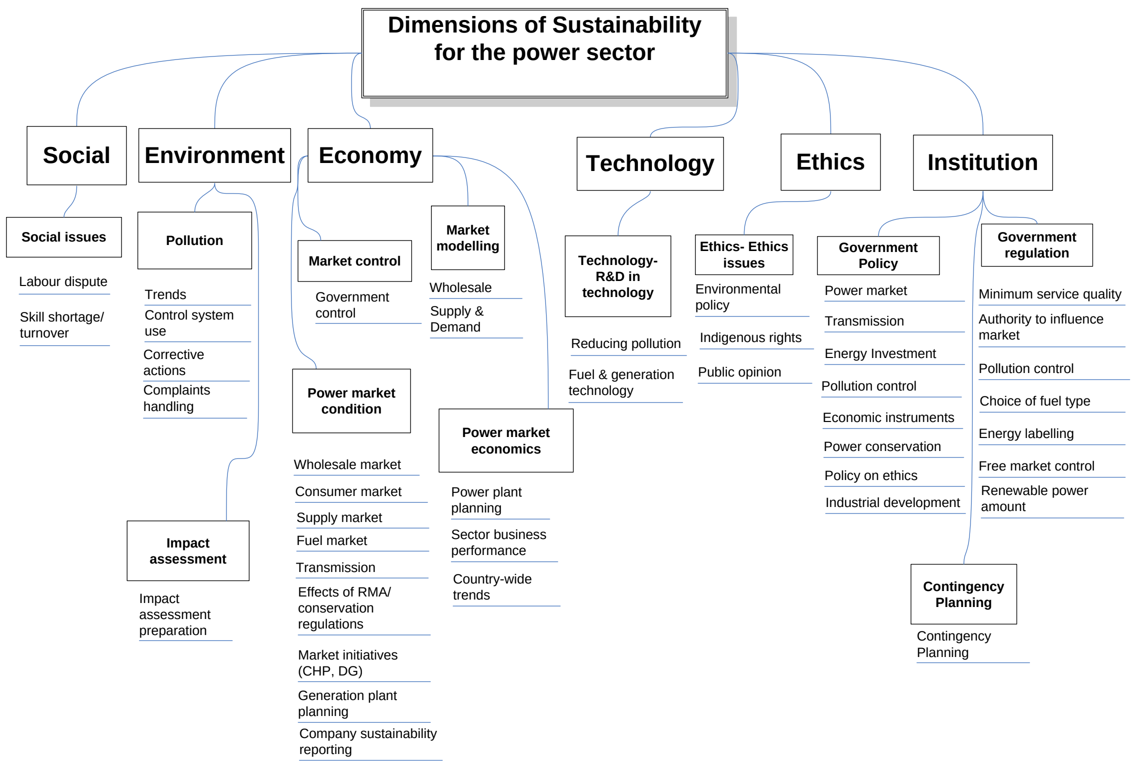


Figure 69 Dimensions of sustainability analysis tree diagram

5.5 Creation of indicators and categorizing them ─ Affinity Diagram.

In this step, by referring to the sustainability issues and proposed solutions identified earlier, a list of ideas are generated in a brain storming session and then converted into indicators by the investigation team. These indicators are organised and categorised by an Affinity Diagram, and in this case study they are grouped under twelve indicator headings, namely: Power market, Transmission, Fuel, Investment, Environmental, Economy, Technological, Generation, Ethical, Industry Structure and Acts of God. The question may arise asking, as the dimensions of sustainability have already been established, why then are the indicators not developed directly from them. It is true that it can be done, but that will not be a clean start for identifying indicators that focuses on sustainability issues which are obtained through a brain storming session and then categorised by an Affinity Diagram. By organizing into indicator groups, the stakeholders' interests can be addressed more directly. To demonstrate this point, an example is that the power market's operation is affected by government policy which has been established as an indicator, but government policy also affects the transmission industry, the generation industry, and investors' confidence, each of which is an indicator itself. In this example, there is a common factor called Government Policy, and in order to analyze how these government policies related indicators perform, these government policies related indicators, reflecting different stakeholders' interests, are gathered together under a government policy sub-dimension and an index can be generated for it. The indicators generated for this case study and their significance are described below.

5.5.1 Power market Indicators

In the 1990s the state owned power market was thought to be relatively inefficient at the time and that a free (or liberalised) market with competition could improve the service levels which included better reliability and lower prices, but there are now doubts on how valid these postulations are (MED 2006). The power market has been liberalised for about ten years now and the following is a set of points where indicators are created, as summarised in Figure 70, targeted at measuring the issues that most threaten the sector's sustainability.

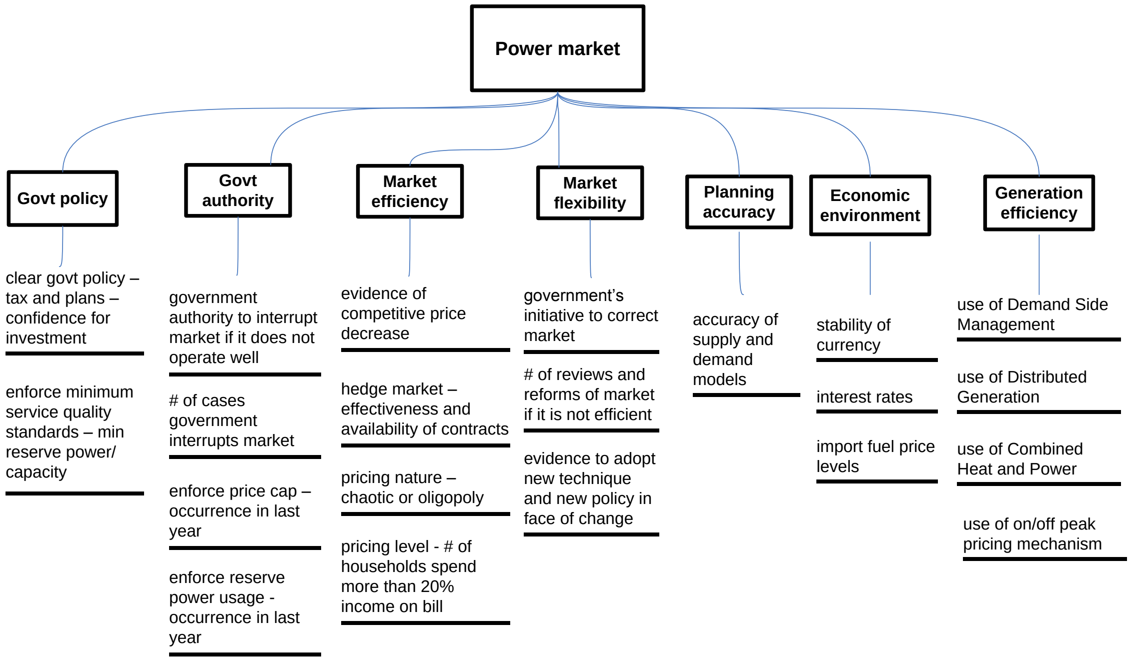


Figure 70 Power market Indicators analysis

Government policies play an important role in the development of an industry sector and if these policies are unclear, they will affect the confidence of potential investors. Low investment is a major factor causing unsustainability in a sector as constant injection of funds is needed to maintain and improve, let alone to expand it. This thesis measures how clear and consistent these policies are. Also government policies are checked for the setting of minimum quality standards, such as minimum power reserve or capacity.

Although it may not seem apparent, the extent to which the government has the means to interrupt the market, should it not perform, is also a crucial factor, thus, a method is developed to measure this. It can be, for example, to measure the extent authority has imposed a price cap or activate special reserved power generation that normally would not be used.

The economic and operational efficiency of the power market can be monitored as proposed in EECA (2001) as one of the main reasons the government turned the nationalized market into a free market was to attempt to increase its efficiency. One such measure is the evidence of competition which is supposed to result in price decrease and improved service level. It is possible that these market characteristics fail to materialise and signs of oligopoly need to be investigated. If it is oligopolistic, it will allow power companies to make “excessive profit” and disadvantage consumers. A measurement of how well the hedged market is working to provide customers with a stable and predictable electricity price also indicates how efficient the free market is. Market efficiency creates competitive pricing and a measure of what portion of household income that consumers spend on power bills is another useful indicator in this area.

A free market is dynamic and may results in situations the government had never previously expected. It is therefore important for the government to monitor the sector, as performed by the Commerce Commission, and be flexible in its actions to meet the market’s needs. Measurements need to be made of how much initiative the government has taken to correct the market if it goes in an undesirable direction, and how many reviews, reforms and new policies it has taken to improve it. Demand and supply modeling is performed by government and independent organisations. Their accuracy affects generators directly in the planning of production and the creation of new generation facilities, therefore, a measurement of their accuracy is needed.

The economic environment also affects the electricity sector in that a high local currency helps generators to import fuels and an interest rate change will affect sector investment decisions.

New initiatives to improve power efficiency in the power market are important and need to be monitored, such as the adaptation of Demand Side Management, Distributed Generation, Combined Heat and Power and Off-peak Pricing.

5.5.2 Transmission Indicators

Transmission (high voltage, long distance) and distribution (low voltage, shorter distance), simplified as transmission from this point on, is what links the generators to the users, a number of indicators are developed for this area (see Figure 71) but two areas are especially found to be important in monitoring their activities ─ the performance side and the business planning side. In the performance side measurements are made in terms of transmission breakdown time, occurrence of bottleneck situation, the amount of spare capacity and the completeness of its coverage to the population, comparing it with international standards or benchmarks. Improving and expanding transmission capacity needs investment and its sufficiency levels are measured. Evidence is also needed to show forward planning for new lines. From the view of the government who provides a structure for this sector, government policy and regulations are monitored, such as tax breaks, to encourage investment or more direct actions such as demanding compulsory spare capacity. To increase the confidence for investments in the sector, the government needs to make the policies clear and consistent and the clarity and consistency of them are measured.

There were a number of cases where overdue and important transmission expansions were delayed or stopped because of legal and public opinion issues (Inder 2006). These cases are monitored and see if regulations are being updated to meet current demands.

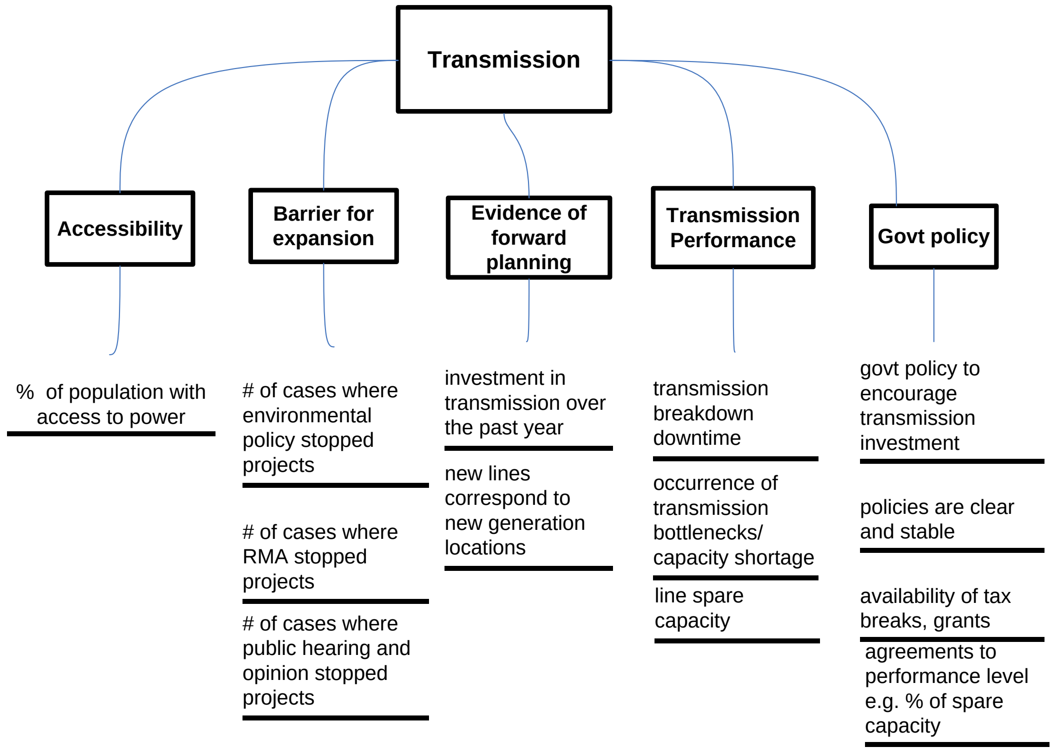


Figure 71 Transmission Indicators analysis

5.5.3 Fuel for generation Indicators

To be self-sustainable with regard to fuel (including fossil fuel) and not dependant upon external fuel sources is a target for a sustainable electricity sector in a country. To measure the magnitude of that, first, the percentage of fuel that is imported or exported is monitored, then, the amount of fuel reserve available, and whether there are regulations controlling these. The stability of imported fuel price is also monitored as well as the seasonal variation of generation resource (as in hydro lake levels that are affected by rainfall), and any fuel delivery problems (such as lack of efficient transportation system) and any long term contracts to secure supply.

To monitor the market planning aspects, the accuracy of fuel price predictions and the predictability of the recent fuel price are measured. Improvements and savings as a result of implementing new technologies from fuel research is also an indicator.

Requirements to use certain types of fuel, or limiting the use of some fuel types, affect the sustainability of the fuel source for the power market. What portion of total power generated needs to be from particular generating sources such as renewable ones enforced through regulations or policies is investigated, as well as what fuels are permitted (such as having a non-nuclear policy).

These indicators are summarised in Figure 72.

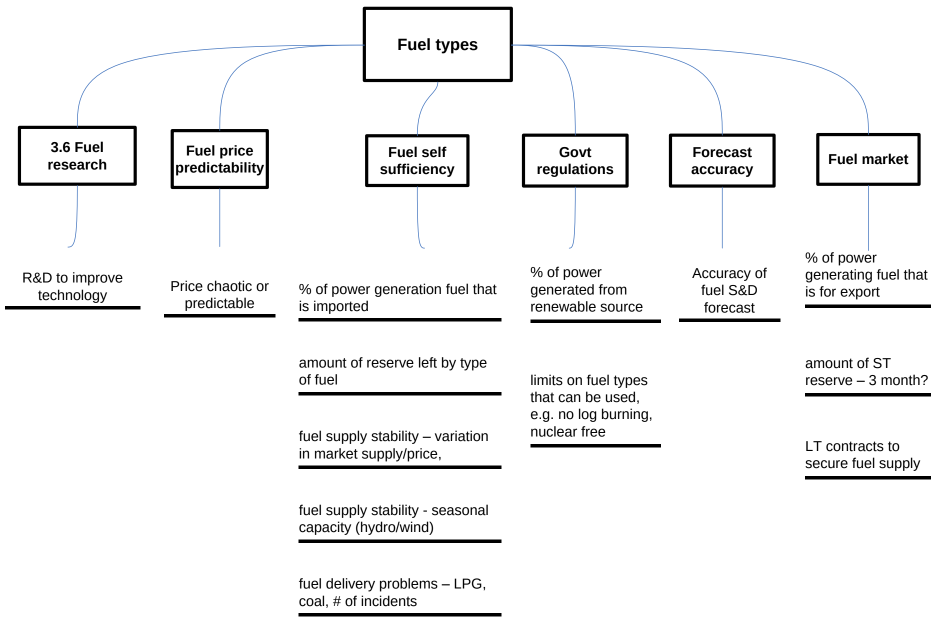


Figure 72 Fuel for generation Indicators analysis

5.5.4 Investment Indicators

Continuous investments keep the sector economically sustainable and the government can play an important role in attracting and retaining investments. Measurements are made on the use of economic tools such as tax breaks and grants in encouraging investment in the sector's R&D and in generation.

The amount of long term investment is affected by the schedule of retiring old generating plants, transmission lines, auxiliary engineering infrastructure and plans to build new plants. Measurements are also made on the availability of these and the supply and demand situation for the future. The indicators are summarised in Figure 73.

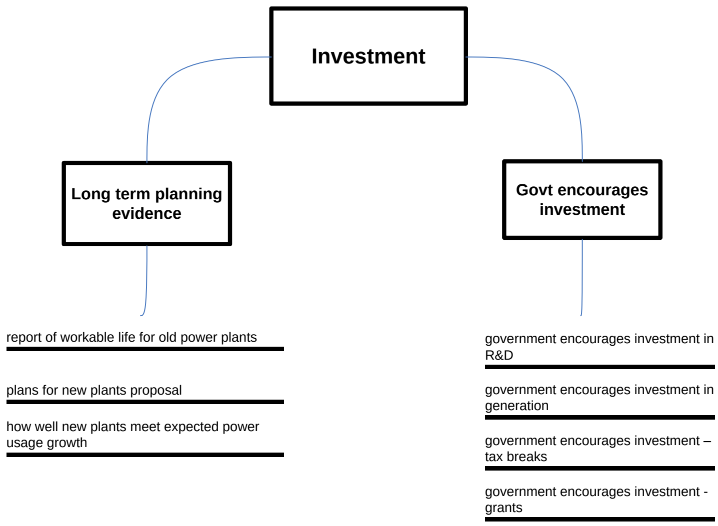


Figure 73 Investment Indicators analysis

5.5.5 Environmental Indicators

A significant amount of environmental issues arise due to the by-products from the electricity sector, be that in atmospheric particulates, greenhouse gas, solid waste, sound, visual effects or waste heat. It is challenging to select a comprehensive list of indicators but our choice here is considered appropriate for this case study.

Pollution and conservation can be effectively controlled by laws and regulations but an overprotective legal system will limit the ability for the sector to develop in a sustainable way — such is one of the many examples of the concept of the "Paradox of

Sustainability" as pointed out in Malitza and Bucharest (2000). Measurements are made on whether the laws and regulations are considered appropriate, and the number of legal cases on pollution brought before the court. The number of projects that are negatively affected by these regulations are looked at and how much the regulations have been reviewed to match current market needs assessed. The results in New Zealand can also be compared with a reference group such as the ODEC countries.

The government's role in reducing pollution can be seen in the usage of economic instruments, like grants and tax breaks, to encourage reductions. Also, the amount of funding for R&D in pollution control and the number of pollution control projects in the sector has direct effects and will be measured.

Statistically, the availability of pollution data is looked at, as well as their trends, and the statistics of companies in the industry that have Environmental Management System (EMS) or ISO 14000 and/or have carried out Impact Assessment studies found out.

These indicators are summarised in Figure 74.

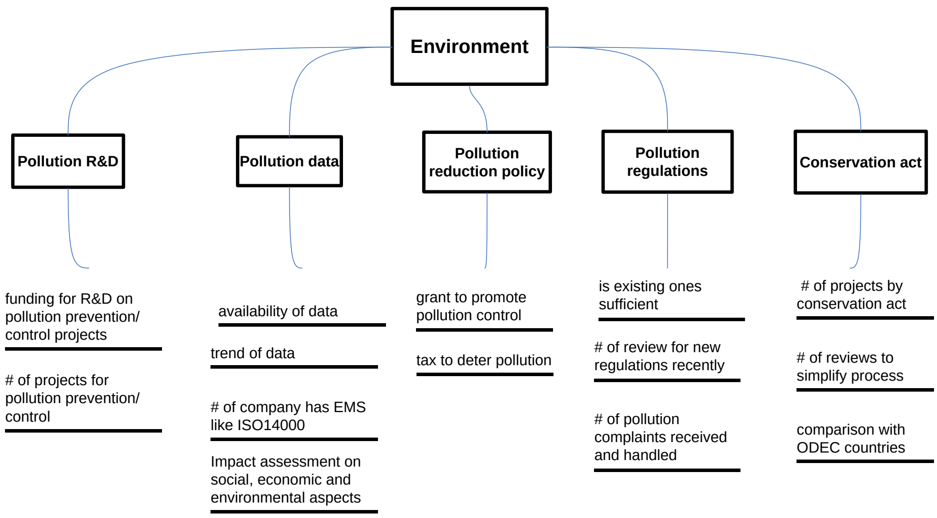


Figure 74 Environment Indicators analysis

5.5.6 Economy Indicators

A sector's production is sustainable if the combined capacity of the companies that make it up, and their service, can support its customer base and if this total output level can continuously meet the changes in demand. Although an individual company may close down, the sustainable economic situation of the average companies can allow the sector to operate at least in the short and medium term. From the business viability point, to monitor the sustainability of a sector, there is a wide range of complicated financial indicators some of which are beyond the scope of this paper. But here, the following indicators have been chosen to measure the sector's trend in production, its turnover and profit, and compare it with other ODEC countries.

The accuracy of scenario modeling and their sufficiency for the sector and for the economy is important and will also be measured.

The Government plays an important role in the planning and the operation of the economy. Measurements are made on the effectiveness of its energy conservation plans, the availability of plans in case of emergency power interruption, such as an earthquake, and the availability of the sector's impact assessment reports. These indicators are summarised in Figure 75.

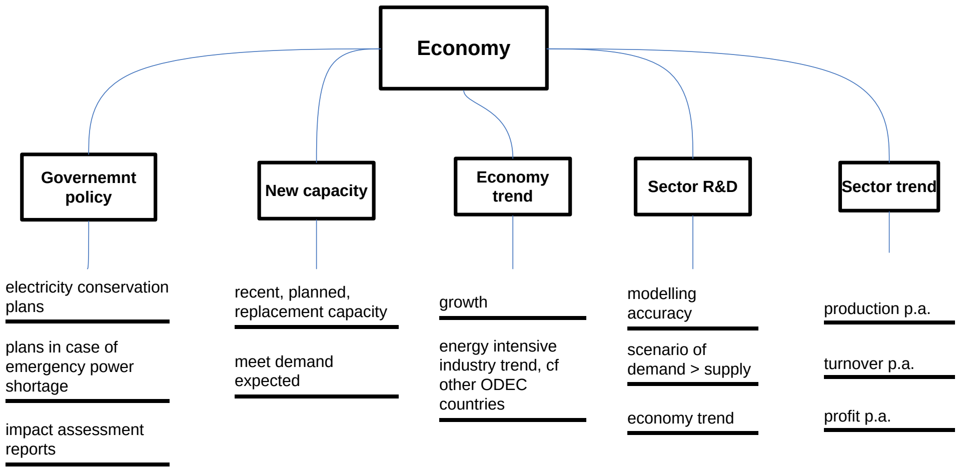


Figure 75 Economy Indicators analysis

5.5.7 Technological Indicators

Besides political and economic solutions, technological solutions are also of utmost important since they affect the production, transmission and usage of electricity. Technological advancements in New Zealand often are initiated by the government with projects such as the implementation of energy labeling systems, energy improvement projects and conservation campaigns, as well as new energy conserving initiatives such as Demand Management, Combined Heat and Power, and Distributed Generation. The amount spend on R&D spend in this area is measured.

On the policy side, whether the government is creating a special workforce to handle these issues is monitored, and whether if economic tools such as tax incentives are introduced for technological advances in increasing efficiency of power use, generation and consumption.

The techniques of modeling supply and demand, their accuracy and the effectiveness of scenarios analysis also need to be measured.

These indicators are summarised in Figure 76.

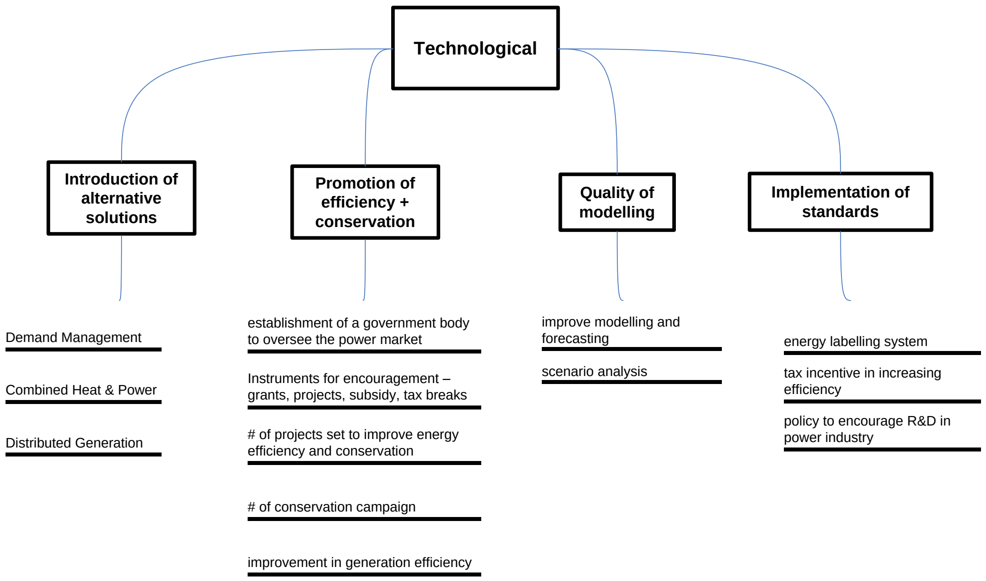


Figure 76 Technological Indicators analysis

5.5.8 Generation Indicators

From the grouping method used in this thesis, Generation indicators fall into three areas: fuel price, generating plant planning and regulation. What needs to be measured is the fuel price trend and its affordability as well as the clarity of potential price increases like the possibility of introducing a carbon tax. Secondly, the number of newly commissioned generation plants is measured, as well as plant upgrades, the number of plants near the end of their life and any plans to replace their capacity. The efficiency of the mix of generation resource (generation mix) is measured and it needs to identify if guidelines or regulations are required for generators to manage generation resources in an efficient way. These indicators are summarised in Figure 77.

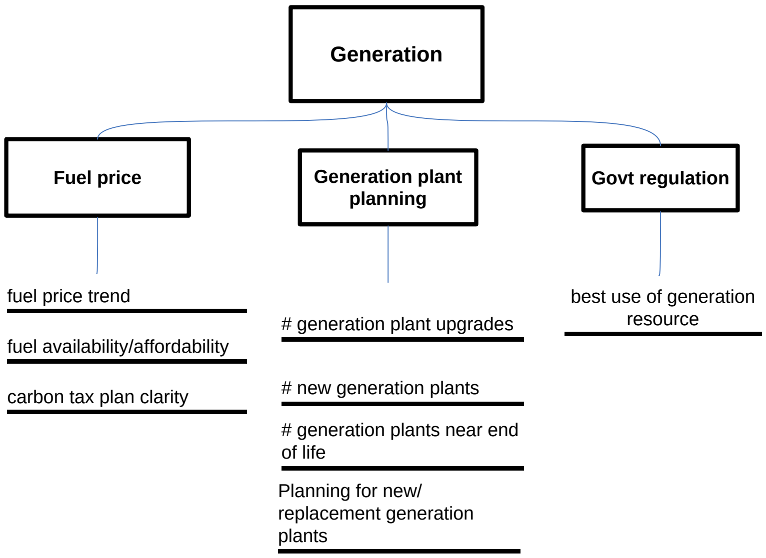


Figure 77 Generation Indicators analysis

5.5.9 Ethical Indicators

An excessively strong ethical stand in the society and an overprotective set of regulations will hinder power project developments such as the cancellation of the Project Aqua as described in Bennett (2007). It is an example of the paradox of sustainability (Malitza and Bucharest 2000) where an attempt to make the society more sustainable, from an environmental view, results in a less sustainable society because the action has increased the risks for power shortages. To that end, the number of projects interrupted or stopped due to ethical disputes are measured and the number of case reviews taken during the public hearing process counted. The methodology also considers how easy it is for the public, even those with non-legitimate claims, to access the public enquiry system and delay projects through the legal process. The effectiveness of the current indigenous rights regulations is rated from the view of constructing essential power services. The willingness of the government to improve the situation is measured in terms of the number of reviews and modifications made to the current regulations and the average time required to resolve the disputes and approve the projects. This area is understandably politically, culturally and ethically debatable, but still, a pre-defined set of criteria is needed to give an objective metric to measure it. The government's stand on generation options are measured and how democratic they are in terms of listening to public opinions are rated. Last of all, the methodology also measures the number of companies that produce ethics reports and sustainability reports with quantitative results or in a descriptive style such as that proposed in GRI (2007). These indicators are summarised in Figure 78.

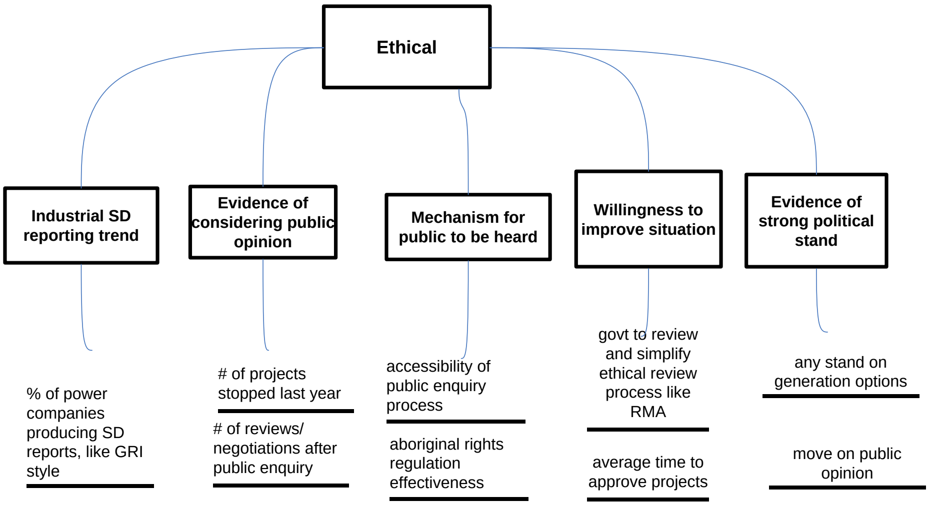


Figure 78 Ethical Indicators analysis

5.5.10 Social Indicators

On the social side, the main concern is the labour market, measuring the strength of the labour unions, and the number of union related work stoppages and interruptions if there are any. These indicators are summarised in Figure 79.

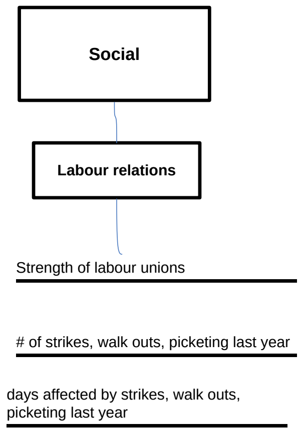


Figure 79 Social Indicators analysis

5.5.11 Industry structure Indicators

If there is an unbalanced growth in the power intensive sectors such as steel work and aluminium smelting, that would put a strain on the power supply market. The number of companies in the electricity power intensive sector is measured, and the growth in their numbers monitored to review the government's policy and see if it encourages power intensive industries. These indicators are summarised in Figure 80.

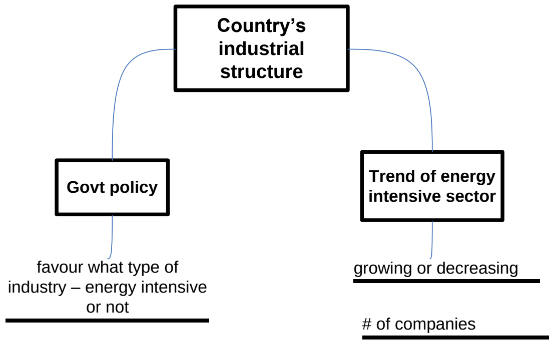


Figure 80 Industry structure Indicators analysis

5.5.12 Acts of God Indicators

In anticipation of the unexpected loss of regular power generation or transmission capacity, the completeness of backup preparations is measured such as backup capacity, amount of reserved fuel, backup generation plans, impact assessment reports and civil defence plans. Historic data is also monitored on areas such as: number of down transmission lines due to natural causes, the weather pattern that causes peak demands, the occurrence of droughts that limit hydro generation and other weather conditions that affect generating and transmission services. These indicators are summarised in Figure 81.

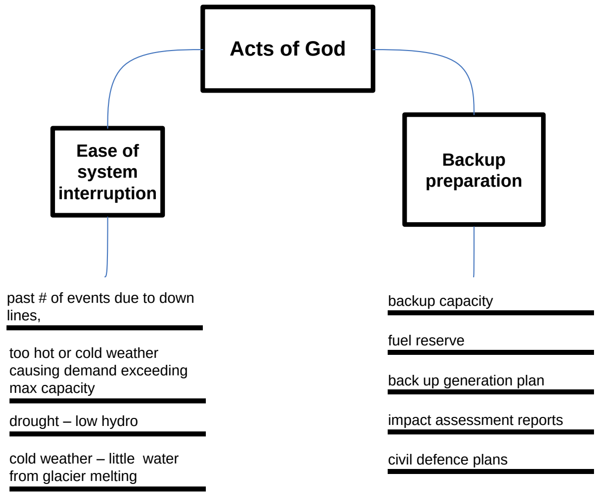


Figure 81 Acts of God Indicators analysis

5.5.13 Conclusion

Indicators of sustainability for the electricity sector of New Zealand were identified by referring to the sector's sustainability issues, their relationships and possible solutions. The indicators were then categorised into twelve groups (see Figure 82).

It is worth emphasizing that these indicators are designed to measure specific issues that were identified as unsustainable, or potentially so, in the electricity sector and they are not the "general" sustainability indicators for the sector. Indices need to be referred to highlighting this context.

While the coverage for the indicators measuring unsustainability is comprehensive for the purpose of this thesis, data may not be available for all of them. In such cases, this shall be noted and best estimates made. If that is not possible, the indicator may then be deemed unsuitable for use and needs to be taken off the list.

After the indicators have been selected, the next step in quantification of the data, as described in section 5.8, is expected to cause controversy. Even so, indicators still need to be converted into a scalar in an open manner, requiring conversation among the stakeholders to arrive at a consensus.

The next step is to analyse the nature of the indicators so that they can be allocated to the appropriate sustainability dimensions and stakeholders.

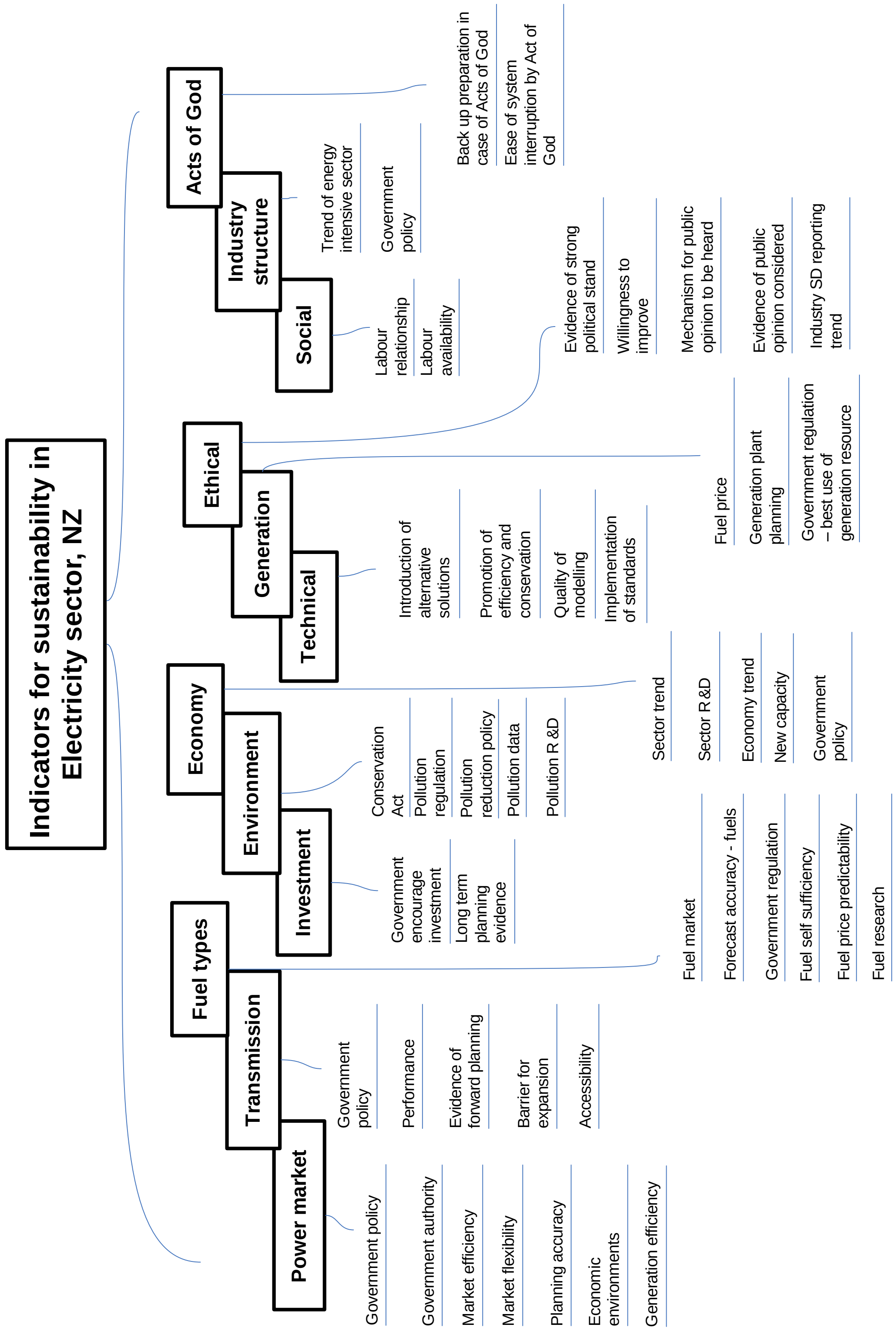


Figure 82 Sustainability issues and their indicators

5.6 Creation of the Indicator/ Issue Matrix

After the indicators are categorised as in section 5.5, with reference to the issues identified and the solutions suggested in section 5.3, the next process is to investigate which indicators can be used to measure the sustainability of each sustainability issue, bearing in mind an indicator can directly or indirectly reflect the sustainability of an issue. For example, for the issue of excessive pollution, it can be measured by indicators in the area of: the sufficiency of pollution regulation, the number of pollution complaints, the trend of pollution level, and the number of pollution control projects introduced in the last measuring period.

To clarify the relationships among the sustainability indicators and the sustainability issues, a Sustainability indicator/Issue Matrix is created which is presented in Appendix 1. Later in the methodology (section 5.12) indicators of significantly low level are identified and traced back to the issues they are related to through the use of this matrix.

5.7 Allocation of indicators to dimensions and stakeholders

The next step in analyzing the sustainability relationships among sustainability indicators, sustainability dimensions and stakeholders is a process that finds out, for each sub-dimension of sustainability, which indicators can best describe the sub-dimension's sustainability status. It is an iterative process where each indicator is tested for its suitability to describe sustainability for the different sub-dimensions and if it is considered suitable, that indicator will go into the list of indicators that describes the sustainability situation of that one sub-dimension. When the allocation process is completed, the indicators for each sub-dimension are further matched to stakeholders so that the stakeholders can choose which indicators in the sub-dimension are most relevant to describe their sustainability concerns. Our findings for each dimension can be summarised below. The process of how the indicators are assigned to the dimensions is described, and the stakeholders that would be involved with each indicator are listed in brackets.

5.7.1 Environmental dimension – indicators allocation

In the environmental dimension, pollution is first considered, on the availability of pollution data in the power industry and the trend of its elements (both related to Generator, Society). The government's effort in reducing pollution in generation is next looked at and the number of court cases regarding excessive pollution (Fuel Supplier, Generator, Society) counted, as shown in Table 21. For the individual businesses in the sector, their contribution to reducing pollution is measured in the installation of an Environmental Management System (EMS) and the number of firms that have that in place is fond out (Fuel Supplier, Generator, Transmission, Society).

The following abbreviations will be used for the stakeholders in the tables Table 21 to Table 40: Fuel Supply = FS, Generation = Gen, Transmission = Tr, Wholesaler = Wh, Retailers = Ret, Consumers = Con, and Society = Soc, and ■ indicates a matching relationship between the indicator and the stakeholder. In these tables, the dimension and sub-dimensions are shown on the left most column with the indicators for them in the second column. The columns on the right show the matching relationship between the stakeholders and the indicators.

Table 21 Environmental dimension indicator allocation to stakeholders

Pollution sub-dimensions	**Indicators**	FS	Gen	Tr	Wh	Ret	Con	Soc
Data on pollution	Availability of pollution data		■					■
	Trend of pollution data		■					■
Company's pollution control program	Number/percentage of power companies that have EMS (Environmental Management System) such as ISO14000	■	■	■				■
Actions taken on pollution	Number of pollution control projects initiated by government in electricity sector.	■	■					■
Pollution complaints data	Number of pollution complaint cases received and handled in electricity sector	■	■					■

Abbreviations used on matrix chart: FS=Fuel Supply, Gen=Generator, Tra=Transmission, Who=Wholesaler, Ret=Retail, Con=Consumers, Soc=Society. ■ indicates a matching relationship between the indicator/index and the stakeholder.

5.7.2 Ethical dimension – indicators allocation

Ethics plays a crucial part in sustainability management. It is shaped by cultural values that may change with time but its bottom line takes the shape of laws and regulations determined by the government and, in a democratic society, occasionally with inputs from the public.

In this sub-dimension, indicators are selected under three sub-dimensions: environmental, indigenous rights and effects of public opinion as shown in Table 22.

Table 22 Ethical dimension indicator allocation to stakeholders

Ethical issues sub-dimensions	**Indicators**	FS	Gen	Tr	Wh	Ret	Con	Soc
Environmental issues – ethical	Number of cases where environmental policy stopped projects	■	■	■				
	Number of cases where public hearing and opinion stopped projects	■	■	■				
Indigenous rights – ethical	Number of cases where public hearing and opinion stopped projects	■	■	■				
	Indigenous rights – fairness and practicality.							■
Public opinion survey – ethical	Number of cases where RMA stopped projects	■	■	■				
	Number of cases where public hearing and opinion stopped projects	■	■	■				
	Cases of projects cancelled because of public opinion	■	■	■				
	Number of projects stopped last year due to public opinion	■	■	■				
	Number of projects approved by resource consent but with changes	■	■	■				

The number of cases where interruption to power projects are looked at to analyse if the causes were due to environmental policies, regulations, public hearings or indigenous rights issues (all related to Fuel Supplier, Generator, Transmission). The fairness of the indigenous rights legal system is reviewed as to its practicality in a modern society, looking at the court cases where appeals have been granted in the interest of the Treaty of Waitangi (Social).

To measure how public opinions affect the industry, measurements are made on the degree of, and how many projects are, stopped or delayed by public objections and the Resource Management Act outright or approved with changes (all related to Fuel Supplier, Generator, Transmission). Some issues are covered by indicators from different indicator groups and this indicates the relative importance, or weighting, of the issues.

5.7.3 Social dimension – indicators allocation

In the social dimension, as seen in Table 23, the main issues that affect the sustainability of the sector are skill shortages in the labour market, where less skilled staff may not operate, or maintain a fault free operation, as efficiently and effectively as compared with skilled labour, and industrial actions that interrupt generation or transmission. In the labour market, the measures chosen are the degree of labour shortage and the amount of labour turnover (all are related to Fuel Supplier, Generator, Transmission).

In measuring the degree of labour dispute threats, industrial action statistics is obtained and rated on to indicate how much influence unions have on causing work interruptions (all are related to Fuel Supplier, Generator, Transmission).

Table 23 Social dimension indicator allocation to stakeholders

Social issues sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
Labour disputes	Existence of labour unions	■	■	■				
	Number of strikes, walk outs, picketing last year	■	■	■				
	Days affected by strikes, walk outs, picketing last year	■	■	■				
Labour skill shortage/turnover	Labour skill shortage	■	■	■				
	Labour turnover	■	■	■				

5.7.4 Technological dimension – indicators allocation

The focus in this dimension is on the R&D of the electricity sector in the technological improvements sub-dimension in areas of pollution (Generator, Society), fuel technology (Fuel Supplier, Generator, Consumers) and in transmission technology (Transmission) as seen in Table 24.

Table 24 Technological dimension indicator allocation to stakeholders

R&D sub-Dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
Pollution – R&D	Government promotes funding for R&D on pollution prevention/control projects in electricity sector		■					■
New generation and fuel technology – R&D	Amount of R&D to improve fuel technology	■	■				■	
R&D in improving transmission	Amount of R&D in improving transmission technologies and planning			■				

5.7.5 Economic dimension – indicators allocation

In this study, economic is the dimension with the most elements, or sub-dimensions, and the following sections describe how indicators are assigned to the sub-dimensions of Market Statistics, Market Analysis, Market Models and Economy Analysis.

Economic dimension - Market Statistics sub-dimension

In the area of Market Statistics the significant events that happened in the free market which affect its sustainability are looked at. To achieve this, the statistic of the government interrupting the free market to keep it within a reasonable state is measured (Fuel Supplier, Generator, Transmitter, Wholesaler, Retailer) (refer to Table 25), including events such as the enforcement of price cap (Transmitter, Wholesaler, Retailer) and activating the ring-fenced reserve power (Generator).

Table 25 Market statistics sub-dimension indicator allocation to stakeholders

Market Statistics sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
Free market statistics	Number of cases where government interrupted free market	■	■	■	■	■		
	Government enforced price cap, number of occurrences in last year			■	■	■		
	Government enforced reserve power usage – occurrence in last year		■					

Economic dimension ─ Market Analysis sub-dimension

In the market analysis sub-dimension, the sub-dimension are broken down into the following elements which will then be described in detail: wholesale market, consumer market, supply market, fuel market, transmission market, effects of Conservation Act, use of energy efficiency practices, generating plant data and the adoption of sustainability reporting.

Economic dimension ─ wholesale market analysis sub-dimension

Economic statistics on the wholesale market can reveal the state of health of the sector. To monitor wholesale electricity price, the evidence of price decrease due to competition is measured (Wholesaler, Consumers). A hedge market that operates well can buffer users against power price spikes that are caused by unforeseeable events. Thus the effectiveness of the hedge market and the nature of the wholesale price is measured, whether it is predictable, chaotic, or whether it shows an oligopoly nature (Wholesaler, Consumers) and conclude how efficient the wholesale market is (Wholesaler). The affordability of power to the public is looked at in terms of number of households that spend more than 20 percent of their income on their power bill (Wholesaler, Consumers). The initiative (Wholesaler) and the amount of effort the government has put in to improve the wholesale market is looked at by measuring the number of government reviews and market reforms to improve efficiency (Wholesaler). The government needs to be flexible and meet the market's needs thus evidence is needed where the government has adopted new techniques and policies in the face of change (Wholesaler). Lastly the fuel price trend is tested for chaotic nature in case it is the main factor that influences the wholesale price spikes (Consumers). The summary of the indicators' allocation to stakeholders can be seen in Table 26.

Table 26 Wholesale market sub-dimension indicator allocation to stakeholders

Wholesale market analysis sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
	Evidence of price decrease due to competition				■		■	
	Wholesale price hedge market – effectiveness and availability of contracts				■		■	
	Wholesale pricing nature – chaotic or oligopoly				■		■	
	Price affordability ─ # of households spend more than 20% income on bill				■		■	
	Evidence of oligopoly/excessive profit/inefficient market				■			
	Government's initiative to correct inefficient market				■			
	Number of government reviews and market reforms to improve efficiency				■			
	Evidence of government adopting new techniques and new policies in face of change				■			
	Fuel price chaotic or predictable						■	

Economic dimension ─ consumer market sub-dimension

In the consumer market, as seen in Table 27, focus is on ways that have enhanced power efficiency from the users' side such as demand side management, distributed generation, combined heat and power, and that can improve energy efficiency and conservation (Generator, Transmitter, Consumers). From the suppliers' side, the implementation of an on/off peak pricing mechanism is looked at (Generator, Transmitter). Direct measures such as the proportion of population that has access to transmitted power and the number of the projects set to improve power use efficiency are used (Consumers) as well as the history of excessively hot or cold weather that caused excessive demand (Generator, Transmission, Consumers).

Table 27 Consumer market sub-dimension indicator allocation to stakeholders

Consumer market analysis sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
	Use of demand side management by customers		■	■			■	
	Adaptation of distributed generation by generators		■	■			■	
	Use of combined heat and power by customers		■	■			■	
	Implement on/off peak pricing mechanism as a market mechanism.		■	■				
	% of population with access to transmitted power						■	
	# of projects set to improve energy efficiency and conservation						■	
	History of too hot or cold weather causing demand above max capacity		■	■			■	

Economic dimension ─ supply market sub-dimension

In measuring the sustainability of the electricity supply market, the main focus is on the generator. Measurements are made on the remaining life of the plants (Generator), the number of, and the sufficiency of, plans for building new ones (Generator), the capacity of the planned ones with respect to expected demand (Generator, Transmission, Consumers), and also cases where proposed plants cannot go ahead because of public opposition (Generator, Transmission). To access the security of supply, the amount of backup capacity and any emergency generation plans is assessed (Generator, Consumers) and any history of interruption of supply due to weather pattern (drought that affects hydro) or earthquake (as NZ is in a volcanic zone) (Fuel Supplier, Generator, Consumers). From the technological side of the supply the improvement of generation efficiency over the years is monitored (Generator). The summary of the indicators' allocation to stakeholders can be seen in Table 28.

Table 28 Supply market sub-dimension indicator allocation to stakeholders

Supply market analysis sub-dimension	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
	Data of remaining workable life for old power plants		■					
	Plans for building new generation plants		■					
	Sufficiency of planned new plants to meet expected need		■					
	Cases of projects cancelled because of public opinion		■	■				
	Amount of recent, planned, replacement generation capacity		■					
	Evidence new planned capacity will meet expected demand		■	■			■	
	Backup capacity		■					
	Back up generation plan		■				■	
	Trend of improvement in generation efficiency		■					
	History of drought – low hydro head	■					■	
	History of events affecting the supply of renewable energy (e.g. earthquake affects hydro dam)	■					■	

Economic dimension ─ fuel market sub-dimension

The fuel market also plays a major role in determining the sustainability of the power market. The components that will be measured are fuel prices, fuel reserve, and stability of supply as shown in Table 29. On the fuel price side what needs to be measures are the stability of fuel price (Fuel Supplier), import fuel price level (Fuel Supplier), and how predictable or modelable are the prices (Fuel Supplier). The affordability of the fuel is also looked at (Fuel Supplier, Generator).

Fuel reserve aspects are covered by how much reserve stock there is (Fuel Supplier, Generator) and how long they can supply the market (Fuel Supplier, Generator). How much fuel is imported and exported is also checked (Fuel Supplier).

For security of supply, information is gathered on the supply stability of renewable fuel resource (e.g. seasonal wind conditions) (Fuel Supplier) and any delivery problems for fuel (e.g. rail system for coal or pipeline for LPG) (Fuel Supplier). The number of long term fuel contracts that help to secure supply is also looked at (Fuel Supplier, Generator).

Table 29 Fuel market sub-dimension indicator allocation to stakeholders

Fuel market analysis sub-dimension	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
	Import fuel price levels	■						
	Percentage of power generating fuel used for export	■						
	Percentage of generation fuel used that is imported.	■						
	Duration stock reserve can last – 3 months?	■	■					
	Long term contracts to secure fuel supply	■	■					
	Amount of reserve fuel held by type of fuel	■	■					
	Fuel supply stability – variation in market supply/price,	■						
	Renewable fuel supply stability ─ seasonal capacity (hydro/wind)	■						
	Fuel delivery problems – LPG, coal, number of cases.	■						
	Fuel price chaotic or predictable	■						
	Generation fuel price trend	■	■					
	Generation fuel availability/affordability	■	■					
	Generation fuel reserve	■	■					

Economic dimension ─ transmission sub-dimension

Transmission is the backbone of the power system. Usually transmission is a term for long distance and distribution is a term for local transmission. In this case study, to avoid over-complication, the two is combined into a single category, “transmission”, and investigate the components that describe its sustainability, as seen in Table 30.

To obtain an overall picture, the amount of downtime on transmission is measured (Transmission, Consumers), the number of households affected by power cuts (Transmission, Consumers) and the occurrence of bottlenecks due to problems of the transmission system (Transmission, Consumers). To investigate how well planning has been done, the amount of spare capacity the transmission system has is calculated (Transmission) and the adequacy of planning to build new hardware to improvement the situation (Transmission). The system cannot be improved without investment and so measurement is also made on the amount invested in the transmission sector (Transmission).

Table 30 Transmission sub-dimension indicator allocation to stakeholders

Transmission analysis sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
	Transmission downtime statistics			■			■	
	Occurrence of transmission bottlenecks/capacity shortage			■			■	
	Transmission line spare capacity			■				
	Investment in transmission over the past year			■				
	Planning of new lines considers location of new generation.			■				
	Statistics of power cut due to downed transmission lines,			■			■	

Economic dimension ─ effects of Conservation Act sub-dimension

The laws on conservation and resource management have stopped and delayed a number of projects before. While resource conservation needs to be considered in all projects, the current regulation has made it difficult for projects to proceed but very easy for the public to delay these projects. This thesis proposes that the government needs to strike a balance by reviewing the laws regarding the current power situation and see if the use of the regulations has been appropriate. To measure this dimension, the statistics of how many power projects were delayed or cancelled because of the Conservation Act is obtained (Fuel Supplier, Generator, Transmission) as well as indigenous rights claims (Fuel Supplier, Generator, Transmission, Society), and next is to find out the average time taken to solve these cases through the legal framework (Fuel Supplier, Generator, Transmission). In case the public has been abusing their rights and making excessive charges without solid ground, a measurement is made on how easily the public can cause delay in the public enquiry process (Fuel Supplier, Generator, Transmission, Society) and lastly, the government's action on reviewing and updating these laws and regulations is assessed (Fuel Supplier, Generator, Transmission).

The summary of the indicators' allocation to stakeholders can be seen in Table 31.

Table 31 Effects of Conservation Act sub-dimension indicator allocation to stakeholders

Effects of RMA/Conserv Act/Env Act analysis sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
	Number of projects/percentage stopped by conservation/resource consent act	■	■	■				
	Evidence of review to simplify the process of conservation/resource consent	■	■	■				
	Average time to solve cases referring to the Conservation Act	■	■	■				
	Average time to approve projects through resource management process.	■	■	■				
	Accessibility of public enquiry process by residents	■	■	■				■
	Number of indigenous rights claim that stop projects.	■	■	■				■

Economic dimension ─ use of energy efficiency practice sub-dimension

Here, on the energy efficiency sub-dimension, as summarised in Table 32 measurements are made on the number of, and the trend of, companies using practices that improve energy efficiency such as Demand Management, Combined Heat and Power and Distributed Generation (Generator, Transmission, Consumers).

Table 32 Use of energy efficiency sub-dimension indicator allocation to stakeholders

Effects and statistics of DSD, CHP, DG sub-Dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
	Number of companies adopting Demand Side Management		■	■			■	
	Number of companies adopting Combined Heat and Power		■	■			■	
	Number of companies adopting Distributed Generation		■	■			■	

Economic dimension ─ generating plant data sub-dimension

A review of the status of generation plants is needed for the planning of new or replacement plants. Here, as shown in Table 33, the statistics on the number of plants that are reaching the end of their lives is considered (Generator). To measure the sufficiency of planning in the generation sector, measurements are made on the number of new plants planned (Generator) and plant upgrades planned (Generator). Ratings are also given to the amount of planning made and their quality (Generator).

Table 33 Generating plan sub-dimension indicator allocation to stakeholders

Generating plants data analysis sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
	Number of generation plant upgrades planned		■					
	Number of new generation plants planned		■					
	Number of generation plants near end of life		■					
	Planning for new/replacement generation plants		■					

Economic dimension ─ sustainability reporting adoption sub-dimension

One of the effective methods to introduce sustainability to a sector is to encourage the businesses to start making sustainability reports. Measurement is made on the number of companies that have sustainability reports (Fuel Supplier, Generator, Transmission, Wholesaler, Retailer, Consumers, Society) as shown in Table 34.

Table 34 Sustainability reporting sub-dimension indicator allocation to stakeholders

EMS / SD report adaptation analysis sub-dimension	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
	Number of power companies producing sustainability reports, e.g. GRI style	■	■	■	■	■	■	

Economic dimension ─ market models sub-dimension

For suppliers to accurately plan their operation and investment, they need accurate forecasting and that is mainly done by modeling and scenario analysis. Measurements are made on the accuracy of models and scope of the scenarios (Fuel Supplier, Generator, Transmission, Consumers). These come in different categories, please refer to Table 35 for details. The efforts by the government to improve modeling are rated

(Fuel Supplier, Generator, Transmission) and scenarios' accuracy assessed (Fuel Supplier, Generator, Transmission).

Table 35 Market model sub-dimension indicator allocation to stakeholders

Market models sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
Wholesale market model	Electricity sector supply and demand modeling accuracy	■	■				■	
S&D modeling	Accuracy of supply and demand models by government	■	■				■	
	Accuracy of fuel S&D forecast	■	■					
	Electricity sector supply and demand modeling accuracy	■	■	■			■	
	Generation of scenario for planning	■	■	■				
	Government improves techniques in modeling and forecasting	■	■	■				
	Government improves techniques in scenario analysis	■	■	■				

Economic dimension ─ economics analysis sub-dimension

The general economy affects the electricity sector in terms of the economy's productivity, which affects power demand, and investors will decide whether the economy provides a secure environment for investment in the power sector. The economy, among other factors, also affects the value of the currency, thus the price of any imported fuels. Here, as in Table 36, three main sub-dimensions: the country's economic performance, the sector's economic performance and investment issues that focus on building new capacity.

For the country's economic data, the growth of the economy is looked at as a whole (Fuel Supplier, Generator, Transmission, Wholesaler, Retailer, Consumers) and of the energy intensive sector (Fuel Supplier, Generator, Transmitter), and compare that with other ODEC countries (Fuel Supplier, Generator, Transmission). The stability of the currency is also monitored (Fuel Supplier, Generator, Transmission) and interest rate noted to see if they favour the development of the electricity sector (Fuel Supplier, Generator, Transmission).

For the electricity sector's economic performance, measurements are made on its total production (Fuel Supplier, Generator), its turnover and profit (Fuel Supplier, Generator, Transmission, Wholesaler, Retailer) in order to see how viable it is as a business sector.

Table 36 Economics sub-dimension indicator allocation to stakeholders

Economic analysis sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
Investment analysis	Data of remaining workable life for old power plants		■					
	Plans for building new generation plants.		■					
	Sufficiency of planned new plants to meet expected need.		■					
Sector data ─ economic analysis	production p.a.	■	■					
	turnover p.a.	■	■	■	■	■		
	profit p.a.	■	■	■	■	■		
Country-wide data analysis	Stability of currency	■	■	■				
	Interest rates and trends	■	■	■				
	Trend of economic growth	■	■	■	■	■	■	
	Energy intensive industry growth trend cf other ODEC countries	■	■	■				
	Growth trend of energy intensive sector	■	■	■				
	Number of companies in the power intensive sector	■	■	■				

From the investment point, the remaining life of current plants is looked at (Generator), and the amount of future planning is assessed (Generator) and rated whether that is sufficient to meet future demand (Generator).

5.7.6 Institution dimension – indicators allocation

In this application of the Institution dimension, four level 2 sub-dimensions exist for allocating indicators to, and the indicators will then be assigned to the stakeholders. The level 2 sub-dimensions are: Government Policy, Government Regulation, Impact Assessment and Contingency Planning and descriptions are made on the indicators considered suitable in representing the sustainability of them.

Institution dimension ─ Government policy sub-dimension (summarised in Table 37)

Regarding government policy on the power market (a level 3 sub-dimension), focus is on its proactive actions to protect the stakeholders, so, in this case, measurements are on its willingness to establish and support a specialised body to oversee the market's efficiency and operation, or to override it (Consumers, Society). On transmission policy, what seems to be lacking in the market is the incentive to invest, therefore, how much the government has done to encourage transmission investment in the form of government policy and economic instruments needs to be established and how clear and consistent these practices need to be considered (Transmission). Regarding the government's channel to encourage investment, potential investors would prefer a secure environment and incentives from the government, so, measurements are made on special policies and innovative approaches to serve this purpose and to monitor level of investment in the power generation (Generator), in R&D and other areas in the electricity sector (Fuel Supplier, Transmission). Still on the point of economic instruments, measurements need to be made on whether any of them are used in encouraging pollution control (Fuel Supplier, Generator), increasing technological efficiency (Generator, Consumers), promoting R&D (Fuel Supplier, Generator, Transmission), encouraging power conservation (Fuel Supplier, Generator, Transmission, Consumers) improving users' efficiency and new technological innovations such as distributed generation (DG), combined heat and power schemes (CHP) or Demand Management (DM) (Generator, Consumers).

The number of conservation plans and projects are measured for the implementation of the power conservation and efficiency policies (Consumers) and in order to see how much effort has been put into reviewing the policies, the number of policy reviews and policy updates is measured (especially from the ethical point) (Generator, Consumers) as well as the degree to which the public views the fairness of the regulation, focusing on indigenous rights and their influence (Society).

In the past when there were plenty of power resources, the government had special policies to attract power intensive industries to invest their operation in the country, but now when the power resource is considered stretched, these moves may not be so ideal. Measurements are made on whether policies favour power intensive policies or not (Society). The summary of the indicators' allocation to stakeholders can be seen in Table 37.

Table 37 Government policy sub-dimension indicator allocation to stakeholders

Government policy sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
Power market – govt policy	Establishment of a government body for power conservation and efficiency						■	■
Transmission – govt policy	Government policy to encourage investment in transmission.			■				
	Government policies in electricity sector are clear and consistent.			■				
	Availability of economic instruments to encourage investment.			■				
Investment encouragement – govt policy	Clear government policy – tax and plans – confidence for investment	■	■	■				
	Government to encourage investment in R&D	■	■	■				
	Government to encourage investment in generation		■					
	Government to encourage investment in other areas in electricity sector	■	■	■				
	Government innovation for new mechanisms to encourage investment	■	■	■				
Pollution control – govt policy	Government economic instruments to promote pollution control	■	■					
Economic instruments – govt policy	Government economic instruments to discourage pollution	■	■					
	Government to provide economic incentives in increasing technological efficiency		■				■	
	Government policy to encourage technological R&D in power industry	■	■	■				
	Economic instruments for encouraging power conservation/ improve efficiency	■	■	■			■	
	Government encourages new technological solutions : Distributed Generation, Combined Heat & Power, Demand Side Management		■				■	
Power conservation/efficiency - govt policy	Number of government's electricity conservation plans						■	
	Number of government's technological projects – energy conservation						■	
Government policy review	Cases of Government reviewing and simplifying ethical review process like RMA		■	■				
	Indigenous rights – fairness and practicality.							■
Industry development – govt policy	Economic policy favours what type of industry – energy intensive or not						■	

Institution dimension ─ Government regulation sub-dimension:

Having considered ways the government's planning can influence the industry in terms of policy, measurements are made on how regulations affect sustainability ─ details are shown in Table 38. One of the most direct methods for government to control the service quality of public commodities is by regulation and measurements are made to see if that is done for the generation and transmission sectors, and if so, how effective these are (Fuel Supplier, Generator, Transmitter, Retailer). A recent example of institutional influence is the introduction of a building code that requires new houses to be more energy efficient, using 30% less energy than older ones (Gregory 2007). On the other hand, energy labeling gives makers of electrical goods incentives to improve efficiency and gives consumers awareness of the amount of power they use. As a result whether any energy labeling laws has been implemented is assessed (Consumers). Although power markets have been deregulated, appropriate regulations are important for the smooth running of the sector. Regulations will be checked on how much authority the government has been given to interrupt the free market (Fuel Supplier, Generator, Transmitter, Wholesaler, Retailer), including whether there is a specific portion of power that must be generated from renewable sources (Fuel Supplier, Generator) and to see if the government has control over how generators should make the best use of their generating resources (Generator). Rating are given on the government's stand on the choice of generating resources, such as the nuclear-free policy and see how much of that decision was affected by public opinion (Fuel Supplier, Generator, Consumers).

On the regulation side, pollution regulations is monitored by looking at the sufficiency of existing regulations (Consumers, Society) and numbers of reviews to update them (Society). As a side-effect, there are some stakeholders that are indirectly affected by the regulations. The number of regulations that limit the type of fuel used is measured (Fuel Supplier, Generator, Consumers), and any regulations that enforce long term contracts to ensure secure fuel supply (Fuel Supplier, Generator). The number of cases where the government uses its special power to interrupt the power market is also monitored (Fuel Supplier, Generator, Transmitter, Wholesaler, Retailer), and the clarification of the possibility of implementing the carbon tax is assessed (Fuel Supplier, Generator, Consumers).

Table 38 Government regulation policy sub-dimension indicator allocation to stakeholders

Government regulation sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
Minimum quality – govt regulation	Government regulations on transmission quality e.g. % of spare capacity			■				
	Government policy for minimum service quality standards/min reserve power/capacity	■	■	■		■		
Authority to interfere market – government regulation	Government authority to interrupt market if it does not operate well	■	■	■	■	■		
Pollution control regulations	Number of cases where government interrupted free market	■	■	■	■	■		
	Regulation to limit usable fuel types, e.g. no log burning, nuclear free	■	■				■	
	Long term contracts to secure fuel supply	■	■					
	Sufficiency of existing pollution regulations.						■	■
	Number of reviews to update pollution regulations		■					■
	Generation fuel carbon tax plan clarity	■	■				■	
Fuel type – government regulation	Regulation to limits usable fuel types, e.g. no log burning, nuclear free	■	■				■	
	Any stand on generation options by society	■	■					
Energy labeling – regulation	Government regulation for energy labeling scheme						■	
Free market control regulation	Government regulation – best use of generation resource		■					
Generation control regulation	Regulation controlling portion of power generated from renewable source	■	■					

Institution dimension ─ Impact assessment sub-dimension

If a government is well prepared and anticipating adequately for disasters, the chance is that accidents or disasters will have an outcome that causes less dysfunction and chaos to the society than otherwise, and that can be done by appropriate Impact Assessment (IA) (Fuel Supplier, Generator, Transmitter, Society). The sufficiency of the government's plans in the situation of emergency power shortage is assessed (Fuel Supplier, Generator, Transmitter, Consumers, Society), and the sufficiency and quality of their IA reports is assessed (Fuel Supplier, Generator, Transmitter, Society).

The summary of the indicators' allocation to stakeholders can be seen in Table 39.

Table 39 Impact assessment sub-dimension indicator allocation to stakeholders

Impact assessment sub-Dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
Impact assessment	Pollution impact assessment on social, economic and environmental aspects	■	■	■				■
	Evidence of government's plans for emergency power shortage	■	■	■			■	■
	Impact assessment reports from government	■	■	■				■

Institution dimension ─ Contingency plans sub-dimension

On a par with Impact Assessment (IA), contingency plans are the practical side of action when disaster strikes. The amount of backup generation is measured (Generator, Consumers, Society) as well as civil defence capability (Fuel Supplier, Generator, Transmitter, Consumers, Society). How IA is incorporated into the contingency plans is also looked at (Consumers, Society). The summary of the indicators' allocation to stakeholders can be seen in Table 40.

Table 40 Contingency plan sub-dimension indicator allocation to stakeholders

Contingency planning sub-dimensions	Indicators	FS	Gen	Tr	Wh	Ret	Con	Soc
Contingency planning	Back up generation plan		■				■	■
	Impact assessment reports done	■	■	■				■
	Civil defence plan sufficiency						■	■

5.7.7 Conclusion

In this section, indicators were assigned to the relevant sub-dimension of sustainability and also to the stakeholders to represent their interests in the sustainability of the electricity sector. When a sub-dimension was made up of a large number of indicators, changing the values of a few of its component indicators may not significantly affect the index, and it in turn can imply that the index is robust and is not overly affected by a small number of changes, but it also runs the risk of not being sensitive enough to pick up significant variations if the methodology does not analyse the indicators in a congruent way. It remains a challenge to balance robustness and sensitivity in designing the indices.

This allocation process is understandably controversial but when it is complete, it provides an important matrix from which sustainability indices can be created for sustainability dimensions and sub-dimensions. Stakeholders can also obtain sustainability indices from this matrix that are relevant to their particular mode of operation.

The next step of the methodology is to quantify the indicators and it is described in the following section, section 5.8.

5.8 Quantifying the data ─ the Data-indicator conversion functions (DICF).

Each indicator is rated through an algorithm which is called the Data-indicator conversion functions (DICF). These indicator values under each sustainability sub-dimension are then normalised to form sustainability indices.

These DICF are designed by the investigation team. Because the different functions to rate the approximately 140 indicators would involve extensive functional and statistical research on each indicator in order to arrive at a set of scaling methods, doing so is beyond the scope of this thesis. In order to demonstrate how the method may work, their values are suggested by the evaluators for the New Zealand electricity sector. This thesis serves the purpose of outlining the method and demonstrates it through a case study. For this study, inputs from three evaluators with different viewpoints are used and the method's robustness in handling indicator rating from contrasting points of view is tested. The evaluators' view can be roughly divided into three groups: a writer's view with academic bias, an environmentally biased view and a commercial interest view. The indicator values for the different views can be seen in Appendix 3.

5.8.1 The concept and template for Data-indicator conversion functions (DICF)

While data comes in absolute form, it needs to be converted into a dimensionless scalar to enable ease of comparison so that it becomes usable as part of our methodology. The span of the indicator range is arbitrary, so it is decided that a suitable mid scale would be zero, indicating neither sustainable, nor unsustainable. For practical reasons, the number of discrete levels needed to be low, and for ease of use, they should be integers. Consequently, a scale is chosen from -2 to +2 spanning from very unsustainable to sustainable. This scale is completely equivalent to say 1 to 5, but it can be argued that the one adopted by this thesis slightly more intuitive.

An example is, when the indicator of "power price affordability under market efficiency" is considered, the data used is the number of households that spend more than 20 percent of household income on power bills. The number in absolute terms, such as 125,000 households, means little, but if normalised to some standard scale, it can mean more. In our example, for the sake of argument, if 125,000 households represent more than 60 percent of total households, then that can be seen as very unsustainable for the society and it can be rated as -2 on an integer scale of -2 to 2 (see Table 41). In a different case when it represent between 29 percent and 15 percent households, it can be rated at -1. Or in another instance where this 125,000 households represents between 10 percent and 15 percent of total users, it can be rated at 0. Similarly it can be rated as 1 if it covers five percent to nine percent and 2 for zero to four percent. As demonstrated, with defined criteria and transparent methodology, this procedure can be repeatable and can be classified as relatively objective.

Table 41 A sample normalised sustainability scale proposed for this thesis

Indicator scalar	Percentage of households spending >20% of total income on electricity.
-2	>30%
-1	>15% and <29%
0	>10% and <15%
1	>5% and <9%
2	<4%

In defining DICF, a format that includes the steps as shown below is proposed:

In step one, which indicator group the indicator belongs to is shown, and in step two, the purpose of the indicator is described. In step three, the indicator’s relevance to sustainability is explained whereas in step four, the methodology in constructing the DICF is described which includes the underlying definitions and concepts, the measuring methods (how to assign ratings values) and spelling out the limitation of the indicator. In the last step, step five, details are described for the data for this indicator, including the type of data needed to compile the indicator and how available is the data. An example is used in section 5.8.2 to illustrate the steps above.

5.8.2 Example of defining the DICF

The following is the second example of defining a DICF by following the steps and format in section 5.8.1. Indicator 1.1.1 is chosen for this example and it measures how confident the investors are to invest in the electricity sector according to the current government's policies.

1.1.1 Clear government policy – tax and plans – confidence for investment

1) Indicator group the indicator belongs to:

Indicator group: Government Policy

Sub-indicator group: Power Market indictors,

2) Purpose of the indicator:

This indicator measures the perceived effects of the government's policies, reflecting their effects on investment confidence and investment level.

3) Indicator's relevance to sustainability

Clear policy increases investment confidence, resulting in more investment. That is a factor to increase sustainability of the electricity sector.

***4) Methodology Description*:**

***Underlying definition and concepts**:*

"Perceived effect" is an opinion and it can be obtained through market survey on a number of stakeholders: investors, generators, and transmitters.

***Measuring methods**:*

A suitable survey system is designed to measure confidence level to invest of potential investors and the values are rated as below:

2 ─ over 66 percent of respondents indicate they are more confident to invest with the current government policies.

1 ─ between 33 and 65 percent of respondents indicate they are more confident to invest with the current government policies.

0 ─ between 0 and 32 percent of respondents indicate they are more confident to invest with the current government policies.

-1 ─ between 33 and 65 percent of respondents indicate they are *less* confident to invest with the current government policies.

-2 ─ over 66 percent of respondents indicate they are *less* confident to invest with the current government policies.

Limitation of the indicator:

Besides statistical limits, the accuracy is affected by the design of the survey including the time of the year it was carried out (e.g. near election day), and the political view of the respondents. Even so, if it were carried out in a consistent manner in the same sector, the results are representative of the general view.

5) Data for this indicator:

Data needed to compile the indicator:

Relevant Government policies over the past 12 months from government sources and a list of stakeholders to carry out survey on.

Data availability:

Policy data should be available from the government. Policy data may need to be given to interviewees beforehand to give them time to form an opinion.

Having defined these DICF, the data values from the survey can be entered to generate the indicators needed.

5.8.3 Obtaining data for the indicators and entering it to the DICF

Data is obtained by the investigation team or by workgroups. The criteria of obtaining data are that they need to be: up-to-date, traceable, from reliable sources, accurate, provable or justifiable. They are put through the DICF to produce indicators in scalar values. These are normalised to form indices as described in section 5.10.

5.8.4 Input from evaluators with different DICF settings

In this thesis, inputs from three evaluators who hold different views of the electricity sector of New Zealand are used to test the robustness of the methodology. Their views can be put into three categories: a standard view from the author and from which a full set of result will be produced, an environmentally biased view and a view biased towards commercial interest. The differences in the indices and indicator values among these three cases are caused by the use of different DICF scales. For example, while an attribute may be rated as 1 in the relatively neutral view, it may be -2 in the environmentally biased view and 2 in the commercial interest one. To put it in other words, the scale can slide with the same physical input. The different values of the input values by the three evaluators can be seen in Appendix 3 and the results are presented in Section 5.13.

5.8.5 Conclusion

In this section 5.8, two examples on the application of the DICF are examined to demonstrate the methodology. Undoubtedly, setting the DICF is one of the subjective steps in the methodology and will be challenged and debated on, but once the definitions are set, to generate the indicator values can then become an objective regular exercise.

The next step in the process is to enter the data to the DICFs and generate the sustainability indicators. An abstract of this is shown in the section 5.9.

5.9 Setting up of Stakeholder/Dimension/Indicator matrix and the entering of indicators – author's view.

In this step, now that the data has been converted to indicators via the DICFs, their values can be entered into the Stakeholder/Dimension/Indicator matrix. A small section from our case study can be seen in Table 42 below and the full result is described in section 5.13.

Table 42 Indicators of sustainability in the New Zealand power market – an abstract

			FS	Gen	Tra	Who	Ret	Con	Soc
ETHICAL									
G) Ethical issues									
	G1) Environmental policy effects – ethical	2.4.1 Number of cases where environmental policy stopped projects	-1	-1	-1				
		2.4.3 Number of cases where public hearing and opinion stopped projects	-1	-1	-1				
	G2) Indigenous rights effects – ethical	2.4.3 Number of cases where public hearing and opinion stopped projects	-1	-1	-1				
		9.3.2 Indigenous rights – fairness and practicality.							-2
	G3) Public opinion effects – ethical	2.4.2 Number of cases where RMA stopped projects	-1	-1	-1				
		2.4.3 Number of cases where public hearing and opinion stopped projects	-1	-1	-1				
		9.1.2 Number of projects cancelled because of public opinion	-2	-2	-2				
		9.4.1 Number of projects stopped last year due to public opinion	-2	-2	-2				
		9.4.2 Number of projects approved by resource consent but with changes	-2	-2	-2				
TECHNOLOGICAL									
H) R&D in technological improvements									
	H1) R&D in reducing pollution	5.4.1 Government promote funding for R&D on pollution prevention/control projects in electricity sector		0					0
	H2) R&D in fuel and new generation technology	3.6.1 Amount of R&D to improve fuel technology	-1	-1				-1	
	H3) R&D in improving transmission	2.6.1 Amount of R&D in improving transmission technologies and planning			1				
ENVIRONMENTAL									
I) Pollution control									
	I1) Pollution trends	5.4.1 Availability of pollution data		2					2
		5.4.2 Trend of pollution data		2					2
	I2) Adaptation of pollution control system eg EMS	5.4.3 Number/percentage of power companies that have EMS (Environmental Management System) like ISO14000	1	1	1				1
	I3) Actions taken on pollution	5.4.2 Number of pollution control projects initiated by government in electricity sector.	1	1					1
	I4) Pollution complaints handling	5.2.3 Number of pollution complaint cases received and handled in electricity sector	1	1					1
INSTITUTIONAL									
J) Impact assessment preparation									
	J1) Impact assessment preparation	5.4.4 Pollution impact assessment on social, economic and environmental aspects	2	2	2				2
		6.5.2 Evidence of Government's plans for emergency power shortage	-2	-2	-2			-2	-2

		6.5.3 Impact assessment reports from Government	-1	-1	-1				-1
SOCIAL									
K) Social issues									
	K1) Labour relationship	10.1.1 Existence of labour unions	2	2	2				
		10.1.2 Number of strikes, walk outs, picketing last year	2	2	2				
		10.1.3 Days affected by strikes, walk outs, picketing last year	2	2	2				
	K2) Labour skill shortage/ turnover	10.2.1 Labour skill shortage	-2	-2	-2				
		10.2.2 Labour turnover	1	1	1				

Abbreviation used: FS=Fuel Supply, Gen=Generator, Tra=Transmission, Who=Wholesaler, Ret=Retail, Con=Consumers, Soc=Society

These are then normalised using formulae inside the spreadsheet holding the matrix with the concepts explained in section 4.5.10. The results from summarizing the indicators in our case study are presented in section 5.10.

5.10 Summarizing the Index under sub-dimensions and dimensions – author's view.

Table 43 Dimension/Stakeholder Sustainability Indices – standard view

	Stakeholders							
Dimensions	Fuel Supply	Generation	Transmission	Wholesaler	Retailers	Consumers	Society	Dimension's Median
ENVIRONMENTAL	1	1	1				1	1
ETHICAL	-1	-1	-1				-2	-1
SOCIAL	0.75	0.75	0.75					0.75
TECHNOLOGICAL	-1	-0.5	1			-1	0	-0.5
ECONOMICAL	1	1.25	1	1	1	0.75	-1.5	1
INSTITUTIONAL	-0.5	-0.75	0	1	1	-0.875	0.25	0
Median Sustainability by stakeholder	-0.5	-0.5	1	1	1	-0.875	0	0

Table 43 shows the Level 2 Indices according to the dimensions of sustainability and analyse them by stakeholders with a summary for each dimension. Six main dimensions are used in this methodology, namely Social, Environmental, Economic, Technological, Ethical and Institutional. The indices from these dimensions can be normalised to one number, the Level 1 index, for use in representing the sustainability on occasions where such level of aggregation is desired. The six Level 2 indices can be used for planning purposes and for use in the media for the public to get an overall feel of the situation. These six Level 2 indices are in turn sub-divided into more detailed categories on Level 3, which is an intermediate stage, and these are further broken down into elements which are of enough detail to pin-point areas of concern.

In our worksheet, by summarizing the list of indicators under the sustainability Level 4 sub-dimension, a Sustainability Index for Level 4 is obtained. By the same token, the Level 4 indices are normalised to form Level 3 indices and the next step is to normalise the Level 3 to form the six Level 2 Indices and then to Level 1, the single number index. This is done for each stakeholder and the result is that, for each stakeholder, the sustainability indices are available on four levels. As discussed in Chapter 4, the median, as opposed to the mean, is used to normalise the indicators. The results are discussed in detail in Section 5.13.

5.11 Summarizing the indicators by indicator groups and issues - author's view.

To obtain an alternative perspective of the data, instead of sorting the indicators by sub-dimensions, the indicators can also be sorted by indicator groups and normalised using the median to obtain Indicator Group/Stakeholder Sustainability Indices as seen in Table 44.

Table 44 Indicator group/Stakeholder Sustainability Indices

Indicator group	Stakeholders							
	Fuel Supply	Generation	Transmission	Wholesaler	Retailers	Consumers	Society	Issue Median
Power generation	-1	-1				-2		-1
Fuel related factors	0	0				-1		0
Transmission factors	-0.5	-0.5	-1	0	0	0	0	0
Acts of God factors	0.75	-0.5	0			-0.5	1	0
Environmental factors	0	0	0	0	0	1	1	0
Ethical factors	-1.5	-1.5	-1.5	0	0	0	-1.75	-1.5
Social factors	0.75	0.75	0.75					0.75
Technological factors	-1	-0.25	-1			1	2	-0.25
Investment factors	0	0.75	0					0
Power market factors	-0.25	-0.5	-0.5	1	0.5	0		-0.125
Country's industrial structure factors	0	0	0			-1		0
Economic factors	1.25	1.5	1	1.5	1.5	1	-1.5	1.25

Another method to present the result is to normalise the indicators by sustainability issues where one issue is often addressed by multiple indicators, as seen in Appendix 1.

It is a personal choice to decide which representation of the data to use, since all the methods allow users to track down the issues that are causing sustainability problems. Even so, as a convention, it may seem more practical to group the indicators under Sustainability Dimensions and then to identify the unsustainable sub-categories.

5.12 Sustainability index results - author's view.

This section starts off with a description of the indices from the study with the author's relatively neutral standard view. To pinpoint the problem areas, first, the sub-dimension(s) with the lowest value is identified. The list of indicators that make up the sub-dimension(s) is analysed and the indicators with the lowest rating values located. From these "unsustainable" indicators, the issues that cause them are traced back. The next step then is to further backtrack, from the unsustainable issues, to the possible solutions. Figure 83 shows a summary of the steps.

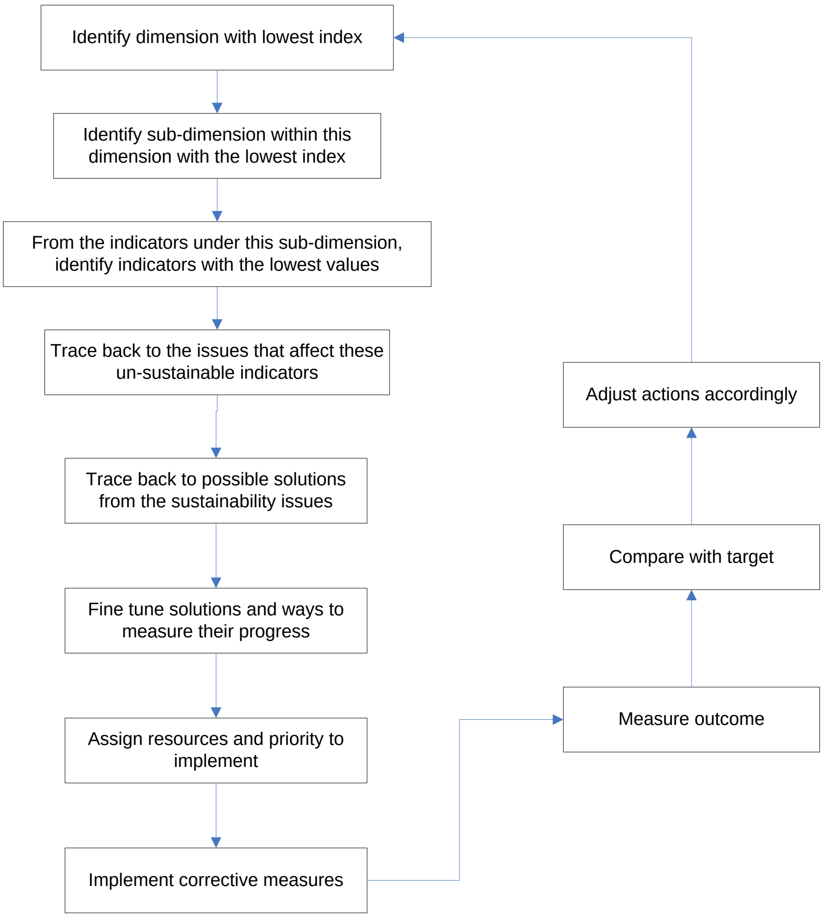


Figure 83 Sustainability index measurements

It is worth noting that many sustainability assessments present data in an absolute form without reference to its estimated or true state of sustainability, and even for those that present the information on a scale or as a trend, they stop short at the stage of presenting the scalar index, without taking the next step of tracking down the least sustainable issues and indicators and finding possible solutions. These missing steps are addressed by this method.

5.12.1 Sustainability Indices for New Zealand electricity sector and proposed corrective actions.

5.12.1.1 Stakeholder Sustainability Index by dimension.

The overall most unsustainable dimension is Ethical with an index of -1, followed by Technological at -0.5, as shown in Table 45. The sustainability indices are also presented on a spider diagram by dimensions, but because of the contrasting nature of some of the dimensions, they are placed in a slightly different order to Table 45 as explained in section 4.5.11: with Ethical opposite Technological, Social next to Ethical in a clockwise direction, but opposite Institutional, and Economic next to Social in a clockwise direction but opposite Environmental, as shown in Figure 84. Investigation is made to analyse the details of the most un-sustainable dimension, Ethical, in the next section.

Table 45 Sustainability index for New Zealand Power Industry - standard view

Dimension	**Dimension's Median**
ENVIRONMENTAL	1
ETHICAL	-1
SOCIAL	0.75
TECHNOLOGICAL	-0.5
ECONOMIC	1
INSTITUTIONAL	0

Dimension- in order for spider diagram use	**Dimension's Median**
ETHICAL	-1
SOCIAL	0.75
ECONOMIC	1
TECHNOLOGICAL	-0.5
INSTITUTIONAL	0
ENVIRONMENTAL	1

5.12.1.2 Analysis of least sustainable dimensions.

In the Ethical dimension the sub-dimensions that have the lowest index are "Indigenous Rights Effects" (G2) and "Public Opinion Effects" (G3) (shaded in Table 46) both with "-2" values applied to some stakeholders. The next step is to look up which indicators are the main causes for un-sustainability in these sub-dimensions.

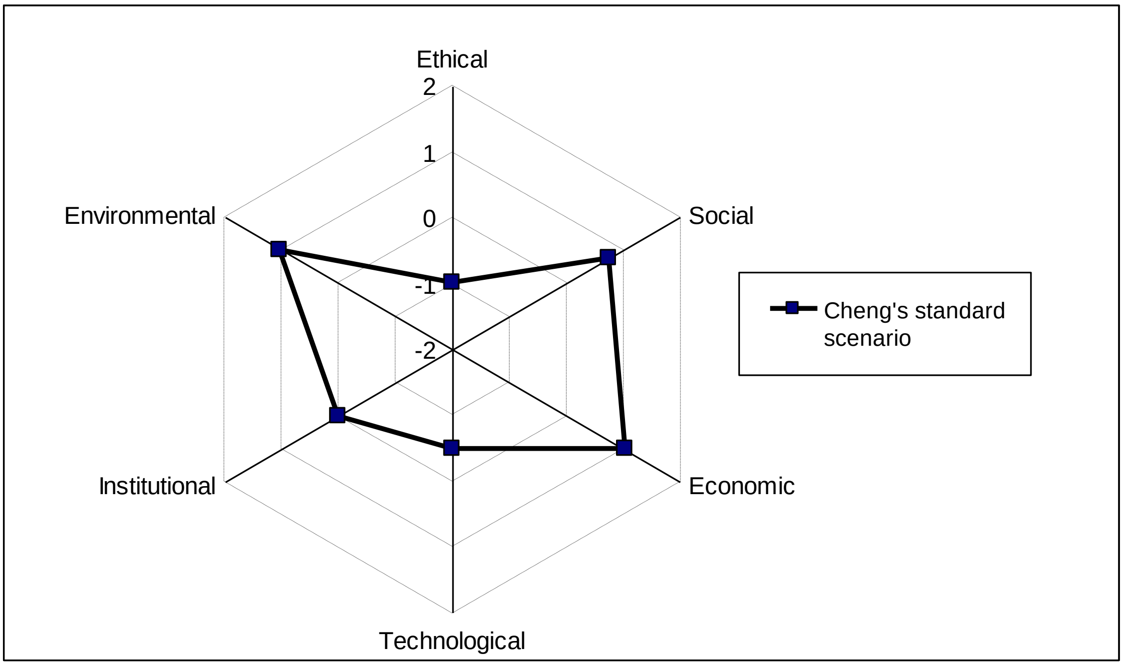


Figure 84 Spider Diagram ─ Sustainability Index for New Zealand Power Industry in the standard view by the author, Cheng.

Table 46 Indices for Ethical sub-dimensions

	Stakeholder							
Dimensions	Fuel Supply	Generation	Transmission	Wholesaler	Retailer	Consumer	Society	Overall
G) Ethical Dimension Overall	**-1**	**-1**	**-1**				**-2**	**-1**
G1) Environmental policy effects – ethical	-1	-1	-1					-1
G2) Indigenous rights effects – ethical	-1	-1	-1				-2	-1
G3) Public opinion effects – ethical	-2	-2	-2					-2

Looking through the list of indicators that make up the dimensions, the ones with the lowest sustainability index values (highlighted in Table 47) are: 9.3.2 Indigenous rights ─ fairness and practicality, 9.1.2 Cases of projects cancelled because of public opinion, 9.4.1 Number of projects stopped last year due to public opinion and 9.4.2 Number of projects approved by resource consent but with changes. These results correlate with the recent news in May 2007 that the Environmental Court has ruled against the building of a 37 turbine wind power expansion project in the Te Waka Range on grounds of visual effects and against Maori spiritual values, as well as a 176 wind turbine facility on the Lammermoor Ranges due to public opposition based on visual impacts (NZPA 2007).

Table 47 Ethical sub-dimensions with indicator values

		Stakeholder						
Sub-Dimensions	Indicators	Fuel Supply	Genera-tion	Trans-mission	Whole-saler	Retailer	Consumer	Society
G2) Indigenous rights effects – ethical	2.4.3 Number of cases where public hearing and opinion stopped projects	-1	-1	-1				
	9.3.2 Indigenous rights – fairness and practicality.							-2
G3) Public opinion effects – ethical	2.4.2 Number of cases where RMA stopped projects	-1	-1	-1				
	2.4.3 Number of cases where public hearing and opinion stopped projects	-1	-1	-1				
	9.1.2 Number of projects cancelled because of public opinion	-2	-2	-2				
	9.4.1 Number of projects stopped last year due to public opinion	-2	-2	-2				
	9.4.2 Number of projects approved by resource consent but with changes	-2	-2	-2				

5.12.1.3 Identify issues from unsustainable indicators

In order to track down the sustainability issues that are represented by these indicators, the Sustainability indicator/Issue Matrix in Appendix 1 is referred to.

As seen in the shaded cells in Table 48, which is an extract from the Sustainability indicator/Issue Matrix in Appendix 1, the significant issues, meaning issues pointed to by the largest number of indicators, which is four in this case, with the lowest sustainability indicator values that degrade the sustainability of the electricity sector are: Issue 9.1: New construction or amendments to existing facilities limited by conservation acts or resource consent, Issue 9.3: SD issues in the society affect the development of the electricity sector and Issue 9.5: Cultural issues such as indigenous culture's stand in the protection of nature.

Table 48 Ethical sustainability indicator/issues matrix

Sustainability Indicators	Sustainability issues					
	9.1 New construction or amendments to existing facilities limited by Conservation Act or resource consent	9.2 Enquiry time of approval takes too long – uncertainty that deters investors.	9.3 SD issues in the society affect the development of the electricity sector.	9.4 Political stand limits generation options (e.g. nuclear free NZ).	9.5 Cultural issues such as indigenous culture's stand in the protection of nature.	9.6 Companies only talk about SD without real actions
9) Ethical factors						
9.1 Evidence of strong political stand – ethical						
9.1.1 Limitation on generation options by political/society stand			■	■	■	
9.1.2 Cases of projects cancelled because of public opinion	■	■	■		■	
9.2 Willingness to improve – ethical						
9.2.1 Cases of Government reviewing and simplifying ethical review process like RMA	■	■			■	
9.2.2 Average time to approve projects through resource management process.	■	■	■		■	
9.3 Mechanism for public opinion to be heard – ethical						
9.3.1 Accessibility of public enquiry process by residents	■	■	■		■	
9.3.2 Indigenous rights – fairness and practicality.	■	■	■		■	
9.4 Evidence of public opinion considered – ethical						
9.4.1 Number of projects stopped last year due to public opinion	■		■	■	■	
9.4.2 Number of projects approved by resource consent but with changes	■		■	■	■	

5.12.1.4 Identify solutions from issues

From the issues identified in Table 48, the suggested solutions that can best improve the sustainability of the electricity sector and solve these significant issues can be found in the Sustainability issue/Solution Matrix in Appendix 7. An extract of it is shown in Table 49 and the related solutions are highlighted, they are: for the government to update rules and regulations on conservation and resource consent to meet today's needs, and to negotiate more on land rights so that the land can be used for electricity sector projects.

Table 49 Ethical sustainability issues/solution Matrix

9) Ethical issues	Proposed solutions: Govt updates regulations to meet today's needs	Govt negotiates on land rights
9.1 Regulations make it difficult for new projects to be approved thus unattractive	X	
9.2 Public hearing takes too long – affects business decisions	X	
9.3 SD issues affect electricity sectors	X	X
9.4 Political stands limit generation options	X	
9.5 Cultural issues leans towards protection of nature	X	X
9.6 Companies only talk about SD without real actions	X	

This is the overall result for the electricity sector of New Zealand and the solutions that can most effectively improve the sector. Of course if resource allows, other indices of low sustainability values can also be looked at, such as the "-1" values in Table 47. It can also be analyzed and have its significant unsustainable issues identified and solutions tracked down.

The result is also analyzed by stakeholder as demonstrated below to facilitate the understanding of the electricity sector's sustainability from the stakeholders' point of view.

5.12.2 Analysis of sustainability by stakeholders

This step is to break down the dimensions' sustainability data and calculate sustainability indices by the individual stakeholders. This analysis is often ignored in other studies but in spite of that, it is important since each stakeholder has their own criteria and view of the business and accordingly they should have their own indices. The results are shown in the following sections.

5.12.2.1 Stakeholder's indices and solutions ─ Fuel Supply

As seen from Table 50, the Ethical and Technological Dimensions have the lowest index value, as shaded cells, both rated at -1. Table 51 highlights the sub-dimensions that account for it.

Table 50 Stakeholder sustainability index – Fuel Supply

Dimension	Fuel Supply
ENVIRONMENTAL	1
ETHICAL	-1
SOCIAL	0.75
TECHNOLOGICAL	-1
ECONOMIC	1
INSTITUTIONAL	-0.5

Table 51 Fuel supply Stakeholder – least sustainable sub-dimensions

Dimension	Index
G) Ethical Dimension	**-1**
G1) Environmental policy effects – ethical	-1
G2) Indigenous rights effects – ethical	-1
G3) Public opinion effects – ethical	-2
H) Technological Dimension	**-1**
H1) R&D in reducing pollution	
H2) R&D in fuel and new generation technology	-1
H3) R&D in improving transmission	

Under the Ethical dimension, the sub-dimension on "Public opinion effects (G3)" has the lowest index whereas under Technological, it is "R&D in fuel and new generation technology (H2)" that has the lowest. The indicators that most adversely affect the sustainability of the Fuel Supply stakeholder is traced back (see Table 52 and Table 53) and they are: 9.1.2 Cases of projects cancelled because of public opinion, 9.4.1 Number of projects stopped last year due to public opinion, 9.4.2 Number of projects approved by resource consent but with changes, and 3.6.1 Amount of R&D to improve fuel technology

Table 52 Fuel supply Stakeholder – least sustainable indicators (1)

Sub-dimension name	Indicators	index
G3) Public opinion effects – ethical	2.4.2 Number of cases where RMA stopped projects	-1
	2.4.3 Number of cases where public hearing and opinion stopped projects	-1
	9.1.2 Cases of projects cancelled because of public opinion	-2
	9.4.1 Number of projects stopped last year due to public opinion	-2
	9.4.2 Number of projects approved by resource consent but with changes	-2

Table 53 Fuel supply Stakeholder – least sustainable indicators (2)

Sub-dimension Name	Indicator	Index
H2) R&D in fuel and new generation technology	3.6.1 Amount of R&D to improve fuel technology	-1

The issues involved are found in the Sustainability indicator/Issue Matrix (Appendix 1) and they are highlighted in Table 54 and Table 55. The significant issues are: 9.1 New construction or amendments to existing facilities limited by the Conservation Act or resource consent, 9.3 SD issues in the society affect the development of the electricity sector, 9.4 Political stand limits generation options (e.g. nuclear free NZ) and 9.5 Cultural issues such as indigenous culture's stand in the protection of nature, and 3.11 Non-efficient fuel use,

Table 54 Fuel supply Stakeholder – Ethical issues

Indicators	Issues					
	9.1 New construction or amendments to existing facilities limited by Conservation Acts or resource consent	9.2 Enquiry time of approval takes too long – uncertainty that deters investors.	9.3 SD issues in the society affect the development of the electricity sector.	9.4 Political stand limits generation options (e.g. nuclear free NZ).	9.5 Cultural issues such as indigenous culture's stand in the protection of nature.	9.6 Companies only talk about SD without real actions
9) Ethical factors						
9.1 Evidence of strong political stand – ethical						
9.1.1 Limitation on generation options by political/society stand			■	■	■	
9.1.2 Cases of projects cancelled because of public opinion	■	■	■		■	
9.2 Willingness to improve – ethical						
9.2.1 Cases of Government reviewing and simplifying ethical review process like RMA	■	■			■	
9.2.2 Average time to approve projects through resource management process.	■	■	■		■	
9.3 Mechanism for public opinion to be heard – ethical						
9.3.1 Accessibility of public enquiry process by residence	■	■	■		■	
9.3.2 Indigenous rights – fairness and practicality.	■	■	■		■	
9.4 Evidence of public opinion considered – ethical						
9.4.1 Number of projects stopped last year due to public opinion	■		■	■	■	
9.4.2 Number of projects approved by resource consent but with changes	■		■	■	■	

Table 55 Fuel supply Stakeholder – Fuel Research issues

Indicators	Issues
3) Fuel related factors	3.11 Non efficient fuel use
3.6 Fuel research	
3.6.1 Amount of R&D to improve fuel technology	■

The solutions for Fuel Supply stakeholders as highlighted are found in the Sustainability issue/Solution Matrix (Appendix 7) and an extract of it is in Table 56 and Table 57. The proposed solutions are: for the Government to update regulations to meet today's needs and to have negotiations on land rights, to improve planning and modeling, and to pass regulations specifying that a fixed portion of generation needs to be from renewable sources.

Table 56 Fuel supply Stakeholder – proposed solutions, Ethical issues

	Proposed solutions	
9) Ethical issues	Govt updates regulations to meet today's needs	Govt negotiates on land rights
9.1 Regulations make it difficult for new projects to be approved thus unattractive	X	
9.3 SD issues affect electricity sectors	X	X
9.4 Political stands limit generation options	X	
9.5 Cultural issues lean towards protection of nature	X	X

Table 57 Fuel supply Stakeholder – proposed solutions, Fuel Supply issues

Issues	**Proposed solutions**	
3) Fuel supply problems	Improve planning and modeling	Government regulations – fixed % from renewable
3.11 Non efficient fuel use	X	X

5.12.2.2 Stakeholder's indices and solutions - Generation

From Table 58 it can be seen that the Ethical and Institutional dimensions have the lowest value for the generation stakeholders. Table 59 (Ethical) and Table 60 (Institutional) highlight the least sustainable dimension. They are G3) "Effects of Public Opinion" under Ethical dimension, and B6) "Free market control regulations" under Institutional.

Table 58 Stakeholder sustainability index – Generation

Dimension	Generation
ENVIRONMENTAL	1
ETHICAL	-1
SOCIAL	0.75
TECHNOLOGICAL	-0.5
ECONOMIC	1.25
INSTITUTIONAL	-0.75

Table 59 Generation Stakeholder – least sustainable sub-dimensions

Ethical Dimensions	Index
G) Ethical issues	**-1**
G1) Environmental policy effects – ethical	-1
G2) Indigenous rights effects – ethical	-1
G3) Public opinion effects – ethical	-2

Table 60 Generation Stakeholder — least sustainable sub-dimension

Institution Dimensions	Index
A) Govt policy	**-1**
A1) Govt policy for power market	
A2) Govt policy for transmission	
A3) Govt policy to encourage investment	-1
A4) Government policy for pollution control	-1
A5) Use of economic instruments in electricity sector	-1
A6) Govt policy for power conservation/efficiency	
A7) Government policy on ethics	-1
A8) Government policy for industrial development	
B) Government Regulations	**-0.5**
B1) Minimum service quality — govt regulations	0
B2) Authority to interfere in market — govt regulations	1
B3) Pollution control regulations	-1
B4) Fuel type choice — govt regulations	-1
B5) Energy labelling — regulations	
B6) Free market control regulations	-2
B7) Renewable power control regulations	1
J) Impact assessment preparation	**-1**
J1) Impact assessment preparation	-1
L) Contingency planning	**0**
L1) Contingency planning	0

From these, the indicators that most adversely affect the sustainability of the Generation stakeholder are traced back and identified. They are (see Table 61 and Table 62): 9.1.2 Cases of projects cancelled because of public opinion, 9.4.1 Number of projects stopped last year due to public opinion, 9.4.2 Number of projects approved by resource consent but with changes and 8.3.0 Government regulation – best use of generation resource.

Table 61 Generation Stakeholder – Ethical sub-dimension least sustainable indicators

Sub-dimension	Indicators	index
G3) Public opinion effects - ethical	2.4.2 Number of cases where RMA stopped projects	-1
	2.4.3 Number of cases where public hearing and opinion stopped projects	-1
	9.1.2 Cases of projects cancelled because of public opinion	-2
	9.4.1 Number of projects stopped last year due to public opinion	-2
	9.4.2 Number of projects approved by resource consent but with changes	-2

Table 62 Generation Stakeholder – Institution sub-dimension ─ least sustainable indicators

Sub- dimension	Indicators	index
B6) Free market control regulations	8.3.0 Government regulation – best use of generation resource	-2

Identify Issues from unsustainable indicators

From these indicators, the significant issues, as seen in highlighted areas in Table 63 and Table 64, are: 9.1 New construction or amendments to existing facilities limited by Conservation Acts or resource consent, 9.3 SD issues in the society affect the development of the electricity sector, 9.4 Political stand limits generation options (e.g. nuclear free NZ), 9.5 Cultural issues such as indigenous culture's stand in the protection of nature and 8.3 Mix of generation resource not maximised to provide generation efficiency.

Table 63 Generation Stakeholder ─ Ethical issues

Indicators	Issues					
9) Ethical factors	9.1 New construction or amendments to existing facilities limited by Conservation Acts or resource consent	9.2 Enquiry time of approval takes too long – uncertainty that deters investment.	9.3 SD issues in the society affect the development of the electricity sector.	9.4 Political stand limits generation options (e.g. nuclear free NZ).	9.5 Cultural issues such as indigenous culture's stand in the protection of nature.	9.6 Companies only talk about SD without real actions
9.1 Evidence of strong political stand ─ ethical						
9.1.1 Limitation on generation options by political/society stand			■	■	■	
9.1.2 Cases of projects cancelled because of public opinion	■	■	■		■	
9.2 Willingness to improve – ethical						
9.2.1 Cases of Government reviewing and simplifying ethical review process like RMA	■	■			■	
9.2.2 Average time to approve projects through resource management process .	■	■	■		■	
9.3 Mechanism for public opinion to be heard ─ ethical						
9.3.1 Accessibility of public enquiry process by resident	■	■	■		■	
9.3.2 Indigenous rights - fairness and practicality.	■	■	■		■	
9.4 Evidence of public opinion considered ─ ethical						
9.4.1 Number of projects stopped last year due to public opinion	■		■	■	■	
9.4.2 Number of projects approved by resource consent but with changes	■		■	■	■	

Table 64 Generation Stakeholder – Generation issues

Indicator	Issues
8) Power generation factors	8.3 Mix of generation resource not maximised to provide generation efficiency.
8.3.0 Government regulation – best use of generation resource	■

Following this, the possible solutions for the issues can be seen in Table 65 (Ethical) and Table 66 (Generation), and they are: Government updates regulations to meet today's needs, Government negotiates on land rights, Policy change to encourage generation efficiency, Regulation change to encourage generation efficiency, Have a mix of generating source to maximise efficiency of the resource and, Better planning to anticipate end of life of old plants

Since most of the solutions are still focused on improving regulations, it appears regulation is the major issue hindering the sustainable development of the sector from the generator's view.

Table 65 Generation Stakeholder – proposed solutions, Ethical issues

	Proposed solutions	
9) Ethical issues	Govt update regulations to meet today's needs	Govt negotiate on land rights
9.1 Regulations make it difficult for new projects to be approved thus unattractive	X	
9.3 SD issues affect electricity sectors	X	X
9.4 Political stands limit generation options	X	
9.5 Cultural issues lean towards protection of nature	X	X

Table 66 Generation Stakeholder – proposed solutions, Technological issues

	Proposed solutions					
8) Generation issues	Improve plant efficiency	Policy change to encourage generation efficiency	Regulation change to encourage generation efficiency	Monitoring and modeling of fuel price	Have a mix of generating sources to maximise efficiency of the resource	Better planning to anticipate end of life of old plants
8.1 Fuel price increase	X	X	X	X	X	
8.2 Unsure carbon tax details – affects investment confidence		X	X	X		
8.3 Mix of generation methods not maximised for efficiency		X	X		X	X

5.12.2.3 Stakeholder's indices and solutions — Transmission

It can be seen from Table 67 that the Ethical dimension also has the lowest index value here, and Table 68 highlights the Ethical dimension, sub-dimension G3) on Effects on Public Opinion which has the lowest index.

Table 67 Stakeholder sustainability index – Transmission

Dimension	Transmission
ENVIRONMENTAL	1
ETHICAL	-1
SOCIAL	0.75
TECHNOLOGICAL	1
ECONOMIC	1
INSTITUTIONAL	0

Table 68 Transmission Stakeholder – least sustainable sub-dimensions

Sub-dimension	Index
G) Ethical issues	-1
G1) Environmental policy effects – ethical	-1
G2) Indigenous rights effects – ethical	-1
G3) Public opinion effects – ethical	-2

Tracing back to find the indicators that most adversely affect the sustainability of the Transmission stakeholder, they are (as highlighted in Table 69): 9.1.2 Cases of projects cancelled because of public opinion, 9.4.1 Number of projects stopped last year due to public opinion and 9.4.2 Number of projects approved by resource consent but with changes

Table 69 Transmission stakeholder — least sustainable indicators

Sub-dimension	Indicators	index
G3) Public opinion effects — ethical	2.4.2 Number of cases where RMA stopped projects	-1
	2.4.3 Number of cases where public hearing and opinion stopped projects	-1
	9.1.2 Cases of projects cancelled because of public opinion	-2
	9.4.1 Number of projects stopped last year due to public opinion	-2
	9.4.2 Number of projects approved by resource consent but with changes	-2

From these indicators, the significant unsustainable issues are traced back, as seen in highlighted areas in Table 70, they are: 9.1 New construction or amendments to existing facilities limited by Conservation Act or resource consent, 9.3 SD issues in the society affect the development of the electricity sector, 9.4 Political stand limits generation options (e.g. nuclear free NZ) and 9.5 Cultural issues such as indigenous culture's stand in the protection of nature.

Table 70 Transmission Stakeholder – Ethical issues

Indicators	Sustainability Issues: 9.1 New construction or amendments to existing facilities limited by Conservation Act or resource consent	9.2 Enquiry time of approval takes too long – uncertainty that deters investors.	9.3 SD issues in the society affect the development of the electricity sector.	9.4 Political stand limits generation options (e.g. nuclear free NZ).	9.5 Cultural issues such as indigenous culture's stand in the protection of nature.	9.6 Companies only talk about SD without real actions
9) Ethical factors						
9.1 Evidence of strong political stand – ethical						
9.1.1 Limitation on generation options by political/society stand			■	■	■	
9.1.2 Cases of projects cancelled because of public opinion	■	■	■		■	
9.2 Willingness to improve – ethical						
9.2.1 Cases of Government reviewing and simplifying ethical review process such as RMA	■	■			■	
9.2.2 Average time to approve projects through resource management process.	■	■	■		■	
9.3 Mechanism for public opinion to be heard – ethical						
9.3.1 Accessibility of public enquiry process by resident	■	■	■		■	
9.3.2 Indigenous rights – fairness and practicality.	■	■	■		■	
9.4 Evidence of public opinion considered – ethical						
9.4.1 Number of projects stopped last year due to public opinion	■		■	■	■	
9.4.2 Number of projects approved by resource consent but with changes	■		■	■	■	

Proposed solutions are found in Table 71 and they are: Government updates regulations to meet today's needs and Government negotiates on land rights. As a conclusion, the main barriers for Transmission have been the hurdle of getting resource consent to expand their facilities.

Table 71 Transmission Stakeholder – proposed solutions, Ethical issues.

9) Ethical issues	Proposed solutions: Govt updates regulations to meet today's needs	Govt negotiates on land rights
9.1 Regulations make it difficult for new projects to be approved thus unattractive	X	
9.3 SD issues affect electricity sectors	X	X
9.4 Political stands limit generation options	X	
9.5 Cultural issues leans towards protection of nature	X	X

5.12.2.4 Stakeholder's indices and solutions ─ Wholesaler

The sustainability of different dimensions under this stakeholder is shown in Table 72. The wholesalers are identified as not facing any immediate sustainability problems. They should refer to the sector's overall sustainability index (Table 45) for potential improvements. The reason is that if the overall sector is not sustainable, the stakeholders by implication will be affected as well.

Table 72 Stakeholder sustainability index - Wholesaler

Dimension	Wholesaler
ENVIRONMENTAL	
ETHICAL	
SOCIAL	
TECHNOLOGICAL	
ECONOMIC	1
INSTITUTIONAL	1

5.12.2.5 Stakeholder sustainability index - Retailers

Similar to the wholesaler in section 5.12.2.4, the retailers are not faced with any immediate sustainability problems that are specific to them (see Table 73). They should refer to the sector's overall result for reference because if the sector is not sustainable, by implication, they will be affected as well.

Table 73 Stakeholder sustainability index - Retailer

Dimension	Retailers
ENVIRONMENTAL	
ETHICAL	
SOCIAL	
TECHNOLOGICAL	
ECONOMIC	1
INSTITUTIONAL	1

5.12.2.6 Stakeholder's indices and solutions ─ Consumers

As seen in Table 74, the Technological dimension has the lowest index value for the customers and the sub-dimension H2) on "R&D in fuel and generation technology" has the lowest index (as highlighted in Table 75).

Table 74 Stakeholder sustainability index – Consumers

Dimension	Consumers
ENVIRONMENTAL	
ETHICAL	
SOCIAL	
TECHNOLOGICAL	-1
ECONOMIC	0.75
INSTITUTIONAL	-0.875

Table 75 Consumers Stakeholder – least sustainable sub-dimensions

Technological Dimension	Index
H) R&D in technological improvements	**-1**
H1) R&D in reducing pollution	
H2) R&D in fuel and new generation technology	-1
H3) R&D in improving transmission	

Tracing back to the indicator that most adversely affects the sustainability of the Consumer stakeholder, it is: Indicator 3.6.1, Amount of R&D to improve fuel technology (see Table 76).

Table 76 Consumers Stakeholder — least sustainable indicators

Sub-dimension	Indicator	Index
H2) R&D in fuel and new generation technology	3.6.1 Amount of R&D to improve fuel technology	-1

The issue involved as seen in highlighted areas in Table 77 is issue 3.11, Non-efficient fuel use.

Table 77 Consumers Stakeholder – Fuel research issues

		Issues
Indicator		3.11 Non efficient fuel use
3.6 Fuel research		
	3.6.1 Amount of R&D to improve fuel technology	■

The possible solutions as shown in Table 78 are: Improve planning and modeling and Government regulations – fixed percentage from renewable. From the consumer's point, the efficient use of fuel is the main issue, and regulations to ensure more fuel is from renewable sources can improve sustainability.

Table 78 Consumers Stakeholder – proposed solutions, Fuel Supply issues.

Issues	Proposed solutions	
3) Fuel supply problems	Improve planning and modeling	Government regulations – fixed % from renewable
3.11 Non efficient fuel use	X	X

5.12.2.7 Stakeholder's indices and solutions ─ Society

Table 79 shows that the Ethical and Economic dimensions have the lowest index values.

Table 79 Stakeholder sustainability index – Society

Dimension	Society
ENVIRONMENTAL	1
ETHICAL	-2
SOCIAL	
TECHNOLOGICAL	0
ECONOMIC	-1.5
INSTITUTIONAL	0.25

Under Ethics dimension, sub-dimension G2) Effects of Indigenous Rights has the lowest value and in Economic dimension, sub-dimension D6) on "Effects on RMA/Conservation Act/Environmental Act" has the lowest index (as highlighted in Table 80 and Table 81).

Table 80 Society Stakeholder – least sustainable sub-dimensions

Sub-dimension	Index
G) Ethical issues	**-2**
G1) Environmental policy effects – ethical	
G2) Indigenous rights effects – ethical	-2
G3) Public opinion effects – ethical	

Table 81 Society Stakeholder – least sustainable sub-dimensions

Economic Dimension	Index
C) Power market control	
C1) Government control of power market	
D) Power market conditions	**-1.5**
D1) Wholesale power market conditions	
D2) Consumer power market conditions	
D3) Power supply market conditions	
D4) Fuel market conditions	
D5) Transmission systems conditions	
D6) Effects of RMA/Conservation Act/Env Act	-1.5
D7) Power market initiatives to improve efficiency	
D8) Generating plants planning	
D9) Sustainability reporting	
E) Market modelling effects	
E1) Wholesale market models performance	
E2) S&D modelling effects	
F) Power market economic	
F1) Power plant planning	
F2) Electricity sector business performance	
F3) Country-wide economics trends	

Tracing back to the indicators that most adversely affect the sustainability of the Society stakeholder, they are, as shown in Table 82 and Table 83: 9.4.3, "Number of indigenous rights claims that stop projects" and 9.3.2, "Indigenous rights — fairness and practicality".

Table 84 shows the significant issues involved, they are highlighted as: 9.1) New construction or amendments to existing facilities limited by conservation acts or resource consent, 9.3) SD issues in the society affect the development of the electricity sector, 9.4) Political stand limits generation options (e.g. nuclear free NZ) and 9.5) Cultural issues such as indigenous culture's stand in the protection of nature.

Table 82 Society Stakeholder – least sustainable indicators (1)

Sub-dimension	Indicator	Index
G2) Indigenous rights effects — ethical		
	2.4.3 Number of cases where public hearing and opinion stopped projects	
	9.3.2 Indigenous rights — fairness and practicality.	-2

Table 83 Society Stakeholder ─ least sustainable indicators (2)

Sub-dimension	Indicator	Index
D6) Effects of RMA/ Conservation Act/ Env Act	5.1.1 Number of projects/percentage stopped by conservation/Resource Management Act	
	5.1.2 Evidence of review to simplify the process of conservation/ resource consent	
	5.1.3 Average time to solve cases referring to the Conservation Act	
	9.2.2 Average time to approve projects through resource management process.	
	9.3.1 Accessibility of public enquiry process by residents	-1
	9.4.3 Number of indigenous rights claims that stop projects.	-2

Table 84 Consumer Stakeholder – Ethics issues

	ISSUES					
	9.1 New construction or amendments to existing facilities limited by Conservation Act or resource consent	9.2 Enquiry time of approval takes too long – uncertainty that deters investment.	9.3 SD issues in the society affect the development of the electricity sector.	9.4 Political stand limits generation options (e.g. nuclear free NZ).	9.5 Cultural issues such as indigenous culture's stand in the protection of nature.	9.6 Companies only talk about SD without real actions
9) Ethical factors						
9.1 Evidence of strong political stand ─ ethical						
9.1.1 Limitation on generation options by political/society stand			■	■	■	
9.1.2 Cases of projects cancelled because of public opinion	■	■	■		■	
9.2 Willingness to improve – ethical						
9.2.1 Cases of Government reviewing and simplifying ethical review process such as RMA	■	■			■	
9.2.2 Average time to approve projects through resource management process.	■	■	■		■	
9.3 Mechanism for public opinion to be heard – ethical						
9.3.1 Accessibility of public enquiry process by residents	■	■	■		■	
9.3.2 Indigenous rights ─ fairness and practicality.	■	■	■		■	
9.4 Evidence of public opinion considered ─ ethical						
9.4.1 Number of projects stopped last year due to public opinion	■		■	■	■	
9.4.2 Number of projects approved by resource consent but with changes	■		■	■	■	
9.4.3 Number of indigenous rights claims that stop projects.	■		■		■	

As seen from Table 85, the proposed solutions for this issue are: Government updates regulations to meet today's needs, and Government negotiates on land rights in order as to facilitate the approval of power projects.

Table 85 Society Stakeholder – proposed solutions, Ethical issues.

	Proposed solutions	
9) Ethical issues	Govt updates regulations to meet today's needs	Govt negotiates on land rights
9.1 Regulations make it difficult for new projects to be approved thus unattractive	X	
9.2 Public hearing takes too long – affects business decisions	X	
9.3 SD issues affect electricity sectors	X	X
9.4 Political stands limit generation options	X	
9.5 Cultural issues lean towards protection of nature	X	X
9.6 Companies only talk about SD without real actions	X	

5.12.2.8 Conclusion

In section 5.12.2, each stakeholder was examined in detail regarding the sustainability indices that applied to them. The most unsustainable dimensions were identified and the indicators that were accountable for most of the unsustainable issues were pointed out. These issues that caused the un-sustainability were identified and the possible solutions tracked down. These solutions are particularly relevant to each stakeholder and it is up to them to prioritise them, to initiate the change process, and to follow through the suggestions to improve their own sustainability.

Having finished going through the results which are sorted by stakeholders, the sustainability indices generated by the other two evaluators are next analysed and the robustness of this methodology assessed.

5.13 Establishing the robustness of the method to bias in the investigating panel.

The quantification of sustainability is a complex process and an interesting consequence of the complexity of the exercise is that it is relatively difficult for an individual or group with special interests to manipulate the inputs to produce biased results. This adds an element of robustness to the quantification procedure. Notwithstanding, it is clear that the results of using this methodology to quantify sustainability can still be potentially influenced by the sympathies of the investigating teams. Ideally, even if the investigating team was “hijacked” by a special interest group, say with a strong environmental agenda or a short-term commercial one, the quantitative results for sustainability would still be invariant. In this section, the robustness of the proposed methodology is explored by asking the question, “Would the result from using this methodology be affected significantly if the evaluators in the investigating team have different agendas?” This, the author has defined as the robustness of the methodology.

As robustness is a difficult criterion to establish concretely, the author has elected to test for it by using two local experts as evaluators to illustrate the potential diverse viewpoints that one would reasonably expect to see in such an undertaking. One is Vanessa Atkinson, the Climate Change Officer of Greenpeace, Auckland, (V. Atkinson, personal communication, May 24, 2007) to represent the environmentally sympathetic vote and the other is the Garry Law, director of Law Associates (G. Law, personal communication, May 28, 2007) who presents a view with a strong commercial agenda.

5.13.1 The composition of the evaluators

For the purpose of this section, three sets of inputs from three evaluators to assess the sustainability of the electricity sector of New Zealand are compared in order to test the robustness and the limitations of this methodology.

One evaluator is Vanessa Atkinson, whose response follows Greenpeace guidelines and is considered having an environmental bias. The other evaluator is Garry Law, a management consultant in Auckland, with a bias towards commercial interest. Finally, for completion, the author is the third evaluator providing a “standard” view for this thesis.

5.13.2 Comparing the results of the three evaluators.

The results of the quantitative sustainability assessments by the three evaluators can be seen in Figure 85 and Table 86. The lowest overall index is generated by Atkinson who holds an environmental biased view, and the highest sustainability result is from the author's view point.

As demonstrated in Table 86, where the shaded area represents the "soft" dimensions, the dimensions that have the smallest range among the three evaluators' views fall in the group of indicators known collectively as "hard" (Institutional, Technological and Economic) reinforcing the idea that this methodology is more robust for the hard dimensions.

A general observation is that for the "soft" dimensions (Environmental, Ethical and Social), the range of the results, as shaded in Table 86, is relatively large (1.5 on average), whereas for the hard ones, it is relatively small (0.667 on average).

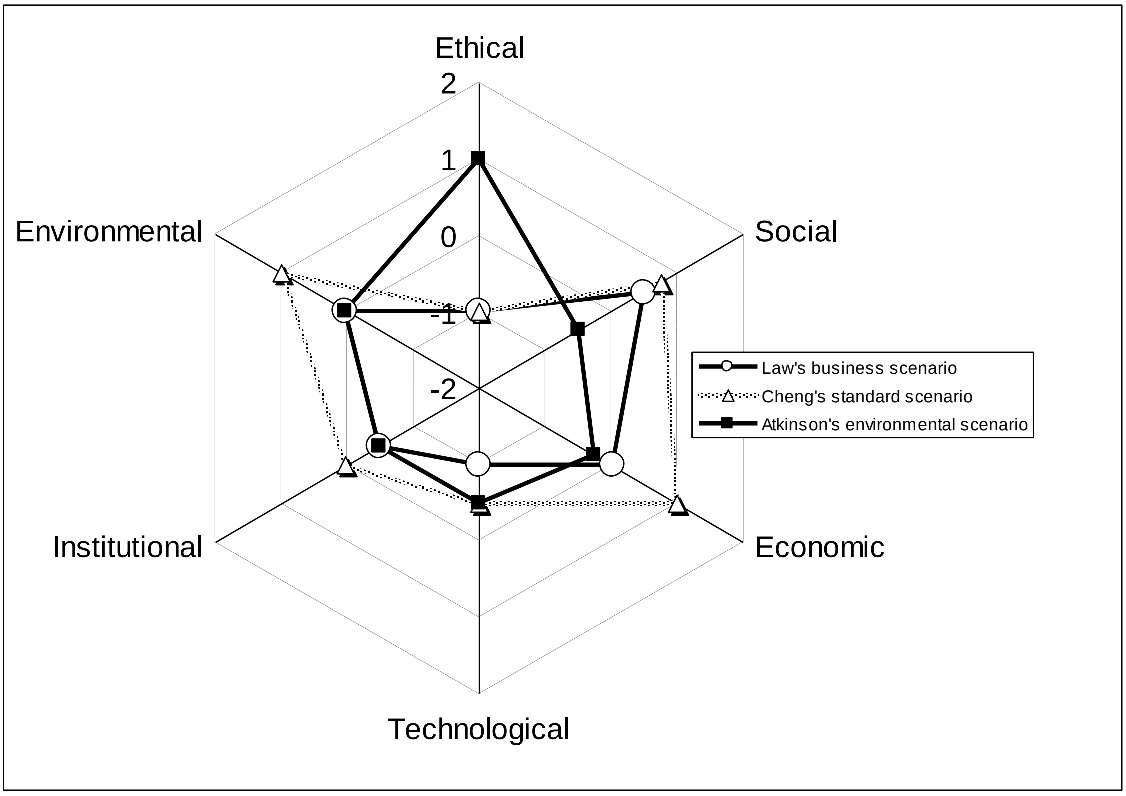


Figure 85 Spider diagram comparing all the results from all evaluators

Table 86 The evaluators' sustainability results

	Atkinson (environmental)	Law (business)	Cheng (standard)	Range
Ethical	1	-1	-1	2
Social	-0.5	0.5	0.75	1.25
Environmental	0	0	1	1
Technological	-0.5	-1	-0.5	0.5
Institutional	-0.5	-0.5	0	0.5
Economic	-0.25	0	1	1.25
Median	-0.375	-0.25	0.375	

5.13.3 Conclusions on analyzing the results of the evaluators

While the potential robustness of the methodology has been illustrated, it is envisaged that the real robustness can only be tested when the methodology is carried out in actual cases by an investigation team with a varied mix of members in the investigation team. Such a project unfortunately is beyond the scope of this PhD thesis.

5.14 Conclusion on the case study

This chapter presented a case study to quantify sustainability for the electricity sector of New Zealand using the methodology proposed in Chapter 4. From the overall result, the Ethical dimension was identified as the most unsustainable aspect and the indicators that have the least values were the ones measuring the number of projects that were delayed or cancelled because of public opinion or native land rights through the Resource Management Act. The most efficient solutions would be for the government to update the regulations to meet today's needs and to have more conclusive negotiations on lands rights with Maori.

Limitations of the methodology were pointed out in the areas of allocating the indicators to the stakeholders and in the definition of the DICFs. As this methodology's purpose is to pin-point issues that may affect sustainability through a set of indices focused on specific sustainability issues, the indices need to be read within their context. Quoting the index without the knowledge of its constituent issues will most likely result in misrepresenting the overall sustainability situation of the sector.

Three different evaluators were used to test the robustness characteristics of this methodology, they hold three different views ─ one with an environmental bias, another with commercial interest and one with an academic/standard view. As expected, the "hard" dimensions (Economics, Technological and Institutional) were found to have a smaller variation in their results across the three evaluators, indicating a more robust trend, whereas the "soft" dimensions (Ethical, Social and Environmental) had a larger variation in the results, indicating less robustness.

The author also acknowledge that the full robustness of the methodology can only be tested on a real case with a hand-picked investigation team with members that are carefully selected for their ability to give fair representation of the stakeholders as well as a voice for the environment and the future generations.

Chapter 6 Conclusions of this thesis and an outlook

This thesis has argued that quantifying sustainability is the first step in improving the sustainability of our society, so, the major contribution of this work is the proposal of a methodology to quantitatively assess sustainability. To make the process manageable, this work is primarily directed at establishing the sustainability of individual sectors.

The conclusions of this thesis are expressed in the main research themes below and in the answers to the research questions.

6.1 Research themes

This thesis includes four research themes regarding sustainability and they are: sustainability definition, sustainability prediction, theoretical framework and basis of analysis, and quantification of sustainability, details are as follows:

Theme one: Sustainability definition

In this thesis a number of proposed Sustainable Development definitions were reviewed and the conclusion was that sustainability concepts are controversial, varied and illusive. However, when the attention was restricted to just considering the sustainability of an industry sector, the definition could be more concrete and useful. For the purpose of this thesis, focus was restricted to the electricity sector and an argument was made that for it to be sustainable, it needs to reliably supply electricity at a reasonable price while satisfying social, environmental, technological, ethical, economic and institutional requirements, and all the time operating as an economically viable business, both in the short, medium and long term, as originally suggested by Cheng & Wilson (2004). This definition can be applied in a slightly altered form to other industry sectors.

Theme two: Sustainability prediction

In assessing the variety of ways to improve sustainability in general and in a case study, this thesis looked at the performance of modelling as a predicting tool to improve the sustainability of a sector. The results from this study, in agreement with many published works, showed, for the example of the electricity sector, that with the current modeling methods on electricity usage, there were doubts concerning their ability to predict future demands accurately. While it was established that there are different levels of accuracy relating to different models types, that was not be further investigated in this thesis. A conclusion was drawn that simplistic models do not necessarily give less accurate predictions over the long term. In fact, historic data suggested the electricity usage in New Zealand has been under-predicted which partly accounts for capacity planning that results in a lack of generating reserve, causing power shortages at times.

Spikes in the New Zealand spot electricity price have been adversely affecting businesses and if it is a phenomenon that can be predicted in advance, it can give users the chance to take measures to minimise their total energy cost. Tests were made on the predictability of, and the ability to be modeled for, the electricity spot price and findings showed that it has a chaotic nature around periods immediately prior to price spikes. That implied that the spot price spikes are not predictable in the medium and long term, thus the conclusion was drawn that a lack of predictability of numeric data modeling necessitates the employment of alternate methods to improve sustainability. The first option was to have the ability to measure sustainability with a metric, because what we can measure, we can improve. However, just because the electric spot price is difficult to predict does not mean that the country's average electricity price is unpredictable in the medium to long term. It is after all the latter prediction that is more important in assessing the sustainability of the industry.

This thesis chose to concentrate on the electricity sector of New Zealand as an example and established that its future cannot be accurately simulated due to its inherent chaotic elements. This thus led the author into using a different approach to systematically improve the sustainability of any industry sector.

Theme three: Theoretical framework and basis of analysis in sustainability

This thesis proposed a methodology that is scale invariant, recursive, robust and is as objective as practical. The thesis concluded that the framework suitable for use with this thesis was the Driving Force, State and Response framework (DSR) approach through which sustainability issues were categorised into six dimensions, namely: Environmental, Ethical, Social, Technological, Economic and Institutional.

A systems approach is taken that puts emphasis on identifying, analyzing and solving problems using quality management tools. The needs of the different stakeholders are also recognised and indicators are collated to show their individual sustainability.

Although not investigated in this thesis, the ideas presented here are suitable for any industrial sector since they face commonly problems of limited resource, a need to act within legislative guidelines, and be responsible to both stakeholders and the society at large. This includes, for example, the fishing industry in New Zealand, and the electricity industry in the United Kingdom.

In fact, the fishing industry is a suitable sector for creating sustainability indices using the methodology proposed in this thesis. It is a significant industry with a turnover of $1.3 billion (compare with around $7.3 billion for the electricity sector), directly employing over 7000 people (Ministry of Fisheries New Zealand 2007), and it is working within a set of limited conditions to keep the industry sustainable. It has regulations for managing the sector and the government has negotiated objectives and licenses with stakeholders to prevent over-harvesting (in the institutional dimension), it also works closely with Maoris to strike agreements for their rights and involvements (in the ethical dimension). The 2006-2011 Statement of Intents has strategies that improve corporate sustainability in the areas of social (staff satisfaction, training), technological, procurement, sustainable building and energy efficiency (Ministry of Fisheries New Zealand 2007). What was not mentioned was what methodology will be used to present this bulk of data from this wide range of information in an easily understood manner. The methodology proposed in this thesis may be adopted with minimal changes.

On the other hand, the electricity sector in the UK has also undergone deregulation since 1990 and has recently undergone a massive effort to improve its sustainability. It has 75GW capacity and employs 141,000 staff directly (Department for Business Enterprise and Regulatory Reform 2007). Because it produces 37% of power from coal and 36% from gas (as well as 18% from nuclear), it is facing great financial challenges from carbon charge and the cost of decommissioning nuclear plants. It needs technological innovation for carbon sequestration or carbon dioxide scrubbing, and needs to handle ethical problems in cleaning up retired nuclear sites (Department for Business Enterprise and Regulatory Reform 2007). This market is similar to that of

New Zealand in that it was recently de-regulated but still needs government intervention in its governing (in institutional dimension) and it has a spot price market that is more vulnerable to international crude oil price. On top of these similarities, the UK electricity market faces a different set of problems and regulations, thus, monitoring its sustainability is crucial. Research by the author cannot locate any sustainability reports that quantify sustainability for this sector with a comprehensive list of indices, thus the methodology proposed in this thesis can be a potential choice. Again, the proposal described in this thesis can be applied with minimal changes to the UK situation, but due to the different settings, sustainability issues, and relationships among stakeholders, the compositions of the dimensions may be quite different.

Theme four: Quantification of sustainability

In quantifying sustainability indicators, an approach has been taken to identify the absolute, or failing that, the relative, sustainability threshold level and create a metric. The metrics are calculated from Data-indicator conversion functions (DICFs) with a numeric scalar between -2 and 2. These are then summarised into multiple levels of indices, with different levels of detail for a variety of usages.

Defining the DICFs remains the crucial step in converting raw data into indices as each indicator needs to have its own DICF clearly formulated. Although some controversy is expected in arriving at the indicators, this process needs to be transparent and the investigation team members that use this methodology need to give consensus on the definitions of the DICFs.

Besides the above research themes, the conclusions of the thesis are further described in the following sections answering the research questions and in the “Research contribution” section.

6.2 Research questions and responses

In Chapter 1, this thesis was opened with eight research questions and their answers are now available as below. These are also summarised in Table 87.

Question 1: ***What framework is suitable for quantifying sustainability in an industry sector?***

As pointed out in section 6.3.1, the Driving Force, State and Response (DSR) framework and the management tools from Total Quality Management (TQM) were used to identify issues, analyse their structures and re-organised them in an easily understandable manner. A group of indicators was selected, and quantified according to a set of guidelines and normalised into indices according to stakeholders and sustainability dimensions. These were then presented as indices at different levels of detail.

Question 2: ***What is an effective methodology for increasing sustainability for industry sectors?***

This thesis has selected a methodology to quantify and improve sustainability according to a standard set of criteria and through the TQM's Plan-Do-Check-Act management cycle. Two special areas were identified that users of the methodology need to make a choice on, and they are: a weighting system for the indicators and dimensions and the choice of a normalization method. They are further discussed below.

The perceived significance of the dimensions and indicators are not the same for all the stakeholders. It is thus worth investigating which weighting system of these attributes best reflect their relative importance in the eyes of the stakeholders during the calculation of the sustainability indices. For the case study in this thesis, they were given equal weights.

To normalise the indicators into indices, the method of taking the median value was adopted. While it can be argued that as the sustainability of a system is limited by its weakest links, what should have been used is the lowest sustainability value. An even more conservative approach could be to consider sustainability issues as risks that threaten the society and the total risk is the multiplication of all the individual risks. However, the results from both these latter two schemes will be overly dominated by the worst cases. Users of the methodology need to clarify the different situations under which the different normalization methods should be used.

The methodology proposed in this thesis is detailed and exhibits multiple levels of indices and dimensions. It may turn out that for smaller studies and restricted domain, it is more efficient to just use a subset of the levels with a consequent reduction of work.

Also in answering Question 2, a piece of software could in principle be written to help automate this methodology. A generic template can be designed for different industry sectors with a focus on a user friendly interface with the result that large amounts of data and conversion functions can be input easily and updated interactively. The presentation of the results can be further refined so that different levels of results can be displayed in a more graphical and colourful media.

Question 3: ***What are the concepts behind the analysis?***

The Driving Force, State and Response (DSR) concept was used to categorised sustainability issues into sustainability dimensions and sub-dimensions according to the needs of the sector. Systems concepts were used to identify stakeholders and their relationships. Based on solution-focused concepts, focus was put on problematic issues with the intention of creating solutions and not on making a general survey of all the SD aspects. In creating a scalar for each indicator, there was a need to specify or estimate its sustainability threshold and reference points, and create a formula to rate the input data in order to quantify sustainability. Stakeholders face their specific sustainability problems and in order for the sustainability index to be meaningful to them, the indices were tailor-made for each one of them.

While this methodology was designed with the concept that it is scale invariant and recursive, further research may be needed to test its ability to be scaled-up or adapted for a country-wide study. A scaled-down version can also be developed for a single company's sustainability measurement and for benchmarking with other firms in the same industry.

Question 4: ***How robust is the methodology to extreme inputs?***

Besides the author's "standard" view, two more evaluators were used to provide two more different views: one was environmentally biased and the other was focused on commercial interest. The results showed that the methodology proved to be reasonably robust in the "hard" dimensions of sustainability, whereas the "soft" dimensions exhibited more variations.

Question 5: ***What are the limitations of the method?***

As mentioned in Chapter 1, some parts of this methodology, such as the selection of issues, the decision on the threshold of indicators and the scaling criteria in the Data Index Conversion Functions, are inherently subjective. Another limitation in the management of the process is in the choice of participants who may have a prior view of the sustainability of the sector under study. The choice of the members in the investigation team, if significantly biased to one view, can inevitably affect the results but the natural robustness of the method can minimise this. Also, there is a danger that sustainability indices are easily quoted out of context unless the ways they were derived are clearly explained.

Question 6: ***What are the areas for further research as a consequence of this thesis?***

Areas for further research are: to fine tune the definitions of the Data-indicator conversion functions, to study the effects of technology change and adaptive change theory, to predict the growth of sustainability awareness, research into the causes of price spikes and to develop a channel to obtain consensus on Sustainable Development policies and methodologies. The details can be seen in section 6.4.

Question7: ***What is a suitable definition of sustainable development for the electricity sector?***

A sustainable electricity sector can be summarised as one that "reliably supplies electricity at a reasonable price while satisfying social, environmental, technological, ethical, economic and institutional requirements, and all the time operating as an economically viable business, both in the short, medium and long term" (Cheng and Wilson 2004).

Question 8: ***How predictable is the development of the electricity sector?***

The accuracy of demand prediction is controversial, and the spot price is particularly difficult to predict in the medium or long term due to its apparently sporadic chaotic nature. However, even if that is the case, it does not automatically imply that the electricity sector is unsustainable.

Table 87 Research questions, related chapters and answer summaries

	Research question	Related chapter	Answer
1	What framework is suitable for quantifying sustainability in industry sector?	Chapter 4	TQM framework for process improvement. Quantification of qualitative information, and putting the sustainability indicators on a simple scalar.
2	What is an effective methodology for increasing sustainability for industry sectors?	Chapter 4	Using TQM tools such as Systems Diagram, Affinity Diagram, Tree Diagram, Matrix Diagram and Flow Chart to categorise and analyze information. Quantify information with Data-indicator conversion functions, normalise data using the median and presentation using spider diagram.
3	What are the concepts behind the analysis?	Chapter 4	Categorise sustainability into sub-dimensions according to the needs of the sector. Systems approach, focus on problem issues and on creating solutions. Need to specify or estimate sustainability threshold and reference points. Create indices to quantify sustainability. Stakeholders face specific sustainability problems and indices need to be tailor made for them.
4	How robust is the methodology to extreme value input?	Chapter 5	Consultation and sensitivity analysis shows the methodology to be robust in a particular set of dimensions where results are not excessively distorted by extremes in inputs.
5	What are the limitations of the method?	Chapter 1	Various steps, such as the selection of issues, deciding the threshold of indicators, may be criticised as subjective. The choice of project participants with their known views of sustainability can affect the results. Results can be quoted out of context if what constituted the indices is not known.
6	What are the areas for further research as a consequence of this thesis?	Chapter 6	Definition of Data-indicator conversion functions. Effect of technology changes. Adaptive change theory. Growth of sustainability awareness. Causes of price spikes. Consensus on SD policies and methodologies
7	What is a suitable definition of sustainable development for the electricity sector?	Chapter 2	It is to "reliably [supply] electricity at a reasonable price while satisfying social, environmental, technological, ethical, economic and institutional requirements, and all the time operating as an economically viable business, both in the short, medium and long term."
8	How predictable is the development of the electricity sector?	Chapter 3	The accuracy of demand modeling is debatable and the electricity spot price has chaotic elements which make it unpredictable in the medium and long term.

6.3 Research contribution

The research contribution can be categorised into four main categories, namely: critical, conceptual, methodological and synthesis.

6.3.1 Critical

This thesis has critically analyzed the definitions and the areas of controversy for Sustainable Development (SD) as well as the status of the current works on SD in industry sectors. As an example, the sustainability issues in the electricity sector are reviewed with a special focus on the situation in New Zealand.

6.3.2 Conceptual

This thesis concluded on a definition of sustainability for the electricity sector and gave evidence that modeling might not be the most appropriate tool to improve sustainability in an industry sector, but instead, a management approach using quantitative indicators might be more effective.

This research raised the question of what is an appropriate way to assess and measure sustainability in an industry sector and proposed that management tools and sufficient knowledge in sustainability is a powerful combination to make improvements in sustainability.

It pointed out that a solution-focused approach is necessary to effectively solve sustainability problems. As a conceptual framework, defining sustainability thresholds and reference points is a subjective but essential step for quantifying sustainability indicators. The fact that different stakeholders are facing specific sustainability problems necessitates the use of tailor-made sets of indices for each of them in order to generate the most relevant information.

6.3.3 Methodological

This thesis has developed an original methodology, making use of a unique combination of tools and the above concepts, to identify and classify sustainability issues, analyze them according to sustainability dimensions and stakeholders, to quantify them and generate indices of sustainability, and to present them in a multi-level format. It also provided a mechanism to trace the indicators back to the significantly unsustainable issues and their possible solutions.

6.3.4 Synthesis

In the case study, the evaluators have synthesised the inputs for the sustainability indices of New Zealand's electricity sector according to their own views. The objective of generating the multiple views was to test the robustness of the methodology and the results indicated its characteristics.

6.4 Further research

Upon reviewing the methodology proposed in the thesis to quantify sustainability, various areas are identified as having the potential for further research. They are discussed as follows:

The Data-indicator conversion functions (DICF) was probably the most important and yet controversial part of the methodology. These are the criteria for putting sustainability indicators onto a scalar. Further research is needed to establish more accurately the sustainability tipping points, or thresholds, for the indicators to be put into the DICF so that, as a result of the stakeholders having a consensus on the validity of the scaling method, the DICFs can be scientifically sound or, failing that, can be rated in a relative but congruent manner.

For a truly sustainable society, the sustainability equilibrium may not need to depend on the invention of new technologies to solve emerging problems – it should be self-sufficient in that it can stay at sustainable equilibrium without additional new inputs. Historically, in the western world, that has not been the case as the developed countries have been depending on new technologies to solve sustainability problems. Research will be valuable to look into the past innovative technologies in solving sustainability problems and investigate if any patterns can be established for this dynamic system. On a contradictory tone, Lighteringen (2006) proposed that adaptive changes instead of technological changes are needed to achieve sustainability. Research is needed to investigate the validity of these different claims.

The next area for potential research is in the area of sustainability awareness. Over the past five years, the efforts put into improving sustainability have increased nearly exponentially. It has come to the top of the agenda for many governments, and many companies now consider sustainability reporting as important as financial reporting. It is thus of interest to study this trend and predict the impacts of an increasing sustainability awareness on the society.

Chapter 4 established that the electricity spot price in New Zealand has an intermittent chaotic nature around and during price spike periods and that has been causing financial and operational difficulties with electricity users. It will benefit the electricity users if further research is made to investigate the causes of these price spikes, identify the triggers of the chaotic events and test if the triggers can be eliminated or predicted.

The concept of sustainability is illusive ─ on the factual side it is based on objective scientific data but on the abstract side, it is also based on subjective democratic opinions, therefore, it is crucial for further research to bring different parties together and arrive at a consensus on the long term sustainability policies and methodologies of measurements so that even while the government change, the sustainability strategy will not and Sustainable Development can become a golden thread that can rise above political differences and link the nation in this common vision.

As a closing remark, quantification of sustainability is a highly controversial topic and this thesis has proposed a process which is aimed to be immune to hijacking, which is robust, scale invariant and recursive. Naturally, different stakeholders have their own opinions and the methodology proposed was an attempt to bring them together to start a conversation. Irrespective of the scalar that the methodology generates, the simple act of requiring conversation among stakeholders will almost certainly produce unexpected benefits. Sustainable Development has been called a journey, and this metaphor is even more appropriate for the process of developing methodologies to quantify sustainability. It is only through the continuation of the Plan-Do-Check-Act cycle of improving sustainability and further research in the quantification of sustainability that this, and future, generation can accomplish this mission of sustainably developing our industries and societies.

Appendix 1 Sustainability Indicator/ Issue Matrix

INDICATORS	ISSUES									
1) Power market factors	1.1 Planning of generating resources (e.g. hydro firming) not catered for meeting demand at times of low reserve capacity but for maximizing profit.	1.2 Oligopoly mode of market operation: charging excessively high prices according to this model, acting against the ideology of a free power market where competition pushed the price down and benefiting the users.	1.3 Ineffective free market causing price to show chaotic characteristics.	1.4 Immature hedge market, market power to force small users to buy at spot price at a higher price risk.	1.5 Unknown carbon tax system causes uncertainty and stopping investments.	1.6 Profit is limited by the government – discourage investors (e.g. transmission in NZ).	1.7 Power is a utility, since changing from central planning, not many free markets have successful stories.	1.8 Power price and demand/supply models do not provide accurate result- error in planning growth and capacity results in power shortage and wrong investments	1.9 Lack of overall planning resulting in demand reaching supply limit without warning.	1.10Lack of power supply alternative and innovation.
1.1 Government policy - power market										
1.1.1 Clear government policy – tax and plans – confidence for investment					■	■	■	■	■	
1.1.2 Government policy for minimum service quality standards/ min reserve power/ capacity	■	■					■	■	■	
1.2 Government authority -power market										
1.2.1 Government authority to interrupt market if it does not operate well	■	■	■	■		■	■			
1.2.2 Number of cases where government interrupted free market	■	■	■	■		■	■			
1.2.3 Government enforced price cap, number of occurrence in last year	■	■	■	■		■	■			
1.2.4 Government enforce reserve power usage - occurrence in last year	■	■	■	■		■	■			
1.3 Market efficiency- power market										
1.3.1 Evidence of price decrease due to competition	■	■		■			■			
1.3.2 Wholesale price hedge market – effectiveness and availability of contracts	■	■	■	■			■			
1.3.3 Wholesale pricing nature – chaotic or oligopoly	■	■	■	■			■			
1.3.4 Price affordability - # of household spend more than 20% income on bill	■	■					■			
1.3.5 Evidence of oligopoly/ excessive profit/ inefficient market	■	■		■			■			
1.4 Market flexibility- power market										
1.4.1 Government's initiative to correct inefficient market	■	■	■	■		■	■			
1.4.2 Number of government reviews and market reforms to improve efficiency	■	■	■	■		■	■			
1.4.3 Evidence of government adopting new technique and new policy in face of change	■	■	■	■		■	■			
1.5 Planning accuracy- power market										
1.5.1 Accuracy of supply and demand models by government							■	■	■	
1.6 Economic environments- power market										
1.6.1 Stability of currency										
1.6.2 Interest rates and trends										
1.6.3 Import fuel price levels					■					
1.7 Generation efficiency- power market										
1.7.1 Use of demand side management by customers										■
1.7.2 Adaptation of distributed generation by generators										■
1.7.3 Use of combined heat and power by customers										■
1.7.4 Implement on/off peak pricing mechanism as a market mechanism.	■									■

2) Transmission factors	2.1 Transmission bottleneck to part of the country. Part of the country with excess reserve cannot serve the part with limited supply because of transmission bottleneck.	2.2 Transmission line reliability – ease of breakdown	2.3 Transmission lines not designed with expansion in mind.	2.4 Transmission system lacks spare capacity to enable lines to be taken out of service and be upgraded.	2.5 Poor planning for expanding current system and replacing lines reaching end of useful live.	2.6 Lack of investment and incentive for that.	2.7 Uncertainty in the complex procedure for approving the building of new lines.
2.1 Government policy - transmission							
2.1.1 Govt policy to encourage investment in transmission.	■					■	
2.1.2 Government policies in power sector are clear and consistent.		■		■	■	■	■
2.1.3 Availability of economic instruments to encourage investment.	■			■		■	
2.1.4 Government regulations on transmission quality e.g. % of spare capacity		■	■	■	■	■	
2.2 Performance - transmission							
2.2.1 Transmission downtime statistics	■	■		■	■	■	
2.2.2 Occurrence of transmission bottlenecks/ capacity shortage	■		■	■	■	■	
2.2.3 Transmission line spare capacity	■	■	■	■	■	■	
2.3 Evidence of forward planning - transmission							
2.3.1 Investment in transmission over the past year	■	■	■	■	■	■	
2.3.2 Planning of new lines considers location of new generation.	■		■	■	■		
2.4 Barrier for expansion - transmission							
2.4.1 Number of cases where environmental policy stopped projects	■		■	■		■	■
2.4.2 Number of cases where RMA stopped projects	■		■	■		■	■
2.4.3 Number of cases where public hearing and opinion stopped projects	■		■	■		■	■
2.5 Accessibility - transmission							
2.5.1 % of population accessible to transmitted power	■				■		
2.6 R&D - transmission							
2.6.1 Amount of R&D in improving transmission technologies and planning	■	■	■	■	■	■	

3) Fuel related factors	3.1 Lack of interest to invest in renewable power	3.2 Fossil fuel reserve runs out	3.3 Worry about peak oil	3.4 Technical problems/ issues for fuel delivery (e. LNG terminal)	3.5 A lack of development of natural fuel resources	3.6 Power source is seasonal (hydro) – may face unexpected shortage	3.7 Import fuel subjected to international price pressure	3.8 Foreign currency fluctuation threat of price increase.	3.9 Fuels exported a shortage for local use.	3.10 Threats from supply security	3.11 Non efficient fuel use
3.1 Fuel market											
3.1.1 Percentage of power generating fuel used for export		■	■		■			■	■		
3.1.2 Duration stock reserve can last – 3 months?		■				■	■		■	■	
3.1.3 Long term contracts to secure fuel supply		■					■	■		■	
3.2 Forecast accuracy- fuels											
3.2.1 Accuracy of fuel S&D forecast		■				■				■	
3.3 Government regulation - fuels											
3.3.1 Regulation controlling portion of power generated from renewable source	■				■	■				■	
3.3.2 Regulation to limits usable fuel types, e.g. no log burning, nuclear free										■	
3.4 Fuel self sufficiency											
3.4.1 Percentage of generation fuel used that is imported.		■	■	■			■	■	■	■	
3.4.2 Amount of reserve fuel hold by type of fuel		■				■				■	
3.4.3 Fuel supply stability – variation in market supply/ price,		■	■		■	■	■	■	■	■	
3.4.4 Renewable fuel supply stability - seasonal capacity (hydro/ wind)										■	
3.4.5 Fuel delivery problems – LPG, coal, number of cases.				■						■	
3.5 Fuel price predictability						■					
3.5.1 Fuel price chaotic or predictable		■	■				■	■		■	
3.6 Fuel research											
3.6.1 Amount of R&D to improve fuel technology											■

4) Investment factors	4.1 Lack of generation investment,	4.2 society outgrow present capacity	4.3 Lack of building new generators, as addition capacity or as replacement for generators reaching the end of their useful life.	4.4 Lack of investment for research - in renewable energy, new energy reserve.
4.1 Government encourage investment				
4.1.1 Government encourage investment in R&D	■			■
4.1.2 Government encourage investment in generation	■		■	■
4.1.3 Government encourage investment in other areas in power sector				■
4.1.4 Government innovation for new mechanisms to encourage investment	■		■	■
4.2 Long term planning evidence-investment				
4.2.1 Data of remaining workable life for old power plants		■	■	
4.2.2 Plans for building new generation plants.		■	■	
4.2.3 Sufficiency of planned new plants to meet expected need.		■	■	

5) Environmental factors	5.1 Excess pollution:	5.2 Carbon tax put extra pressure on price of fossil fuel.	5.3 Environmental regulations hinder the building of new facilities – generating, transmission	5.4 Company do not perform environmental assessment	5.5 Minimal R&D on pollution research	5.6 Threats of climate change	5.7 Damaged ecology
5.1 Conservation act							
5.1.1 Number of projects/ percentage stopped by conservation/resource consent act			■				
5.1.2 Evidence of review to simply the process of conservation/ resource consent			■				
5.1.3 Average time to solve cases referring to the conservation act			■				
5.2 Pollution regulation							
5.2.1 Sufficiency of existing pollution regulations.	■	■				■	■
5.2.2 Number of reviews to update pollution regulations	■	■					■
5.2.3 Number of pollution complaint cases received and handled in power sector	■						■
5.3 Pollution reduction policy							
5.3.1 Government economic instruments to promote pollution control	■	■					■
5.3.2 Government economic instruments to deter pollution	■	■					■
5.4 Pollution data							
5.4.1 Availability of pollution data	■	■				■	■
5.4.2 Trend of pollution data	■	■				■	■
5.4.3 Number/ percentage of power company that has EMS (Environmental Management System) like ISO14000				■			
5.4.4 Pollution impact assessment on social, economic and environmental aspects		■		■		■	
5.5 Pollution R&D							
5.5.1 Government promote funding for R&D on pollution prevention/control projects in power sector					■	■	
5.5.2 Number of pollution control projects initiated by government in power sector.	■			■			■

6) Economy factors	6.1 Growth of economy leads to unexpected increase in power use, leads to power shortage	6.2 Economy grows in sector that are relatively more energy intensive.	6.3 Capacity cannot meet demand.	6.4 Plans of capacity increase do not meet plans of building new generation.	6.5 Power companies close due to economical reasons	6.6 Power companies in financial problems	6.7 Lack of contingency plan by government
6.1 Sector trend							
6.1.1 production pa	■	■	■	■			
6.1.2 turnover pa					■	■	
6.1.3 profit pa					■	■	
6.2 Sector R&D - economy indicators							
6.2.1 Power sector supply and demand modeling accuracy	■		■	■			
6.2.2 Generation of scenario for planning	■		■	■			
6.3 Economy trend							
6.3.1 Trend of economic growth	■	■				■	
6.3.2 Energy intensive industry growth trend cf other ODEC countries		■	■	■			
6.4 New capacity - economy indicators							
6.4.1 Amount of recent , planned, replacement generation capacity			■	■			
6.4.2 Evidence new planned capacity will meet expected demand.			■	■			
6.5 Government policy - economy indicators							
6.5.1 Number of Government's electricity conservation plans			■				
6.5.2 Evidence of Government's plans for emergency power shortage							■
6.5.3 Impact assessment reports from Government							■

7) Technical factors	7.1 Lack of increase in energy efficiency for generators - equipment not upgraded.	7.2 Efficiency not increased at user's end.	7.3 Do not adopt new technology to improve efficiency	7.4 Poor modeling technique causes Poor planning
7.1 Government policy/ regulation - technical issues				
7.1.1 Government regulation for energy labeling scheme	■	■		
7.1.2 Government to provide economic incentives in increasing technical efficiency	■	■	■	
7.1.3 Government policy to encourage technical R&D in power industry	■	■	■	
7.2 Government initiative - technical issues				
7.2.1 Government improve techniques in modeling and forecasting				■
7.2.2 Government improves techniques in scenario analysis				■
7.3 government promote energy efficiency and conservation - technical issues				
7.3.1 Establishment of a government body for power conservation and efficiency		■	■	
7.3.2 Economics instruments for encouraging power conservation/ improve efficiency		■	■	
7.3.3 # of projects set to improve energy efficiency and conservation	■	■	■	
7.3.4 Number of government's technical projects - energy conservation		■	■	
7.3.5 Trend of improvement in generation efficiency	■	■	■	
7.4 government encourage alternative solutions - technical issues				
7.4.1 Number of companies adopting Demand Side Management		■	■	
7.4.2 Number of companies adopting Combined Heat and Power	■	■	■	
7.4.3 Number of companies adopting Distributed Generation	■	■		
7.4.4 Government encourages new technical solutions : Distributed Generation, Combines Heat Power, Demand side Management		■	■	

8) Power generation factors	8.1 Fuel price increase	8.2 Carbon tax uncertainty.	8.3 Mix of generation resource not maximised to provide generation efficiency.
8.1 Fuel price - generation			
8.1.1 Generation fuel price trend	■		■
8.1.2 Generation fuel availability/ affordability	■		■
8.1.3 Generation fuel carbon tax plan clarity	■	■	■
8.2 Generation plant planning			
8.2.1 Number of generation plants upgrade planned			■
8.2.2 Number of new generation plants planned			■
8.2.3 Number of generation plants near end of life			■
8.2.4 Planning for new/ replacement generation plants			■
8.3.0 Government regulation – best use of generation resource			
8.3.0 Government regulation – best use of generation resource			■

9) Ethical factors	9.1 New construction or amendments to existing facilities limited by conservation acts or resource consent	9.2 Enquiry time of approval takes too long –uncertainty that deters investment.	9.3 SD issues in the society affect the development of the power sector.	9.4 Political stand limits generation options (e.g. nuclear free NZ).	9.5 Cultural issues such as aboriginal culture's stand in the protection of nature.	9.6 Companies only talk about SD without real actions
9.1 Evidence of strong political stand - ethical						
9.1.1 Limitation on generation options by political/society stand			■	■	■	
9.1.2 Cases of projects cancelled because of public opinion	■	■	■		■	
9.2 Willingness to improve - ethical						
9.2.1 Cases of Government reviewing and simplifying ethical review process like RMA	■	■			■	
9.2.2 Average time to approve projects through resource management process.	■	■	■		■	
9.3 Mechanism for public opinion to be heard - ethical						
9.3.1 Accessibility of public enquiry process by residence	■	■	■		■	
9.3.2 Aboriginal rights - fairness and practicality.	■	■	■		■	
9.4 Evidence of public opinion considered - ethical						
9.4.1 Number of projects stopped last year due to public opinion	■		■	■	■	
9.4.2 Number of projects approved by resource consent but with changes	■		■	■	■	
9.4.3 Number of Aboriginal rights claim that stop projects.	■		■		■	
9.5 Industry SD reporting trend - ethical						
9.5.1 Number of power companies producing sustainability report ,e.g. GRI style						■

10) Social factors	10.1 Company cannot generate due to social reasons such as strike, picketing, work out, boycott	10.2 Due to demand in pay rise	10.3 Due to work issues,	10.4 Due to political reasons.	10.5 Due to ethical reasons	10.6 No graduates from power engineering course	10.7 Lack of skilled labour
10.1 Labour relationship - social							
10.1.1 Existence of labour unions	■	■	■	■	■		
10.1.2 Number of strike, walk outs, picketing last year	■	■	■	■	■		
10.1.3 Days affected by strike, walk outs, picketing last year	■	■	■	■	■		
10.2 Labour availability - social							
10.2.1 Labour skill shortage						■	
10.2.2 Labour turnover							■

11) Country's industrial structure factors	11.1 Industry structure change, users do not buy from the power sector, instead generate own power.	11.2 Too strong energy intensive industry - insufficient capacity for other parts of the economy
11.1 Trend of energy intensive sector		
11.1.1 Growth trend of energy intensive sector	■	■
11.1.2 Number of companies in the power intensive sector	■	■
11.2 Government policy - industry sector		
11.2.1 Economic policy favours what type of industry – energy intensive or not	■	■

12) Acts of God factors	12.1 Severe weather – too hot or cold that draws demand that exceeds capacity.	12.2 Severe weather – bring transmission lines down.	12.3 Dry weather – less fuel for hydro generation.	12.4 Too cold weather – river flow is less due to less snow melting – affects hydro power.	12.5 Other natural disaster that stops generation and interrupts transmission – earth quake, strong solar flare.
12.1 Back up preparation - from Acts of God					
12.1.1 Backup capacity	■		■	■	■
12.1.2 Generation fuel reserve	■		■	■	.
12.1.3 Back up generation plan	■	■	■	■	■
12.1.4 Impact assessment reports done	■	■	■	■	■
12.1.5 Civil defence plan sufficiency	■	■			■
12.2 Ease of system interruption by Act of God					
12.2.1 Statistics of power cut due to downed transmission lines,		■			■
12.2.2 History of too hot or cold causing demand above max capacity	■				
12.2.3 History of draught – low hydro head			■		
12.2.4 History of events affecting the supply of renewable energy. (e.g. earthquake affects hydro dam)		■	■		■

Appendix 2 Sustainability Dimensions and the involved indicators.

INSTITUTIONAL

A) Govt policy

A1) Govt policy for power market	7.3.1 Establishment of a government body for power conservation and efficiency
A2) Govt policy for transmission	2.1.1 Government policy to encourage investment in transmission 2.1.2 Government policies in electricity sector are clear and consistent 2.1.3 Availability of economic instruments to encourage investment
A3) Govt policy to encourage investment	1.1.1 Clear government policy – tax and plans – confidence for investment 4.1.1 Government encourages investment in R&D 4.1.2 Government encourages investment in generation 4.1.3 Government encourages investment in other areas in electricity sector 4.1.4 Government innovation for new mechanisms to encourage investment
A4) Govt policy for pollution control	5.3.1 Government economic instruments to promote pollution control
A5) Use of economic instruments in electricity sector	5.3.2 Government economic instruments to deter polluters 7.1.2 Government to provide economic incentives in increasing technological efficiency 7.1.3 Government policy to encourage technological R&D in power industry 7.3.2 Economics instruments to encourage power conservation/ improve efficiency 7.4.4 Government encourages new technological solutions : Distributed Generation, Combined Heat and Power, Demand Side Management
A6) Govt policy for power conservation/efficiency	6.5.1 Number of government's electricity conservation plans 7.3.4 Number of government's technological projects ─ energy conservation
A7) Govt policy on ethics	9.2.1 Cases of government reviewing and simplifying ethical review process such as RMA 9.3.2 Indigenous rights ─ fairness and practicality.
A8) Govt policy for industrial development	11.2.1 Economic policy favors what type of industry – energy intensive or not

B) Government Regulations

B1) Minimum service quality ─ govt regulations	2.1.4 Government regulations on transmission quality e.g. % of spare capacity 1.1.2 Government policy for minimum service quality standards/min reserve power/capacity
B2) Authority to interfere market ─ govt regulations	1.2.1 Government authority to interrupt market if it does not operate well
B3) Pollution control regulations	1.2.2 Number of cases where government interrupted free market 3.3.2 Regulations to limit usable fuel types, e.g. no log burning, nuclear free 3.1.3 Long term contracts to secure fuel supply 5.2.1 Sufficiency of existing pollution regulations 5.2.2 Number of reviews to update pollution regulations 8.1.3 Generation fuel carbon tax plan clarity
B4) Fuel type choice ─ govt regulations	3.3.2 Regulations to limit usable fuel types, e.g. no log burning, nuclear free 9.1.1 Limitation on generation options by political/society stand
B5) Energy labeling ─ regulations	7.1.1 Government regulation for energy labeling scheme
B6) Free market control regulations	8.3.0 Government regulation – best use of generation resource
B7) Renewable power control	3.3.1 Regulation controlling portion of power generated from renewable source

regulations	

ECONOMIC

C) Power market control

C1) Government control of power market	1.2.2 Number of cases where government interrupted free market 1.2.3 Government enforced price cap, number of occurrences in last year 1.2.4 Government enforced reserve power usage ─ occurrence in last year

D) Power market conditions

D1) Wholesale power market conditions	1.3.1 Evidence of price decrease due to competition 1.3.2 Wholesale price hedge market – effectiveness and availability of contracts 1.3.3 Wholesale pricing nature – chaotic or oligopoly 1.3.4 Price affordability ─ # of households spending more than 20% income on bill 1.3.5 Evidence of oligopoly/excessive profit/inefficient market 1.4.1 Government's initiative to correct inefficient market 1.4.2 Number of government reviews and market reforms to improve efficiency 1.4.3 Evidence of government adopting new techniques and new policies in face of change 3.5.1 Fuel price chaotic or predictable
D2) Consumer power market conditions	1.7.1 Use of Demand Side Management by customers 1.7.2 Adaptation of distributed generation by generators 1.7.3 Use of Combined Heat and Power by customers 1.7.4 Implement on/off peak pricing mechanism as a market mechanism. 2.5.1 % of population with access to transmitted power 7.3.3 # of projects set to improve energy efficiency and conservation 12.2.2 History of too hot or cold causing demand above max capacity
D3) Power supply market conditions	4.2.1 Data of remaining workable life for old power plants 4.2.2 Plans for building new generation plants. 4.2.3 Sufficiency of planned new plants to meet expected need. 9.1.2 Cases of projects cancelled because of public opinion 6.4.1 Amount of recent, planned, replacement generation capacity 6.4.2 Evidence new planned capacity will meet expected demand. 12.1.1 Backup capacity 12.1.3 Back up generation plan 7.3.5 Trend of improvement in generation efficiency 12.2.3 History of drought – low hydro head 12.2.4 History of events affecting the supply of renewable energy (e.g. earthquake affects hydro dam)
D4) Fuel market conditions	1.6.3 Import fuel price levels 3.1.1 Percentage of power generating fuel used for export 3.4.1 Percentage of generation fuel used that is imported 3.1.2 Duration stock reserve can last – 3 months? 3.1.3 Long term contracts to secure fuel supply 3.4.2 Amount of reserve fuel held by type of fuel 3.4.3 Fuel supply stability – variation in market supply/price 3.4.4 Renewable fuel supply stability ─ seasonal capacity (hydro/wind) 3.4.5 Fuel delivery problems – LPG, coal, number of cases. 3.5.1 Fuel price chaotic or predictable 8.1.1 Generation fuel price trend 8.1.2 Generation fuel availability/affordability 12.1.2 Generation fuel reserve
D5) Transmission systems	2.2.1 Transmission downtime statistics

conditions	2.2.2 Occurrence of transmission bottlenecks/capacity shortage 2.2.3 Transmission line spare capacity 2.3.1 Investment in transmission over the past year 2.3.2 Planning of new lines considers location of new generation. 12.2.1 Statistics of power cuts due to downed transmission lines,
D6) Effects of RMA/ Conservation Act/Env Act	5.1.1 Number of projects/percentage stopped by conservation/resource consent act 5.1.2 Evidence of review to simply the process of conservation/ resource consent 5.1.3 Average time to solve cases referring to the conservation act 9.2.2 Average time to approve projects through resource management process. 9.3.1 Accessibility of public enquiry process by residents 9.4.3 Number of indigenous rights claims that stop projects.
D7) Power market initiatives to improve efficiency	7.4.1 Number of companies adopting Demand Side Management 7.4.2 Number of companies adopting Combined Heat and Power 7.4.3 Number of companies adopting Distributed Generation
D8) Generating plants planning	8.2.1 Number of generation plant upgrades planned 8.2.2 Number of new generation plants planned 8.2.3 Number of generation plants near end of life 8.2.4 Planning for new/replacement generation plants
D9) Sustainability reporting	9.5.1 Number of power companies producing sustainability reports, e.g. GRI style

E) Market modeling effects

E1) Wholesale market models performance	6.2.1 Electricity sector supply and demand modeling accuracy
E2) S&D modeling effects	1.5.1 Accuracy of supply and demand models by government 3.2.1 Accuracy of fuel S&D forecast 6.2.1 Electricity sector supply and demand modeling accuracy 6.2.2 Generation of scenarios for planning 7.2.1 Government improves techniques in modeling and forecasting 7.2.2 Government improves techniques in scenario analysis

F) Power market economic

F1) Power plant planning	4.2.1 Data of remaining workable life for old power plants 4.2.2 Plans for building new generation plants. 4.2.3 Sufficiency of planned new plants to meet expected need.
F2) Electricity sector business performance	6.1.1 Production p.a. 6.1.2 Turnover p.a. 6.1.3 Profit p.a.
F3) Country-wide economic trends	1.6.1 Stability of currency 1.6.2 Interest rates and trends 6.3.1 Trend of economic growth 6.3.2 Energy intensive industry growth trend cf other ODEC countries 11.1.1 Growth trend of energy intensive sector 11.1.2 Number of companies in the power intensive sector

ETHICAL

G) Ethical issues

G1) Environmental policy effects – ethical	2.4.1 Number of cases where environmental policy stopped projects 2.4.3 Number of cases where public hearing and opinion stopped projects
G2) Indigenous rights effects –	2.4.3 Number of cases where public hearing and opinion stopped projects

	ethical	9.3.2 Indigenous rights - fairness and practicality.
	G3) Public opinion effects – ethical	2.4.2 Number of cases where RMA stopped projects 2.4.3 Number of cases where public hearing and opinion stopped projects 9.1.2 Cases of projects cancelled because of public opinion 9.4.1 Number of projects stopped last year due to public opinion 9.4.2 Number of projects approved by resource consent but with changes
TECHNOLOGICAL		
H) R&D in technological improvements		
	H1) R&D in reducing pollution	5.5.1 Government promotes funding for R&D on pollution prevention/control projects in electricity sector
	H2) R&D in fuel and new generation technology	3.6.1 Amount of R&D to improve fuel technology
	H3) R&D in improving transmission	2.6.1 Amount of R&D in improving transmission technologies and planning
ENVIRONMENTAL		
I) Pollution control		
	I1) Pollution trends	5.4.1 Availability of pollution data 5.4.2 Trend of pollution data
	I2) Adaptation of pollution control system e.g. EMS	5.4.3 Number/percentage of power companies that have EMS (Environmental Management System) such as ISO14000
	I3) Actions taken on pollution	5.5.2 Number of pollution control projects initiated by government in electricity sector.
	I4) Pollution complaints handling	5.2.3 Number of pollution complaint cases received and handled in electricity sector
INSTITUTIONAL		
J) Impact assessment preparation		
	J1) Impact assessment preparation	5.4.4 Pollution impact assessment on social, economic and environmental aspects 6.5.2 Evidence of government's plans for emergency power shortage 6.5.3 Impact assessment reports from government
SOCIAL		
K) Social issues		
	K1) Labour relationship	10.1.1 Existence of labour unions 10.1.2 Number of strikes, walk outs, picketing last year 10.1.3 Days affected by strikes, walk outs, picketing last year
	K2) Labour skill shortage/ turnover	10.2.1 Labour skill shortage 10.2.2 Labour turnover
INSTITUTIONAL		
L) Contingency planning		
	L1) Contingency planning	12.1.3 Back up generation plan 12.1.4 Impact assessment reports done 12.1.5 Civil defence plan sufficiency

Appendix 3 Indicator values from the evaluators

	Atkinson (environmental)	Law (commercial)	Cheng (standard)
1) Power market factors			
1.1 Government policy - power market			
1.1.1 Clear government policy – tax and plans – confidence for investment	-1	0	-1
1.1.2 Government policy for minimum service quality standards/ min reserve power/ capacity	-1	0	0
1.2 Government authority -power market			
1.2.1 Government authority to interrupt market if it does not operate well	-2	-1	1
1.2.2 Number of cases where government interrupted free market	-2	-1	1
1.2.3 Government enforced price cap, number of occurrence in last year	-1	-1	1
1.2.4 Government enforce reserve power usage - occurrence in last year	0	-1	2
1.3 Market efficiency- power market			
1.3.1 Evidence of price decrease due to competition	-2	1	-2
1.3.2 Wholesale price hedge market – effectiveness and availability of contracts	0	1	-1
1.3.3 Wholesale pricing nature – chaotic or oligopoly	0	1	-2
1.3.4 Price affordability - # of household spend more than 20% income on bill	-1	1	2
1.3.5 Evidence of oligopoly/ excessive profit/ inefficient market	-2	1	0
1.4 Market flexibility- power market			
1.4.1 Government's initiative to correct inefficient market	-1	1	1
1.4.2 Number of government reviews and market reforms to improve efficiency	-1	1	1
1.4.3 Evidence of government adopting new technique and new policy in face of change	0	1	1
1.5 Planning accuracy- power market			
1.5.1 Accuracy of supply and demand models by government	1	2	0
1.6 Economic environments- power market			
1.6.1 Stability of currency	-1	0	-1
1.6.2 Interest rates and trends	-1	0	-1
1.6.3 Import fuel price levels	-2	0	0
1.7 Generation efficiency- power market			
1.7.1 Use of demand side management by customers	-2	0	-2
1.7.2 Adaptation of distributed generation by generators	-2	0	0
1.7.3 Use of combined heat and power by customers	-1	0	1
1.7.4 Implement on/off peak pricing mechanism as a market mechanism.	-2	0	-1
2) Transmission factors			
2.1 Government policy - transmission			
2.1.1 Govt policy to encourage investment in transmission.	-1	1	-2
2.1.2 Government policies in power sector are clear and consistent.	-2	1	-1
2.1.3 Availability of economic instruments to encourage investment.	-1	1	-1
2.1.4 Government regulations on transmission quality e.g. % of spare capacity	0	1	-2
2.2 Performance - transmission			
2.2.1 Transmission downtime statistics	0	-1	-1
2.2.2 Occurrence of transmission bottlenecks/ capacity shortage	-1	-1	-2
2.2.3 Transmission line spare capacity	0	-1	-2
2.3 Evidence of forward planning - transmission			
2.3.1 Investment in transmission over the past year	0	-1	-2
2.3.2 Planning of new lines considers location of new generation.	0	-1	-2
2.4 Barrier for expansion - transmission			
2.4.1 Number of cases where environmental policy stopped projects	1	-1	-1
2.4.2 Number of cases where RMA stopped projects	1	-1	-1

2.4.3 Number of cases where public hearing and opinion stopped projects	1	-1	-1
2.5 Accessibility - transmission			
2.5.1 % of population accessible to transmitted power	2	1	2
2.6 R&D - transmission			
2.6.1 Amount of R&D in improving transmission technologies and planning	-1	1	1
3) Fuel related factors			
3.1 Fuel market			
3.1.1 Percentage of power generating fuel used for export	0	-1	1
3.1.2 Duration stock reserve can last – 3 months?	1	-1	1
3.1.3 Long term contracts to secure fuel supply	1	-1	1
3.2 Forecast accuracy- fuels			
3.2.1 Accuracy of fuel S&D forecast	0	-1	0
3.3 Government regulation - fuels			
3.3.1 Regulation controlling portion of power generated from renewable source	-2	-2	1
3.3.2 Regulation to limits usable fuel types, e.g. no log burning, nuclear free	0	-2	-1
3.4 Fuel self sufficiency			
3.4.1 Percentage of generation fuel used that is imported.	0	0	2
3.4.2 Amount of reserve fuel hold by type of fuel	1	0	2
3.4.3 Fuel supply stability – variation in market supply/ price,	-1	0	2
3.4.4 Renewable fuel supply stability - seasonal capacity (hydro/ wind)	1	0	0
3.4.5 Fuel delivery problems – LPG, coal, number of cases.	1	0	-1
3.5 Fuel price predictability			
3.5.1 Fuel price chaotic or predictable	0	1	1
3.6 Fuel research			
3.6.1 Amount of R&D to improve fuel technology	0	-1	-1
4) Investment factors			
4.1 Government encourage investment			
4.1.1 Government encourage investment in R&D	-1	0	-1
4.1.2 Government encourage investment in generation	0	0	-2
4.1.3 Government encourage investment in other areas in power sector	-2	0	0
4.1.4 Government innovation for new mechanisms to encourage investment	0	0	1
4.2 Long term planning evidence- investment			
4.2.1 Data of remaining workable life for old power plants	1	-1	2
4.2.2 Plans for building new generation plants.	2	-1	2
4.2.3 Sufficiency of planned new plants to meet expected need.	2	-1	2
5) Environmental factors			
5.1 Conservation act			
5.1.1 Number of projects/ percentage stopped by conservation/resource consent act	2	0	-2
5.1.2 Evidence of review to simply the process of conservation/ resource consent	0	0	-1
5.1.3 Average time to solve cases referring to the conservation act	0	0	-2
5.2 Pollution regulation			
5.2.1 Sufficiency of existing pollution regulations.	-2	1	2
5.2.2 Number of reviews to update pollution regulations	0	1	-1
5.2.3 Number of pollution complaint cases received and handled in power sector	0	1	1
5.3 Pollution reduction policy			
5.3.1 Government economic instruments to promote pollution control	-2	-1	-1
5.3.2 Government economic instruments to deter pollution	-2	-1	-1
5.4 Pollution data			
5.4.1 Availability of pollution data	-1	0	2
5.4.2 Trend of pollution data	-2	0	2
5.4.3 Number/ percentage of power company that has EMS (Environmental Management System) like ISO14000	0	0	1
5.4.4 Pollution impact assessment on social, economic and environmental aspects	-2	0	2
5.5 Pollution R&D			
5.5.1 Government promote funding for R&D on pollution prevention/control projects in power sector	-1	-1	0
5.5.2 Number of pollution control projects initiated by government in power sector.	0	-1	1

6) Economy factors

6.1 Sector trend			
6.1.1 production pa	1	1	1
6.1.2 turnover pa	0	1	2
6.1.3 profit pa	-2	1	2
6.2 Sector R&D - economy indicators			
6.2.1 Power sector supply and demand modeling accuracy	0	1	1
6.2.2 Generation of scenario for planning	0	1	2
6.3 Economy trend			
6.3.1 Trend of economic growth	0	-1	1
6.3.2 Energy intensive industry growth trend cf other ODEC countries	0	-1	1
6.4 New capacity - economy indicators			
6.4.1 Amount of recent , planned, replacement generation capacity	0	0	2
6.4.2 Evidence new planned capacity will meet expected demand.	0	0	1
6.5 Government policy - economy indicators			
6.5.1 Number of Government's electricity conservation plans	-1	0	-2
6.5.2 Evidence of Government's plans for emergency power shortage	0	0	-2
6.5.3 Impact assessment reports from Government	0	0	-1

7) Technical factors

7.1 Government policy/ regulation - technical issues			
7.1.1 Government regulation for energy labeling scheme	0	1	1
7.1.2 Government to provide economic incentives in increasing technical efficiency	-2	1	1
7.1.3 Government policy to encourage technical R&D in power industry	-1	1	-1
7.2 Government initiative - technical issues			
7.2.1 Government improve techniques in modeling and forecasting	0	1	1
7.2.2 Government improves techniques in scenario analysis	0	1	1
7.3 government promote energy efficiency and conservation - technical issues			
7.3.1 Establishment of a government body for power conservation and efficiency	-1	1	2
7.3.2 Economics instruments for encouraging power conservation/ improve efficiency	-2	1	-1
7.3.3 # of projects set to improve energy efficiency and conservation	-2	1	2
7.3.4 Number of government's technical projects - energy conservation	-2	1	1
7.3.5 Trend of improvement in generation efficiency	-2	1	0
7.4 government encourage alternative solutions - technical issues			
7.4.1 Number of companies adopting Demand Side Management	-2	0	-2
7.4.2 Number of companies adopting Combined Heat and Power	-1	0	1
7.4.3 Number of companies adopting Distributed Generation	-2	0	-1
7.4.4 Government encourages new technical solutions : Distributed Generation, Combines Heat Power, Demand side Management	-2	0	-2

8) Power generation factors

8.1 Fuel price - generation			
8.1.1 Generation fuel price trend	0	1	0
8.1.2 Generation fuel availability/ affordability	0	1	-1
8.1.3 Generation fuel carbon tax plan clarity	-2	1	-2
8.2 Generation plant planning			
8.2.1 Number of generation plants upgrade planned	0	-1	1
8.2.2 Number of new generation plants planned	0	-1	1
8.2.3 Number of generation plants near end of life	0	-1	-1
8.2.4 Planning for new/ replacement generation plants	0	-1	0
8.3.0 Government regulation – best use of generation resource			
8.3.0 Government regulation – best use of generation resource	0	-1	-2

9) Ethical factors

9.1 Evidence of strong political stand - ethical			
9.1.1 Limitation on generation options by political/society stand	0	-2	-1
9.1.2 Cases of projects cancelled because of public opinion	1	-2	-2
9.2 Willingness to improve - ethical			

9.2.1 Cases of Government reviewing and simplifying ethical review process like RMA	0	0	-1
9.2.2 Average time to approve projects through resource management process.	0	0	-2
9.3 Mechanism for public opinion to be heard - ethical			
9.3.1 Accessibility of public enquiry process by residence	0	1	-1
9.3.2 Aboriginal rights - fairness and practicality.	0	1	-2
9.4 Evidence of public opinion considered - ethical			
9.4.1 Number of projects stopped last year due to public opinion	1	1	-2
9.4.2 Number of projects approved by resource consent but with changes	1	1	-2
9.4.3 Number of Aboriginal rights claim that stop projects.	0	1	-2
9.5 Industry SD reporting trend - ethical			
9.5.1 Number of power companies producing sustainability report ,e.g. GRI style	-1	2	0
10) Social factors			
10.1 Labour relationship - social			
10.1.1 Existence of labour unions	0	2	2
10.1.2 Number of strike, walk outs, picketing last year	0	2	2
10.1.3 Days affected by strike, walk outs, picketing last year	0	2	2
10.2 Labour availability - social			
10.2.1 Labour skill shortage	-2	-1	-2
10.2.2 Labour turnover	0	-1	1
11) Country's industrial structure factors			
11.1 Trend of energy intensive sector			
11.1.1 Growth trend of energy intensive sector	-1	0	1
11.1.2 Number of companies in the power intensive sector	-1	0	-1
11.2 Government policy - industry sector			
11.2.1 Economic policy favours what type of industry – energy intensive or not	0	-1	-1
12) Acts of God factors			
12.1 Back up preparation - from Acts of God			
12.1.1 Backup capacity	0	-1	-1
12.1.2 Generation fuel reserve	0	-1	1
12.1.3 Back up generation plan	0	-1	-1
12.1.4 Impact assessment reports done	0	-1	1
12.1.5 Civil defence plan sufficiency	-1	-1	1
12.2 Ease of system interruption by Act of God			
12.2.1 Statistics of power cut due to downed transmission lines,	0	0	-1
12.2.2 History of too hot or cold causing demand above max capacity	0	0	-1
12.2.3 History of draught – low hydro head	0	0	-1
12.2.4 History of events affecting the supply of renewable energy. (e.g. earthquake affects hydro dam)	0	0	2

Appendix 4 Sustainability Indices for the Standard view

	STANDARD VIEW MEDIAN	Fuel Supply	Genera-tion	Trans-mission	Whole-saler	Retail-ers	Consum-ers	Society	Stake-holder Median
INSTITUTIONAL	**A) Government policy**	**-1**	**-1**	**-1**			**-0.75**	**0**	**-1**
	A1) Govt policy for power market						2	2	2
	A2) Govt policy for transmission			-1					-1
	A3) Govt policy to encourage investment	-0.5	-1	-0.5					-0.5
	A4) Govt policy for pollution control	-1	-1						-1
	A5) Use of economic instruments in electricity sector	-1	-1	-1			-1		-1
	A6) Govt policy for power conservation/efficiency						-0.5		-0.5
	A7) Govt policy on ethics		-1	-1				-2	-1
	A8) Govt policy for industrial development						-1		-1
	B) Government Regulations	**0**	**-0.5**	**1**	**1**	**1**	**-1**	**0.5**	**0.5**
	B1) Minimum service quality – govt regulations	0	0	-1		0			0
	B2) Authority to interfere market – govt regulations	1	1	1	1	1			1
	B3) Pollution control regulations	0	-1	1	1	1	-1	0.5	0.5
	B4) Fuel type choice – govt regulations	-1	-1				-1		-1
	B5) Energy labelling – regulations						1		1
	B6) Free market control regulations		-2						-2
	B7) Renewable power control regulations	1	1						1
	J) Impact assessment preparation	**-1**	**-1**	**-1**			**-2**	**-1**	**-1**
	J1) Impact assessment preparation	-1	-1	-1			-2	-1	-1
	L) Contingency planning	**1**	**0**	**1**			**0**	**1**	**1**
	L1) Contingency planning	1	0	1			0	1	1
ECONOMIC	**C) Power market control**	**1**	**1.5**	**1**	**1**	**1**			**1**
	C1) Government control of power market	1	1.5	1	1	1			1
	D) Power market conditions	**0.25**	**0**	**-1**	**0.25**	**0**	**-0.5**	**-1.5**	**0**
	D1) Wholesale power market conditions				0.5		-1		-0.25
	D2) Consumer power market conditions		-1	-1			0.5		-1
	D3) Power supply market conditions	0.5	1	-0.5			0		0.25
	D4) Fuel market conditions	1	1						1
	D5) Transmission systems conditions			-2			-1		-1.5
	D6) Effects of RMA/Conservation Act/Env Act	-2	-2	-2				-1.5	-2
	D7) Power market initiatives to improve efficiency		-1	-1			-1		-1
	D8) Generating plants planning		0.5						0.5
	D9) Sustainability reporting	0	0	0	0	0	0		0
	E) Market modelling effects	**1**	**1**	**1**			**0.75**		**1**
	E1) Wholesale market models performance	1	1				1		1
	E2) S&D modelling effects	1	1	1			0.5		1
	F) Power market economics	**1**	**2**	**1**	**1.5**	**1.5**	**1**		**1.25**
	F1) Power plant planning		2						2
	F2) Electricity sector business performance	2	2	2	2	2			2
	F3) Country-wide economic trends	0	0	0	1	1	1		0.5
ETHICAL	**G) Ethical issues**	**-1**	**-1**	**-1**				**-2**	**-1**
	G1) Environmental policy effects – ethical	-1	-1	-1					-1
	G2) Indigenous rights effects – ethical	-1	-1	-1				-2	-1
	G3) Public opinion effects – ethical	-2	-2	-2					-2
TECHNOLOGICAL	**H) R&D in technological**	**-1**	**-0.5**	**1**			**-1**	**0**	**-0.5**

	STANDARD VIEW MEDIAN	Fuel Supply	Genera-tion	Trans-mission	Whole-saler	Retail-ers	Consum-ers	Society	Stake-holder
	improvements								
	H1) R&D in reducing pollution		0					0	0
	H2) R&D in fuel and new generation technology	-1	-1				-1		-1
	H3) R&D in improving transmission			1					1
ENVIRON-MENTAL	**I) Pollution control**	**1**	**1**	**1**				**1**	**1**
	I1) Pollution trends		2					2	2
	I2) Adaptation of pollution control system e.g. EMS	1	1	1				1	1
	I3) Actions taken on pollution	1	1					1	1
	I4) Pollution complaints handling	1	1					1	1
SOCIAL	**K) Social issues**	**0.75**	**0.75**	**0.75**					**0.75**
	K1) Labour relationship	2	2	2					2
	K2) Labour skill shortage/turnover	-0.5	-0.5	-0.5					-0.5

Appendix 5 Sustainability issues/Solution Matrix

Relationship table between Sustainability issues and the proposed solutions

	Proposed solutions							
1) Electricity market issues	Refine market structure	Improves model accuracy	Govt fine tune economics activities	Review reform effectiveness	Enforce minimum quality standards	Government install own reserve power	Govt authority to interrupt power market if needed	Government gives incentive for innovative solutions
1.1 Planning of generating resources - max profit	X				X		X	
1.2 Sign of oligopoly pricing - insufficient competition	X			X			X	
1.3 Wholesale price chaotic, inefficient free market	X	X		X				
1.4 Immature hedge market	X						X	
1.5 Uncertainty - carbon tax system	X			X			X	
1.6 Profit is limited by regulation	X		X				X	
1.7 Historically not many successful free power market				X				
1.8 Inaccuracy in modeling		X						
1.9Lack of overall planning	X		X	X	X	X	X	
1.10 Lack of power supply alternative and innovation	X			X		X		X

	Proposed solutions					
2) Transmission Problems	Simplify application procedure for expansion	Increase transmission capacity	Penalty system for unreliability	Improve expansion planning	Compulsory quality standards	Government encourage investment
2.1 Transmission bottleneck exists		X	X	X	X	
2.2 Transmission line vulnerability			X		X	
2.3 Transmission line not designed for growth				X		X
2.4 Lacks spare capacity		X		X		X
2.5 Lack of upgrade plans	X		X	X	X	X
2.6 Lack of investment	X					X
2.7 Prohibitive complicated procedure to expand system.	X					X

3) Fuel supply problems	Proposed solutions: improve local fuel availability	Improve planning and modeling	Government regulations – fixed % from renewable	Government policy – fuel self sufficiency	Setup long term supply contract for security of supply.	Government fuel type policy	Increase R&D in renewable energy	Govt policy – encourage local fuel exploration
3.1 Lack of interest to invest in renewable power			X	X		X	X	
3.2 fossil fuel reserve runs out						X	X	
3.3 Peak oil		X			X	X	X	
3.4 fuel delivery issues (e.g. LNG terminal)	X			X		X	X	X
3.5 A lack of natural resources		X			X	X	X	X
3.6 Seasonal power source availability (hydro)		X	X				X	
3.7 Import fuel – affected by overseas supply.	X			X	X	X	X	X
3.8 currency fluctuations affect buying ability.		X	X	X	X		X	X
3.9 Fuels exported, not used locally				X	X	X		
3.10 Threats from supply security			X	X	X		X	X
3.11 Non efficient fuel use		X	X					

4) Investment shortage	Proposed solutions: Government regulation change to encourage investment	Government policy change to encourage investment
4.1 Lack of investment in R&D	X	X
4.2 society outgrow present capacity	X	X
4.3 Lack of plans to replace retiring generators	X	X
4.4 Lack of generation/ transmission investment,	X	X

5) Environmental issues	Proposed solutions: Government review policy – pollution control.	Government incentives to decrease pollution	Government penalty system - Carbon tax , pollution charge.	Increase investment in R&D for pollution control.
5.1 Excess pollution:	X	X	X	X
5.2 Carbon tax increase fuel price.	X		X	X
5.3 Environmental regulations hinder growth	X			
5.4 Company do not perform environmental assessment	X	X		
5.5 Minimal R&D on pollution research		X		X
5.6 Climate change	X	X	X	X
5.7 Damaged ecology	X	X	X	X

6) Economic Issues	Proposed solutions: improve modeling accuracy & scenario analysis	Government select growth in less energy intensive industries	Government campaign on power conservation.	Install new capacity	Government policy to assist generation company
6.1 Growth of economy - unexpected power use increase	X	X	X		
6.2 Unbalanced growth in energy intensive sectors.	X	X	X	X	
6.3 capacity cannot meet growth		X	X		
6.4 Growth in capacity too small.	X			X	
6.5 Power companies close due to economical reasons	X				X
6.6 Power companies in financial problems	X				X
6.7 Lack of contingency plan by government					X

7) Technical issues	Proposed solutions: Govt policy to encourage research in power technology	Govt incentive to improve user/generator efficiency	Govt campaign – to conserve power & to improve efficiency	Implement energy labeling	Govt. encourage distributed generation	Govt encourage demand management programs	Govt encourage combined heat and power schemes	Govt improve modeling technique
7.1 Lack of improvement in efficiency in generation		X	X	X	X	X	X	
7.2 Lack of improvement in efficiency by end-users		X	X	X		X		
7.3 Technology still needs to be improved	X	X			X			
7.4 Poor modeling technique causes poor planning			X					X

8) Generation issues	Proposed solutions: Improve plant efficiency	Policy change to encourage generation efficiency	Regulation change to encourage generation efficiency	Monitor and modeling of fuel price	Have a mix of generating source to maximise efficiency of the resource	Better planning to anticipate end of life of old plants
8.1 Fuel price increase	X	X	X	X	X	
8.2 Unsure carbon tax details – affects investment confidence		X	X	X		
8.3 Mix of generation methods not maximised for efficiency		X	X		X	X

	Proposed solutions	
9) Ethical issues	Govt update regulation to meet today's needs	Govt negotiate on land right
9.1 Regulations make new projects difficult to be approved thus unattractive	X	
9.2 Public hearing takes too long – affects business decisions	X	
9.3 SD issues affect power sectors	X	X
9.4 Political stands limit generation options	X	
9.5 Cultural issues leans towards protection of nature	X	X
9.6 Companies only talk about SD without real actions	X	

	Proposed solutions
10) Social issues	Govt policy on solving these issues.
10.1 Stoppage due to industrial action	X
10.2 Industrial actions due to pay rise demand	X
10.3 Industrial actions due to work issue	X
10.4 Political reasons	X
10.5 Industrial actions due to ethical reasons	X
10.6 No graduates from power engineering course	X
10.7 Lack of skilled labour	X

	Proposed solutions	
11) Industry structure issues	Govt. assists sector by selecting best policy	Govt policy to balance industrial structure
11.1 User generate own power - do not buy from main generators		X
11.2 Too much energy intensive industry - insufficient capacity	X	X

	Proposed solutions	
12) Acts of God	Govt review civil defence program	Install back up power for additional short
12.1 Too cold or hot weather - increase demand unexpectedly	X	X
12.2 Severe weather - bring lines down	X	X
12.3 Dry weather - hydro power shortage	X	X
12.4 Weather change - affects snow melting for hydro	X	X
12.5 Other disaster that stops the industry	X	X

References

(1989). Ministry of Energy (Abolition) Act 1989. 1989 No 140.

(2002). "Johannesberg Summit 2002, Basic Information." Retrieved 23 March, 2005, from http://www.johannesburgsummit.org/html/basic_info/csd.html.

(2003). 50-year plan to meet Punjab housing needs. Pakistan Daily Times. Pakistan.

AAP (2007). Nuclear must be pursued, Howard says. New Zealand Herald.

Alley, R. B., J. Marotzke, et al. (2003). "Abrupt climate change." Science **299**.

Anon (2002). Electricity sector report for the World Summit on sustainable development. Montreal, Canada, e7 Network of Expertise for the Global Environment.

Atkinson, K. (2006). Warnings issued over energy sector sustainability. The New Zealand Herald.

Audet, N., P. Heiskanen, et al. (2002). Modelling of electricity forward curve dynamics. INFORMS 2002.

Australia's National Local Government Newspaper Online (2003). Green for our future. Australia's National Local Government Newspaper Online.

Australia Government (2004). Triple Bottom Line Report 2003-2004. Canberra, Department of the Environment and Heritage**:** 50.
indicators of Australia TBL environment

Baker, P. and G. Sise (2004). Analysis of HVDC outage 9-12 Jan 2004, Energy Link Ltd. for Electricity Commission.

Barrera-Roldan, A. and A. Saldivar-Valdes (2002). "Proposal and application of a Sustainable Development Index." Ecological Indicators **2**: 251-256.

Barrett, S. (2004). Options for New Zealand's Energy Future. Power Conference, Auckland, New Zealand.

Beckerman, W. (1994). "Sustainable development: Is it a useful concept?" Environmental Values **3**: 191-209.

Bennett, A. (2007). Government ready to help rush renewable energy plans. New Zealand Herald.

Berkeley University (2001). Manifesto on the California electricity crisis. Berkeley, University of California.

Berkes, F., J. Colding, et al. (2000). "Rediscovery of traditional ecological knowledge as adaptive management." Ecological Applications **10**(5): 1251-1262.

Blakeley, J., S. Goldthorpe, et al. (2003). The story of Maui. The need for improved management of New Zealand's gas resource, Sustainable Energy Forum.

Blaza, A. and N. Chambers (1997). Environmental Management Standards: who cares? ISO 14001 and beyond. C. Sheldon. Sheffield, Greenleaf Publishing.

Boldger, P. S. and H. S. Tay (1987). "Logistic and energy Substitution models for electricity forecasting: a comparison using New Zealand Consumption data." Technological forecasting and social change **31**: 27-48.

Bossel, H. (1999). Indicators for sustainable development: theory, method, applications. Winniepeg, Canada, International Institute for Sustainable Development.

Bower, J. (2004). Blackouts: invest, intervene or inveigh? Oxford, UK, Oxford Institute for Energy Studies (OIES).

Boyle, C. (2004). Achieving sustainability. International Conference on Sustainability Engineering and Science, Auckland, New Zealand.
good summary and excellent ideas.

Briguglio, L. (2003). The usefulness of sustainability indicators. Symposium Sustainability Indicators for Malta, Valletta, Malta.

Brown, B. J. (1988). "Global Sustainability: towards measurement." Environmental Management **12**(2).

Brown, B. J., D. M. Liverman, et al. (1988). "Global Sustainability: Towards Measurement." Environmental Management **12**(2).

Brown, M. M., N. Desai, et al. (2000). World Energy Assessment - Energy and the challenge of sustainability. New York, United Nation Development Program (UNDP).

Brundtland Commission (1987). Our Common Future, World Commission on Environment and Development.

Brundtland, H. G. (1986). Sir Peter Scott Lecture. Bristol.

Career Services - New Zealand Government. (2007). "Mechanical Engineering, Mataarotanga Purere."   Retrieved 18-4-2007, 2007, from http://www.careers.govt.nz/default.aspx?id0=10104&id1=A155B757-F0AA-4803-86CA-5F4834BD7866.

Chapman, R. J. (2006). Tools and techniques of enterprise risk management. Hoboken, N.J., John Wiley & Sons.

Charles River Associates (Asia Pacific) Ltd. (2005). Competition and investment incentives in New Zealand's electricity markets. Wellington**:** 70.

Cheng, B. C. M. and D. I. Wilson (2004). Predicting the unpredictable: Is the electricity spot price chaotic? International Conference on Sustainability Engineering and Science, Auckland, AUT.

Chwee, V. (1998). "Chaos in Natural Gas Futures." The Energy Journal **19**(2).

Civil, M. (2005). Review of HVDC Inter-Island Link Upgrade Project, Investment Proposal, Cost Benefit Analysis, Transpower**:** 33.

Look at HVDC link

Cole, R. E. and W. R. Scot (2000). The Quality Movement & Organization Theory. The Quality Movement & Organization Theory. R. E. Cole and W. R. Scot. Thousand Oaks, California, USA, Sage Publishing Ltd.**:** 425.

Commerce Commission New Zealand (2006). Intention to declare control of Vector Limited published. Wellington, Commerce Commission of New Zealand,.

Connell Wagner Pty Ltd. (2006). Review of report on Auckland transmission outage of 12 June 2006, Ministry of Economic Development. Neutral Bay, New South Wales, Australia, Connell Wagner Pty Ltd.

Costanza, R. (1995). "Ecological economics: a research agenda." Structural Change Economics **2**: 335-42.

Costanza, R. (2000). "The dynamics of the ecological footprint concept." Ecological Economics **32**: 341-5.

Craven, R. (2004). A national grid for the future. National Power Conference, New Zealand, Auckland.

give deadline

Criag, P. P., A. Gadgil, et al. (2002). "What can history teach us? A retrospective examination of long-term energy forecast for the United States." Annual Rev. Energy Environment **27**: 83-118.

Crow, R. T. (2003). Avoiding mistakes in electricity restructuring: what India can learn from California and elsewhere. Ahmedabad, Indian Institute of Management.

Cullen, M. (2004). Infrastructure stocktake reportback, Ministry of Economic Development.

summary from report by PriceWaterhouseCoopers on 2004-1

Dalai Lama, F. Quaki, et al. (1999). Imagine all the people: A conversation with the Dalai Lama on money, politics and life as it could be. Boston, Wisdom Publication.

Dale, B. and H. Bunney (1999). Total quality management blueprint. Oxford, UK, Blackwell Publishers Ltd.

Dang, H. D. T. (2003). New Zealand Energy Data File, January 2003. Wellington, Ministry of Economic Development, New Zealand.

Dang, H. D. T. (2004). New Zealand Energy Data File Jan 2004, MED, New Zealand.

Deming, W. E. (1994). The new economics for industry, government, education. Cambridge, MA, USA, Massachusettes Institute of Technology.

Department for Business Enterprise and Regulatory Reform, U. (2007). Meeting the energy challenge: a white paper on energy, Depart for Business Enterprise and Regulatory Reform, UK,**:** 343.

Department for Business Enterprise and Regulatory Reform, U. (2007). UK Energy in brief , July 2007, Depart for Business, Enterprise and Regulatory Reform.

Donnelly, R. and C. Boyle (2004). Sustainability - why is it way beyond the Triple Bottom Line? Int. Conference on Sustainability Engineering and Science, Auckland.

e7 Network of Expertise for the Global Environment (2002). Electricity sector report for the World Summit on sustainable development. Montreal, Canada, e7 Network of Expertise for the Global Environment.

Edwards, C. (2001). The Californian power crisis, Transpower New Zealand Ltd.

EECA (2001). National Energy Efficiency and Conservation Strategy, EECA.

EECA (2005). Energy Efficiency & Conservation Authority statement of intent 2005-2008, EECA, New Zealand.

EECA (2005). The journey continues - EECA and the National Energy Efficiency and Conservation Strategy Overview. Wellington, New Zealand, Energy Efficiency and Conservation Authority.

Elder, D. (2004). Options for security in energy & electricity. Power Conference, Auckland.

Electricity Commission (2003). Statement of intent. Wellington, New Zealand, The Electricity Commission, New Zealand Government.
Elec commission

Electricity Commission (2005). Explanatory paper to the initial security of supply policy, Electricity Commission, New Zealand.

Electricity Commission (2007). Economic Analysis of the Revised North Island Grid Upgrade Project, Electricity Commission, New Zealand.
Grid transmission expansion

Electricity Commission (2007). Economic Assessment of the Auckland Proposal. B. Smith.

Electricity Commission. (2007). "Electricity industry markets and operational structure." Retrieved 28th April, 2007, from http://www.electricitycommission.govt.nz/industry/.

Encyclopædia Britannica (2006) environmental law. Encyclopædia Britannica Online **Volume**, DOI:

EPRI, E. P. R. I. (2003). Electricity sector framework for the future - summary. 3420 Hillview Avenue, Palo Alto, CA 94304, USA Electric Power Research Institute.

EPRI, E. P. R. I. (2003). Electricity sector framework for the future Vol II, expert discussion and stakeholder input. 3420 Hillview Avenue, Palo Alto, CA 94304, USA, Electric Power Research Institute.

Esty, D. C., M. Levy, et al. (2005). 2005 Environmental sustainability index: benchmarking national environmental stewardship. New Haven, Yale centre for Environmental Law and Policy.

European Statistical Laboratory. (2007). "Dashboard of Sustainability " Retrieved 23rd March, 2007, from http://esl.jrc.it/.

Evans, J. R. (2005). Total Quality Management, Organisation, and Strategy. Toronto, ONT, Canada, Rob Dewey, South-West, Thomson Corporation.

Fallow, B. (2005). Kyoto bill creates $1 billion deficit New Zealand Herald. Auckland

Fallow, B. (2006). Kyoto protocol taxpayer liability more than doubles to $656 million. New Zealand Herald. Auckland.

Fallow, B. and A. Young (2004). Higher electricity prices and blackouts loom after a $1.2bn power project is cancelled. NZ Herald**:** A1.

Flemings, M. C. (2004). Invention, enhancing inventiveness for quality of life, competitiveness, and sustainability, Lemelson-MIT Program
National Science Foundation.

Freudenberg, M. (2003). Composite indicators of country performance: a critical assessment. France, Organisation for Economic Co-operation and Development (OECD).

German Wind Energy Association (BWE) (2006). A clean issue – Wind energy in Germany. Berlin, German Wind Energy Association (BWE)**:** 36.

Golovko, V., Y. Savitsky, et al. (2001). Some aspects of chaotic time series analysis. The 2nd International Conference on Neural Networks and Artificial Intelligence, Minsk, Belarus.

Gordan, D. J., A. Blaza, et al. (2005). "A sustainability risk analysis of the low cost airline sector." World Transport Policy & Practice **11**(1).

Gould, L. (2007). Connecting new generation in New Zealand. AWATEA 1st Annual Conference "Blue Energy - Taking the Plunge", Wellington.

Gray, R. H. and M. J. Milne (2002). "Sustainability reporting: who's kidding whom?" Chartered Accountants Journal of New Zealand: 66-70.

Gregory, A. (2007). $5000 extra for hot homes. New Zealand Herald.

GRI (2007). GRI Electric utility sector suppliment - draft for public comment. Keizersgracht 209, 1016 DT, Amsterdam, The Netherlands Global Reporting Initiative.

Gross, T. P., C. Rufin, et al. (2003). Analysis of the sustainability of the electrical power sector. Washington, USA, Advanced Engineering Associates International (AEAI).

Halliburton, T. (2002). A review of Leyland and Transpower security of supply projections, Ministry of Economic Development, New Zealand.

Hancock, J. (2004). Twelve months on: blacking out through reforming the unreformable. 750 7th Avenue, Suite 1800, New York, New York 10019, USA Capgemini.

Hardi, P. and T. Zdan, Eds. (1997). Assessing sustainable development - principles in practice. Manitoba, Canada, The International Institute for Sustainable Development.

Hasen, C. (2004). Improving hedge market arrangements in New Zealand. 6th Annual National Power New Zealand 2004 Conference, Hilton Hotel, Auckland.

Hemmingway, R. (2004). Statement of Intent 2004-2007, Electricity Commission, Electricity Commission, New Zealand.

Hemmingway, R. (2004). Upper South Island Planning Well Advanced, Electricity Commission, New Zealand.

Hemmingway, R. and P. Rebstock (2006). Memorandum of understanding between the Electricity Commission and the Commerce Commission. Wellington, New Zealand Government.

Henderson, J. (2002). Sustainability Reporting Guidelines (GRI). Amsterdam, Global Reporting Initiative.

Hens, L. and J. D. Wit (2003). "The development of indicators and core indicators for sustainable development: a state of the art review." Int. J. Environment and Sustainable Development **6**(4): 437-459.

Hobbs, M. (2002). The government's approach to sustainable development. Wellington, Ministry of Economic Development, New Zealand.

Hobbs, M. (2003). Sustainable Development for New Zealand - programme of action, Minister for the Environment, New Zealand.

Hodgson, P. (2003). Govt ready to take on electricity governance responsibility M. o. Energy, Minister of Energy, New Zealand.
Govt announcement set up Elec Commission

Hodgson, P. (2005). Carbon tax speech. Wellington, Minister of Energy, New Zealand.

Hopwood, B., M. Mellor, et al. (2005). "Sustainable development: mapping different approaches." Sustainable Development **13**: 38-52.

Hubbard, J. (2001). Different worlds: strategic drivers of Australia's new energy industry, PriceWaterhouseCooper.

Hunter, A. (2002). Sector sustainability - best practice strategy toolkit. East Kilbridge, UL, Optimat Ltd.

IEA/ODEC (2004). World Energy Outlook, International Energy Agency / ODEC.

Inder, R. (2006). Decision on Transpower's pylon project delayed until next year. New Zealand Herald.

Inder, R. (2006). Double blow for power regulator. New Zealand Herald. Wellington.

Inder, R. (2006). Vector row threatens future of power cuts. New Zealand Herald. Auckland.

International Aluminium Institute (2004). Aluminium for future generations. London, International Aluminium Institute.

International Atomic Energy Agency (2005). Energy indicators for sustainable development: guidelines and methodologies. Vienna, International Atomic Energy Agency.

International Institute for Sustainable Development. (1996). "The Bellagio Principles." Retrieved 25 October, 2006, from http://www.iisd.org/measure/principles/bp_developed.asp.

International Institute for Sustainable Development. (2006). "Energy Sustainability Gauge." Retrieved 10 October, 2006, from http://www.iisd.org/energy/gauge.asp.

International Organization for Standardization (1996). ISO 14001:1996. Environmental management systems -- Specification with guidance for use International Organization for Standardization**:** 14.

International Organization for Standardization (2005). ISO 9000:2005. Quality management systems - Fundamental and vocabulary, International Organization for Standardization**:** 30.

IUCN (1993). Guide to preparing and implementing national sustainable development strategies and other multi-sectoral environment and development strategies, First Draft. S. W. G. o. S. f. S. IUCN's Commission on Environment, I. Secretariat and I. I. f. E. a. Development. Rue Mauverney 28, Gland, 1196, Switzerland, World Conservation Union.

IUCN (1993). Guide to preparing and implementing national sustainable development strategies and other multisector environmental and development strategies. Rue Mauverney 28, Gland, 1196, Switzerland, World Conservation Union.

IUCN, UNEP, et al. (1980). World Conservation Strategy: Living Resource Conservation for Sustainable Development. Rue Mauverney 28, Gland, 1196, Switzerland, United Nations Environment Programme (UNEP), World Wildlife Fund (WWF).

IUCN, UNEP, et al. (1991). Caring for the earth. Rue Mauverney 28, Gland, 1196, Switzerland, IUCN.

Iyer, V., C. C. Fung, et al. (2003). A fuzzy-neural approach to electricity load and spot-price forecasting in a deregulated electricity market. TENCON 2003. Conference on Convergent Technologies for Asia-Pacific Region, School of IT, Murdoch University, Western Australia.

James, C. (2004). How two killers could put an end to Labour's rule. New Zealand Herald. Auckland.

Janic, M. (2004). "An application of the methodology for assessment of the sustainability of the air transport system." Journal of Air Transportation **9**(2): 40.

Jevons, W. S. (1866). Coal Question: An Inquiry Concerning the Progress of the Nation, and the Probable Exhaustion of Our Coal-Mines. London, Macmillan and Co.

Kang, C., X. Cheng, et al. (2003). "Novel approach considering load-relative factors in short-term load forecsting." Electric Power System Research.

Klimpt, J.-E., C. Rivero, et al. (2002). "Recommendations for sustainable hydroelectricity development." Energy Policy **30**: 1305-1312.

Langhelle, O. (1999). "Sustainable development: exploring the ethics of Our Common Future." International Political Science Review **20**(2): 129-149.

Layton, B. (2005). Market Design Report - initial stock-take paper. Report to the Electricity Commission. 8 Halswell St., Thorndon, Wellington, New Zealand, New Zealand Institute of Economic Research (NZIER)**:** 112.

Leyland, B. (2002). Implications of the Winter Electricity Crisis. Energy Watch. E. Watch, Energy Watch.

Leyland, B. and S. Mountain (2002). Electricity supply & demand to 2015. Auckland, Sinclair Knight Merz, Centre for Advanced Engineering, Canterbury University.

Leyland Consultants Ltd. (1994). Electricity supply & demand to 2010, on the basis of existing generating capacity. Auckland, Leyland Consultants Ltd., Centre for Advanced Engineering, Canterbury University.

Lighteringen, E. (2006). Will the experts please stand up! The adaptive nature of sustainability reporting. Sustainable Development International, Special GRI G3 Lauch Conference Edition.

> we have no previous experience with SD threats, no experts and no technical change. Need to change value, expectation attitide, habit, behaviour therefore adaptative change.

see notes oin paper

M-co. (2003, 25 August). "Trends in the New Zealand Electricity Market." 2003 Power and Fuel Supply Summit, from http://nz.m-co.com/upload/sectionimages/15103_Current_Policy_Developments_in_Electricity.ppt#398,1,Trends

Macgowan, C. (2004). Towards sustainability - the UK automotive sector, 5th annual report, The Society of Motor Manufacturers and Traders Ltd. (SMMT).

Malitza, M. and Bucharest (2000). Sustainability, a new way to look at the world. A Sustainable Future for Russia?!, Moscow, The Culb of Rome.

Malthus, T. (1798). An Essay on the Principle of Population. St. Paul's Church-yard, London, UK, J. Johnson.

Maslow, A. H. (1998). Maslow on management New York, John Wiley.

McDonald, G. and D. D. Patterson (2003). Ecological footprint of New Zealand and its regions, 1997/98, Massey University for the MoE, New Zealand.

McGuinness, W. (2005). A national sustainable development strategy: how New Zealand measures up against international commitments. Wellington, Sustainable Future Ltd.**:** 55.

Meadows, D. H., D. l. Meadows, et al. (1974). Limits to Growth, Chelsea Green Publishing Company.

Mebratu, D. (1998). Sustainability and sustainable development: history and conceptual review. Lund, Lund University.

MED (2006). New Zealand Energy Data File Sept 2006. H. D. T. Dang. Wellington, Ministry of Economic Development**:** 200.

Melhuish, M. (2002). End-use energy options for a reliable electricity supply. NZ Energy Conference, Wellington.

Melhuish, M. (2002). Energy and sustainable development in New Zealand. Wellington, Sustainable Energy Forum.

Mighty River Power (2001). Broad understanding of consent issues. Mighty River Power News.

Mighty River Power (2003). The single bottom line, sustainability and Mighty River Power 2003, Mighty River Power, New Zealand.

Ministry of Commerce, N. Z. (1994). Energy supply and demand scenarios to 2020.

Ministry of Economic Development (2001). Post-winter review of electricity system, summary of submissions, Croydon Consultants.

Ministry of Economic Development. (2005). "General Objectives for the electricity sector." Retrieved 2 March, 2005, from http://www.med.govt.nz.

Ministry of Economic Development (2006). New Zealand's Energy Outlook to 2030. Wellington, Ministry of Economic Development, New Zealand**:** 147.

Ministry of Economic Development (2006). New Zealand Energy Data File Sept 2006. H. D. T. Dang. Wellington, Ministry of Economic Development, New Zealand**:** 200.

Ministry of Fisheries New Zealand (2007). Annual Report 2006/7, Ministry of Fisheries, New Zealand. Wellington, Ministry of Fisheries**:** 92.

Moffatt, I. (2000). "Ecological footprint and sustainable development." Ecological Economics **32**(32): 359-62.

Morrison, J. I. M. (2002). The UK aluminium industry progress on sustainability, November 2002. Birmingham, Aluminium Federation.

Murcott, S. (1997). Definitions of Sustainable Development. IIASA Sustainability Indicators Symposium, Seattle, WA, Massachusetts Institute of Technology.

National Round Table on the Environment and the Economy (2003). Environment and Sustainable development indicators for Canada. H. L. Mead, National Round Table on the Environment and the Economy**:** 54.

Nickerson, M. (1995). Planning for Seven Generations: Guideposts for a Sustainable Future Hull (Que.), Voyager Club.

Nychka, D., S. Ellner, et al. (1992). LENNS, a program to estimate the dominant Lypunov exponent of noisy nonlinear systems from time series data., Inst. of Statistic Mimeo Series, North Carolina State University, Raleigh, US.

Nychka, D., S. Ellner, et al. (1992). "Finding Chaos in Noisy Systems." Journal of the Royal Statistical Society **54**(2): 399-426.

NZ Herald Editor (2007). Sustainable solutions, not slogans. New Zealand Herald. Auckland**:** 2.

NZPA (2003). New Zealanders reach electricity savings target. New Zealand Herald.

NZPA (2006). Electricity Commission chairman removed from office. New Zealand Herald. Auckland.

NZPA (2006). NZ missing the energy efficiency mark. New Zealand Herald. Aucklanf.

NZPA (2007). NZ Greenhouse gases keep rising. New Zealand Herald.

NZPA (2007). Our energy utilities in "vulnerable position". New Zealand Herald.

OECD. (1960). "Building Partnerships for Progress." Retrieved 17 Nov 2005, 2005, from http://www.oecd.org/document/7/0,2340,en_2649_201185_1915847_1_1_1_1,00.html.

Office of the Renewable Energy Regulator (2006). Fact sheet - Mandatory Renewable Energy Target Overview. Australia, Office of the Renewable Energy Regulator,.

Organisation for Economic Co-operation and Development (1960). Convention on the Organisation for Economic Co-operation and Development Paris, Organisation for Economic Co-operation and Development.

Orsman, B. (2005). Rules ban tiny apartments. New Zealand Herald. Auckland.

Parliamentary Commissioner for the Environment (2002). Creating our future - sustainable development for New Zealand. Wellington, Parliamentary Commissioner for the Environment.

Parliamentary Commissioner for the Environment (2006). Electricity, energy and the environment: Environmental performance assessment 1 July 2004 - 30 June 2005 Wellington, Parliamentary Commissioner for the Environment, Government of New Zealand.

Parris, T. M. and R. W. Kates (2003). "Characterizing and measuring sustainable development." Annual Review of Environmental Resources **28**: 559-86.

Patterson, M. (2002). Headline indicators for tracking progress to sustainability in New Zealand. Palmerston North, Massey University for The Ministry for the Environment.

Patterson, M. and N. Jollands (2004). "The power of one: developing a headline indicator for tracking progress to sustainability in New Zealand." Int. J. Environment and Sustainable Development **3**(3/4 2004): 316-337.

Pearce, D. and J. Warford (1993). World without end: economics, environmental and sustainable development. New York, Oxford University Press.

Peat, J. (2000). "An ethics based systems approach to indicators of sustainable development." Int. J. Sustainable Development **3**(3): 221-238.

Peet, J. (2003). Strength from Sustainability, University of Canterbury, Christchurch NZ.

Pink, B. (2002). Monitoring progress towards a sustainable New Zealand, Statistics New Zealand.

Porritt, J. (2003). Pioneering the strategic route to sector sustainability. UK, Sustainable Development Commission.

Potter, N., I. McAuley, et al. (2005). Future Currents electricity scenarios for New Zealand 2005-2050, Parliamentary Commissioner for the Environment.

Price, D. H. R. and J. A. Sharp (1986). "A comparison of the performance of different univariable forecasting methods in a model of capacity acquisition in UK electricity supply." International Journal of Forecasting **1986**: 333-348.

PriceWaterhouseCoopers (2004). Infrastructure Stocktake, PriceWaterhouseCoopers for Ministry of Economic Development.

PriceWaterhouseCoopers (2005). Under pressure, utilities global survey 2005, PriceWaterhouseCoopers.

Redcliff, M. (1987). Sustainable Development. London, Methuen.

Redcliff, M. (2005). "Sustainable Development (1987-2005): An Oxymoron Comes of Age." Sustainable Development **13**: 212-227.

Rennie, H. (1998). Auckland power supply failure 1998, Ministry of Commerce, New Zealand.

RMIT University (2001). Global sustainability - the history/time line of an idea. Melbourne, Australia, RMIT University.

Rudkevich, A., M. Duckworth, et al. (1998). Modeling electricity pricing in a deregulated generation industry - the potential for oligopoly pricing in a poolco. Boston, Tellus Institute.

SAM Indexes GmbH. (2007). "Dow Jones Sustainability Indexes."   Retrieved 18-4-2007, 2007, from http://www.sustainability-indexes.com/.

Schenler, W. W., A. V. Gheorghe, et al. (2002). "Strategic electric sector assessment methodology under sustainability conditions: a Swiss case study on CO_2 emission, competition and stranded costs." Int. J. Sustainable Development **5**(1/2): 63-101.

Schultink, G. (1992). "Evaluation of Sustainable Development Alternatives: Relevant Concepts, Resource Assessment, Approaches and Comparative Spatial Indicators." International Journal of Environmental Studies **41**: 203-224.

Serletis, A. and P. Gogas (1999). "The North American Natural Gas Liquid Markets are Chaotic." The Energy Journal **20**(1): 83.

Shreeve, J. (2006). Human journey. National Geographic.

Smith, A., R. Fairclough, et al. (2003). New Zealand Energy Outlook to 2025, Ministry of Economic Development, New Zealand,.

Snively, G. and J. Corsiglia (1998). Discovering indigenous science: implications for science education. Victoria, BC, Canada, University of Victoria.

Steel Construction Sector Sustainability Committee , S. (2003). Sustainable Steel Construction, building a better future - First Annual Report on Progress. UK, Steel Construction Sector Sustainability Committee.

Steger, M. B. (2005). Ideology and sustainability in the age of imperial globalism. The International Conference on Environmental, Culture, Economics & Social sustainability, Hawaii.

Stokes, J. (2006). Firms look forward to big spin-off from new oilfield. New Zealand Herald. Auckland.

Strong, M. (1992). Required Global Changes: Close Linkages Between Environment and Development. Change: Threat or Opportunity. U. Kirdar. NY, United Nations.

Strong, M. (2002). US senate environmental treaty implementation review, US Senate.

Swanson, D. A. (2003). Gauging progress towards sustainability - a communicative innovation. Winniepeg, Canada, International Institute for Sustainability Gauge.

Taylor, J. (2002). "Sustainable Development - a dubious solution in search of a problem." Policy Analysis **449**: 1-49.

Taylor, J. and P. VanDoren (2001). "California's electricity crisis, what's going on, who's to blame, and what to do." Policy Analysis **406**.

Taylor, K. (2004). Aqua axing puts heat on planning law. New Zealand Herald.

Taylor, M. and G. Eng (2000). New Zealand Energy Outlook to 2020, Ministry of Commerce, New Zealand.

TERI (1997). Energy and economic growth: is sustainable growth possible? 20th Annual International Conference , International Association for Energy Economics (IAEE), New Delhi, India.

The Energy and Resources Institute (2005). A framework for energy sustainability assessment. IHC Complex, Lodhi Road, New Delhi 110 003, India. **2005**.
Retrieved 22nd February, 2005 from
http://www.teriin.org/ee/gbr/fesa/fesa_report.htm

The National Business Review (2001). Planning blunders create - THINK BIG. The National Business Review. **9 March 2001:** 31-2.

The National Party (2005). National's 2005 Climate Change Policy. Wellington, The National Party, New Zealand.
National will scrap carbon tax

Thienen, B. V. (2002). Ethibel Sustainability Index. Vooruitgangstraat 333, B - 1030 Brussels, Ethibel.

Transpower. (2007). "Maps - Transmission Lines." Retrieved 23rd May, 2007, from http://www.gridnewzealand.co.nz/n70,7.html.

Transpower. (2007). "National grid upgrade, Process and Timeline." Retrieved 28 March, 2007, from http://www.gridupgrade.co.nz/?id=6160.
transmission upgrade details

Turner, N. J., M. B. Ignace, et al. (2000). "Traditional ecological knowledge and wisdom of aboriginal peoples in British Columbia." Ecological Applications **10**(5): 1275-1287.

UK Government (2004). Sustainable development indicators in your pocket 2004. London, Department for Environment Food and Rural Affairs, UK.

Umez-Eronini and Eronini (1999). Systems dynamic and control, Pacific Grive: PWS Publishing Co. c1999.

UN (1992). Agenda 21. New York, United Nations.

United Nations (1990). Human Development Report. New York, United Nations.

United Nations (1992). Agenda 21. UN Conference on Environment and Development (Earth Summit), Rio De Janeiro.

United Nations (1996). Indicators of sustainable development — framework and methodologies. New York, United Nations.

United Nations (2000). United Nations Millennium Declaration, United Nations.

United Nations (2003). Indicators of sustainable development: guidelines and methodologies, United Nations.

United Nations. (2006). "Institutional aspects of sustainable development in New Zealand." Retrieved 2/11/2006, 2006, from http://www.un.org/esa/agenda21/natlinfo/countr/newzea/inst.htm.

Verburg and Wiegel (1997). "On the compatibility of sustainability and economic growth." Environmental Ethics **19**: 247-265.

Verschuere, M. (2003). Modeling electricity markets. 1st Flemish Actuarial and Financial Mathematics Day, Luven, Switzerland.

Viederman, S. (1995). Knowledge for Sustainable Development:What Do We Need to Know? A Sustainable World: Defining and Measuring Sustainable Development. T. Trzyna. Sacramento and London, California Institute of Public Affairs and Earthscan for IUCN, 1995.

Wackernagel, M., C. Monfreda, et al. (2002). "Ecological Footprint of Nations: November 2002 uptake." Retrieved 2005 March 22, from http://www.redefiningprogress.org/publications/ef1999.pdf.

WCED (1987). Our common future., World Commission on Environment and Development (WCED)**:** 400.

Webb, M. (2004). Striking a balance, 2004 - the sustainability strategy update and progress report of the UK offshore oil and gas industry, UK Offshore Operators Association**:** 10.

Weir, J. (2001). Power crisis drags growth rate down. The Dominion. Wellington, New Zealand.

Wells, P. (2006). Is Democracy Sustainable? 12th Annual International Sustainable Development Research Conference, Hong Kong.

Weron, R., M. Bierbrauer, et al. (2004). "Modeling electricity prices: jump diffusion and regime switching." Physica A **336**: 39-48.

Williams, D. J. M. (2000). Getting more from less, Parliamentary Commissioner for the Environment, New Zealand.

Williams, D. J. M. (2003). Sustaining what? Our lifestyles, our natural capital, our economic systems. Canterbury Sustainability Expo. Canterbury, Parliamentary Commission for the Environment.

Williams, M. (2007). Hardwiring sustainability: some key ingredients? Talking and Walking Sustainability, 2nd Internal Conference on Sustainability Engineering and Science, Auckland.

Wilson, R. (2007). Communications Manager, Corporate Affairs, Transpower New Zealand Ltd. Wellington.

Woodham, K. (2005). This one's going to cost us. New Zealand Herald. Auckland.

World Bank (1992). World Development Report, 1992: Development and the Environment. New York, Oxford University Press.

World Business Council for Sustainable Development (2002). Sustainability in the electricity sector. Geneva, World Business Council for Sustainable Development.

World Economic Forum (2001). 2001 Environmental Sustainability Index: an initiative of the global leaders of Tomorrow Environment Task Force. Davos, Switzerland, World Economic Forum.

Wright, J. C. (1991). Indicators of sustainable energy development. Canterbury, New Zealand, Lincoln University, Canterbury.

Yamin, H. Y., S. M. Shahidehpour, et al. (2004). "Adaptive short-term electricity price forecasting using artificial neural networks in the restructured power markets." Electric Power & Energy Systems **26**: 571-581.

Yao, A. W. L., S. C. Chi, et al. (2003). "An improved Grey-based approach for electricity demand forecasting." Electric Power System Research **67**: 217-224.

Young, A. (2007). Climate change - at Parliament. New Zealand Herald.