Exploration of Service – Availability Economic Model for Resource-Constrained Markets

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Abstract

New Zealand, as a remote island without major fossil energy resources, generates its electricity mainly from hydropower. As water resources are finite, the country is already having to deal with the problem of how the demand for electricity can be satisfied. Especially at peak load times during cold winter mornings and afternoons, the supply of electricity becomes insecure, particularly when hydro lakes are low after a dry year. With a growing population and a growing economy it can be expected that the electricity demand will rise in the future whereas water resources remain constant.

This paper explores the present electricity service in Canterbury, a region in the South Island of New Zealand. With the aim to design a sustainable economic model for that resource-constrained region, the meaning of sustainability is analysed and economic approaches to achieve it are investigated. By analysing the present electricity service, the attempt to shave peak loads is regarded as very important to solve electricity availability problems. On that basis, different methods of achieving a sustainable economic model for the electricity market in Canterbury are researched. The approaches of supply and demand, signalling the shortage of electricity and Electricity Supply Chain Management are assessed using selected criteria within a utility analysis. A means to realise the so recommended Electricity Supply Chain Management is designed and the future work required to effect its integration into the electricity market of Canterbury is shown.

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1. INTRODUCTION

"Once upon a time, people thought that the supply of energy available to do useful work was inexhaustible. Once upon a time, fossil fuels – oil and coal – were so cheap that no one was concerned if they were wasted. Once upon a time the people were so few in number that they thought they could throw away anything, and it would never contaminate the air, the water, or the land, and there would always be room."[1] Now it has to be recognized that resources like fossil fuels are limited on Earth and that humans have to live within the resource constraints.

New Zealand, as a remote island without major oil resources, is a resource-constrained country. New Zealand's electricity is mainly generated from hydropower but because of the limited amount of water peak load constraints are already a problem. Electricity supply shortage mainly happens during the mornings and afternoons in cold winters when the year was dry.[2] In future it can be expected that the demand for electricity will increase with New Zealand's increasing population and economy.[3] However, as the water resources are finite, the supply of electricity will become more and more insecure.

That makes New Zealand a very suitable country to develop a sustainable economic energy system that allows management of a resource-constrained market. The investigations within this diploma thesis focus on the area of Canterbury, a region in the South Island of New Zealand. Nevertheless, the solution could be a milestone for the entire world, as all countries will become resource-constrained in the foreseeable future. With regard to the analysis of the electricity market in Canterbury the conceptual formulation requires that growth in energy supply is not necessary, inevitable, desirable or sustainable. Thus the research within this thesis will be focused on solutions for dealing with the currently available resources now and in future.

While the Department of Mechanical Engineering at Canterbury University researches on the technical side of a sustainable energy system in the resource-constrained market of Canterbury, this paper is focused on the economic side.

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[1] AUBRECHT (2006), p. xvii.

[2] See E-Mail CHRIS ROBERTS, TRANSPOWER at 10.11.2005.

[3] See THE WORLD FACTBOOK (2005).

Therefore, this paper seeks to achieve the following goals:

- As this thesis focuses on New Zealand, and particularly the Canterbury area, it should be portrayed by showing its local peculiarities, its energy resources as well as the design of the electricity infrastructure.
- To identify possibilities for the development of a sustainable economic model for Canterbury, the circumstances of the electricity market should be analysed. The literature review should also deal with the analysis of the meaning of sustainability as well as of economic approaches for reaching sustainability.
- With regard to the results of the literature review, the research objectives should be derived and different methods for achieving a sustainable economic model should be researched.
- In order to identify the most sustainable economic solution for the electricity market in Canterbury, the results of the investigated methods should be assessed by a utility analysis. The different options should be compared and judged by selected criteria. The best approach for managing a resource-constrained market should become obvious and a way to realise the so recommended concept should be shown.
- On the basis of the findings, a sustainable economic model should be designed and the future work required should be shown.

2. BACKGROUND

This chapter gives an overview of New Zealand, showing its local peculiarities, its energy resources and the existing electricity grid.

2.1 New Zealand Peculiarities

This chapter introduces New Zealand's geography, showing its remote position that restricts the importing of electricity. A short overview of the history of the country is given, that includes the liberalisation of the electricity market during the 1990s. All above the structure of the government in New Zealand takes part to underline its stable social, political and judicial system. As the demography as well as the economy influence the needs of electricity their development and future trend is depicted.

2.1.1 Geography

New Zealand is a geographically isolated country and with a land area of 268,000 km^2 it is similar in size to Japan. New Zealand is situated in the South Pacific Ocean, about 6,500 km south-southwest of Hawaii and about 1,900 km east of Australia. The only significant landmass to the south is Antarctica and to the east French Polynesia.[4]

Figure 1: Map of New Zealand (THE WORLD FACT BOOK (2005), P. 1)

As illustrated in figure 1, New Zealand consists of two main components, the North Island and the South Island, which are separated by Cook Strait. New Zealand contains other inhabited islands like Stewart Island, the Chatham Islands and Great Barrier Island. The country's longest river (the Waikato) and its largest lake (Lake Taupo) are both located in the North Island that spans 115,000 km². The North Island includes Auckland, the largest city of New Zealand and the capital city, Wellington. In contrast to the volcanic conformation of the North Island, the South Island is characterized by the Southern Alps along its west coast. The South Island covers 151,000 km² and its largest city is Christchurch.[5]

New Zealand is divided into 16 regions with regional councils and authorities. In a roughly north to south order, in the North Island the regions are Northland, Auckland, Waikato, Bay of Plenty, Gisborne, Hawke´s Bay, Taranaki, Manawatu-Wanganui and Wellington. The South Island comprises Tasman, Marlborough, Nelson, West Coast, Canterbury, Otago, and Southland.[6] The region of Canterbury, that includes the city of Christchurch, is the focus of this diploma thesis.

2.1.2 History

In about the year 1000, Maori were the first inhabitants of New Zealand. About 642 years later, the first Europeans reached New Zealand led by the Dutch navigator ABEL TASMAN. In 1769 JAMES COOK, a British captain, made three voyages to the islands and was the first who mapped and called them New Zealand.[7] Because of the strong Maori and British influence the official languages in New Zealand are English and Maori.

Britain formally annexed the islands in 1840. The TREATY OF WAITANGI, seen as New Zealand's founding document, established the country as a nation. The Treaty guaranteed Maori the full possession of their land in exchange for their recognition of British sovereignty. The TREATY OF WAITANGI was signed in 1840 between leading Maori chiefs and representatives of the British Crown at Wai-

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[4] See RICKERBY (2005), p. 34.

[5] See WILLIAMS ET AL (2000), pp. 23f.

[6] See WIKIMEDIA FOUNDATION (2005e).

[7] See RICKERBY (2005), p. 34.

tangi, in the Bay of Islands. The signing of the TREATY began on 6 February that has become New Zealand's national day, known as WAITANGI DAY.[8]

The first capital city of New Zealand was Kororareka (today known as Russell) but shortly afterwards it moved to Auckland. There were political concerns following the discovery of gold in Central Otago in 1861 that the South Island would form a separate colony. So in 1865 the capital was officially moved to the more central city of Wellington.[9]

On 26 September 1907 New Zealand became an independent dominion by royal proclamation. With the STATUTE OF WESTMINSTER, the United Kingdom Parliament granted full independence and the New Zealand Parliament adopted the Statute in the year 1947. Since that time New Zealand has been a sovereign constitutional monarchy within the Commonwealth of Nations.[10]

During WORLD WAR I and WORLD WAR II New Zealand fought on the side of the Allies and supported the UN forces in the Korean War. The country also sent troops to support U.S. forces in South Vietnam in the 1960s. In 1951, New Zealand joined in a mutual defence treaty with the United States and Australia. This pact was suspended in 1986 after New Zealand refused to let U.S. ships with nuclear arms enter its ports.[11]

During the 1990s the deregulation of the electricity market in New Zealand took place. The introduction of competition into the production and sale of electricity was realized by the implementation of wholesale and retail markets.[12] The national transmission grid now acts as the “physical hub of the wholesale markets with generators competing to supply electricity to retailers and end-use consumers across the grid.”[13] The arrangements of the retail markets provide “a basis for reconciliation of end-consumer consumption with wholesale market purchases” as well as “arrangements by which end-use customers can switch between retailers.”[14] In consequence of the greater transparency of operation and self-regulation,

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[8] See BELL (2002), p. 18; pp. 40f.

[9] See BELL (2002), p. 18; pp. 41f.

[10] See BELL (2002), pp. 18f; p. 41.

[11] See THE COLUMBIA ELECTRONIC ENCYCLOPEDIA (2005).

[12] See SOLID ENERGY NEW ZEALAND LTD (2004), p. 72.

[13] SOLID ENERGY NEW ZEALAND LTD (2004), p. 72.

[14] SOLID ENERGY NEW ZEALAND LTD (2004), p. 73.

the New Zealand government maintains no influence over either the price controls or the supply of electricity. The prices "reflect the national balance between supply and demand, modified to account for marginal transmission losses and grid constraints. (…) Typically, generators and purchasers trading electricity through the half-hourly spot market experience significant price volatility as a result of the rapidly shifting balance between supply and demand and competitor interaction. To manage this price risk, buyers and sellers tend to enter bilateral financial contracts referenced to spot market prices."[15]

In 1997, JENNY SHIPLEY of the National Party became New Zealand's first female Prime Minister. The Labour Party, led by HELEN CLARK, and its centre-left coalition defeated the National Party in the 1999 elections and formed a minority government. Clark's coalition retained power, again as a minority government, at the elections in 2002 as well as in 2005. After the COURT OF APPEAL ruled in the year 2004 that Maori could pursue land claims to New Zealand's beaches and seabed, the government passed legislation that nationalized the contested areas in an effort to prevent Maori from gaining an exclusive legal title to them. The law alienated the government's Maori supporters and prompted the establishment of a Maori political party.[16]

It should be pointed out that New Zealand has been in the forefront in instituting social welfare legislation from the outset. New Zealand was the world's first country to grant women the right to vote (1893), adopted old-age pensions (1898) and a national child welfare program (1907). It ensures social security of the aged, widows and orphans along with family support mechanism. New Zealand also established a 40-hour working week and cared for employment and health benefits (1938) and it socialized medicine (1941). In recent times, the Parliament legalized prostitution (2003) and recognized same-sex unions by giving them the same legal and property rights as married couples (2004).[17]

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[15] SOLID ENERGY NEW ZEALAND LTD (2004), pp. 72f.

[16] See THE COLUMBIA ELECTRONIC ENCYCLOPEDIA (2005).

[17] See INFOPLEASE (2005).

2.1.3 Government

New Zealand is an independent nation with a stable social and political environment. Its democratic parliamentary government is based on the Westminster system. Therefore New Zealand's government consists of the governor-general (representing the British crown), a prime minister and cabinet (the effective executive), and a 120-seat unicameral parliament (the House of Representatives), whose members are elected for three-year terms.[18]

New Zealand has two major political parties: the Labour Party on the Left and the National Party on the Right. In 1993 the country voted for a new electoral system, a form of proportional representation known as MIXED MEMBER PROPORTIONAL (MMP). This increased the importance of a wider range of parties and means governments are likely to be formed by a coalition of parties. Since 1996 more than six political parties have been represented in the Parliament.[19]

The judicial system in New Zealand is also based on the British model. In consequence the judiciary is independent from the executive, which means that the judiciary and officials in the public service are appointed independently from the political process. Therefore New Zealand is consistently regarded as one of the world's most transparent and least corrupt countries.[20]

2.1.4 Demography

New Zealand has a ratio of 1.1 men to 1 woman within a population of about 4.1 million inhabitants in 2005. Actually, New Zealand is positive about further migration and is committed to increase its population. By 2051 the population is projected to increase up to 5.05 million citizens (see figure 2).[21]

New Zealand is a very multicultural country, as is depicted in figure 3. In 2004 the New Zealand Europeans (New Zealanders of predominantly European descent) were, at 74.5% the largest ethnic group of New Zealand's population. Maori made up 9.7%. About 4.6% were other European cultures that mainly

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[18] See THE COLUMBIA ELECTRONIC ENCYCLOPEDIA (2005).

[19] See NEW ZEALAND EMBASSY (w. y. c).

[20] See NEW ZEALAND EMBASSY (w. y. c).

[21] See STATISTICS NEW ZEALAND (2004).

include Dutch, Greek, Italian, French, German, Scandinavian and Dalmatian, while 3.8% of the people were Pacific Islander, 7.4% were Asian and other.

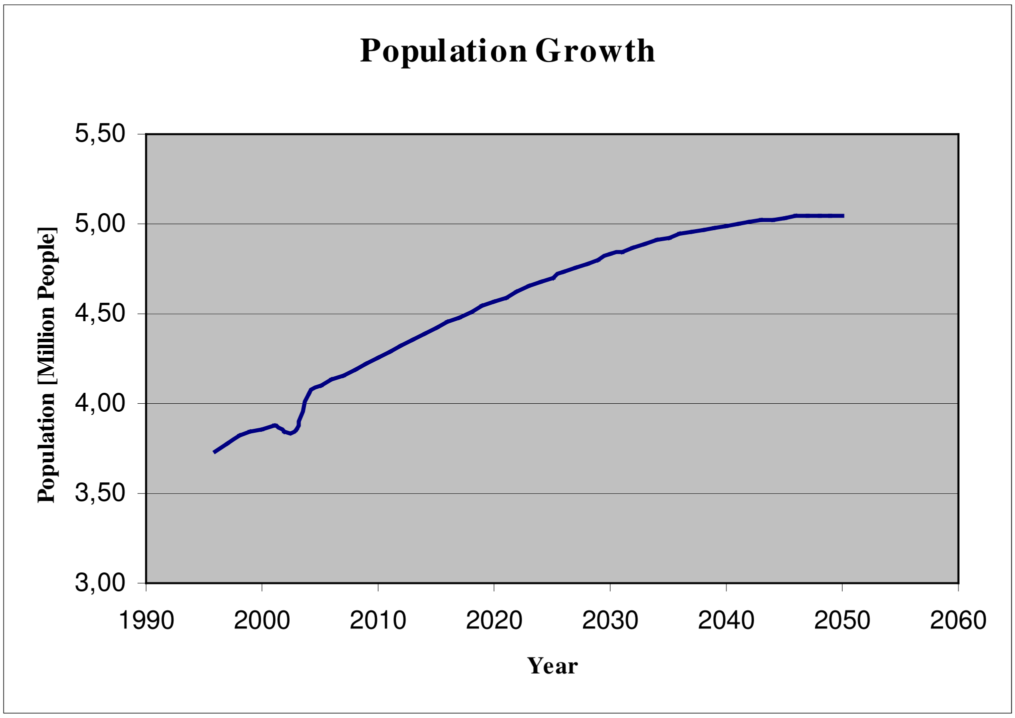

Figure 2: Population Growth in New Zealand (see STATISTICS NEW ZEALAND (2004))

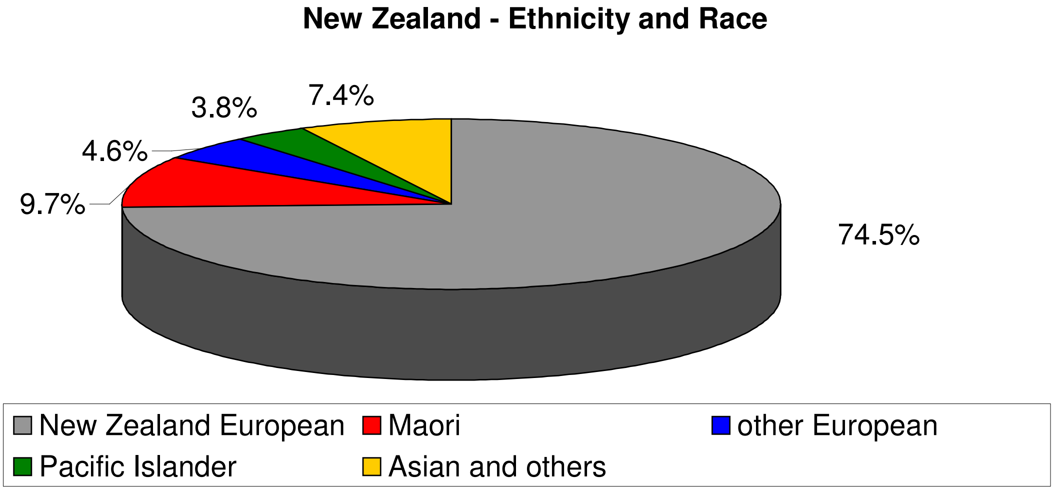

Figure 3: Ethnicity and Race in New Zealand (see INFOPLEASE (2005))

2.1.5 Economy

New Zealand is a modern country with a well-developed and internationally competitive economy that was historically based on the farming sector. Since 1984 the government engaged in major microeconomic restructuring by transforming New Zealand from a highly protectionist and regulated economy in a privatised, market oriented and liberalised one. The reforms included the removal of subsidies, tariffs and price controls as well as the floating of the exchange rate, the abolition of controls on capital movement and the privatisation of many state assets (such as telecommunication and electricity).[22] New Zealand has a strong focus on international trade. Its essential export commodities are wool, meat, dairy products, fish, fruit, and timber products. The primary import commodities mainly include machinery and equipment, vehicles and aircraft, petroleum, electronics, textiles and plastics. New Zealand's top export and import partners are Australia, the United States, Japan and China.[23] In 2004 the merchandised imports comprised 34.9 billion NZ$ and the merchandised exports were 29.5 billion NZ$.[24]

As shown in figure 4 New Zealand's GROSS DOMESTIC PRODUCT (GDP)[25] has been rising since the year 1998. In the year ended in March 2005, the Gross Domestic Product was amounted to 122.936 billion NZ$.

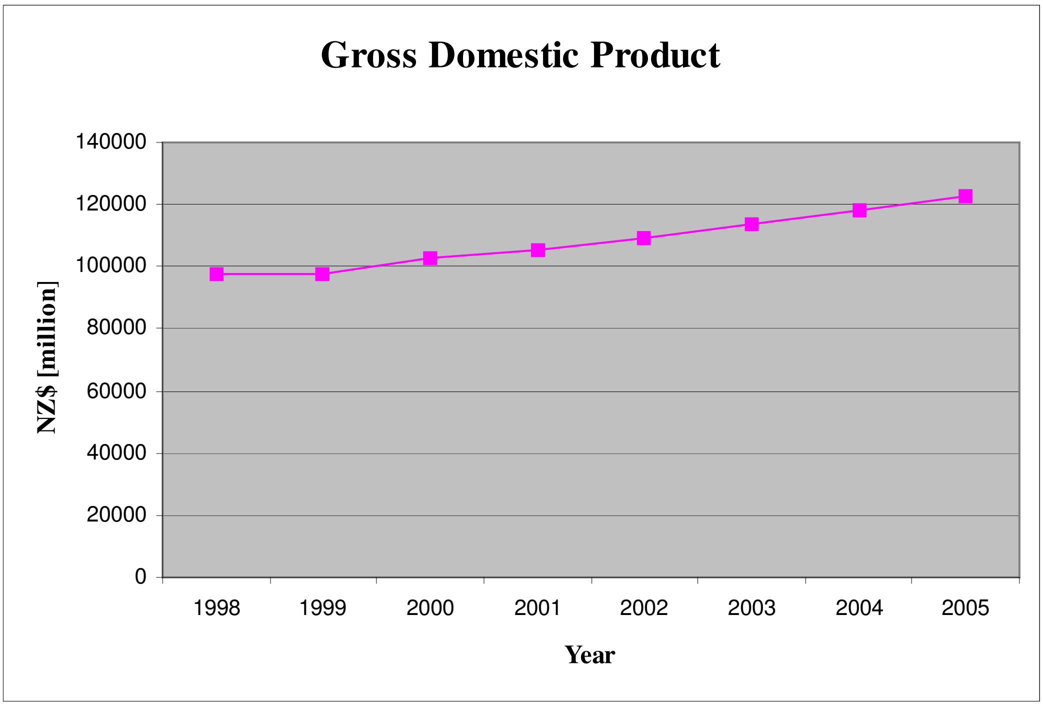

Figure 4: Growth of the Gross Domestic Product in New Zealand (see STATISTICS NEW ZEALAND (2005))

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[22] See NEW ZEALAND EMBASSY (w. y. a).

[23] See INFOPLEASE (w. y.).

[24] See MARKET NEW ZEALAND (2005).

[25] GDP measures the value added from all economic activity in New Zealand. It is expressed in 1995/96 prices.

For the future it is predicted that the “GDP growth steadily picks up, increasing to around 3.4% at the end of 2006 and beginning of 2007.”[26]

2.2 Energy Resources in New Zealand

This chapter deals with New Zealand energy data. It considers the two islands separately and includes the process of electricity generation in the South Island.

2.2.1 Resources for the Generation of Electricity in New Zealand

Its remote location means that New Zealand must be largely self-sufficient in energy.[27] Energy data for 2001 and 2002 shows that New Zealand neither imported nor exported electricity (see table 1). A discussion with an expert confirms that this fact is also valid for 2005.[28]

Electricity - Supply and Demand (2002):	
Electricity - imports: 0 kWh	Electricity - exports: 0 kWh
Electricity - production: 38.39 TWh	Electricity - consumption: 35.71 TWh
Electricity - Production by Source (2001):	
Hydro: 57.8%	Nuclear: 0%
Fossil Fuel: 31.6%	Other: 10.7%

Table 1: Energy Data of New Zealand (see THE WORLD FACTBOOK (2005), P. 6; see WIKIMEDIA FOUNDATION (2005a), P. 2)

As shown with table 1, New Zealand generated 38.39 TWh [Terawatthours] of electricity in 2002. The total consumption of electricity during that year was 35.71 TWh. Data regarding the sources of electricity generation in New Zealand were only available for 2001. From this it can be seen that in 2001 57.8% of the electricity was generated from hydropower and that nuclear power is not used as

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[26] THE TREASURY (2005).

[27] See NEW ZEALAND EMBASSY (w. y. b).

[28] See Meeting with DR. SUSAN KRUMDIECK at 17.08.2005.

an energy source. Moreover, 31.6% of the electricity in 2001 was operated from fossil fuels and 10.7% from other sources, like wind.

The major methods of generating electricity in the North Island are hydroelectric and geothermal, located in the centre of the island, and natural gas in the west. The South Island has only hydroelectric power stations that are located in remote areas.[29]

2.2.2 Resources for the Generation of Electricity in the North Island

Figure 5 depicts the North Island load duration curve that is determined by the demand for electricity and the hours per week which different resources for generating electricity are used. The load duration curve is determined from historical data and reduces the identified week's demand data from the North Island (measured half hourly) to a probability distribution. The data is ordered from the peak demand half hour down to the lowest half hour of demand.

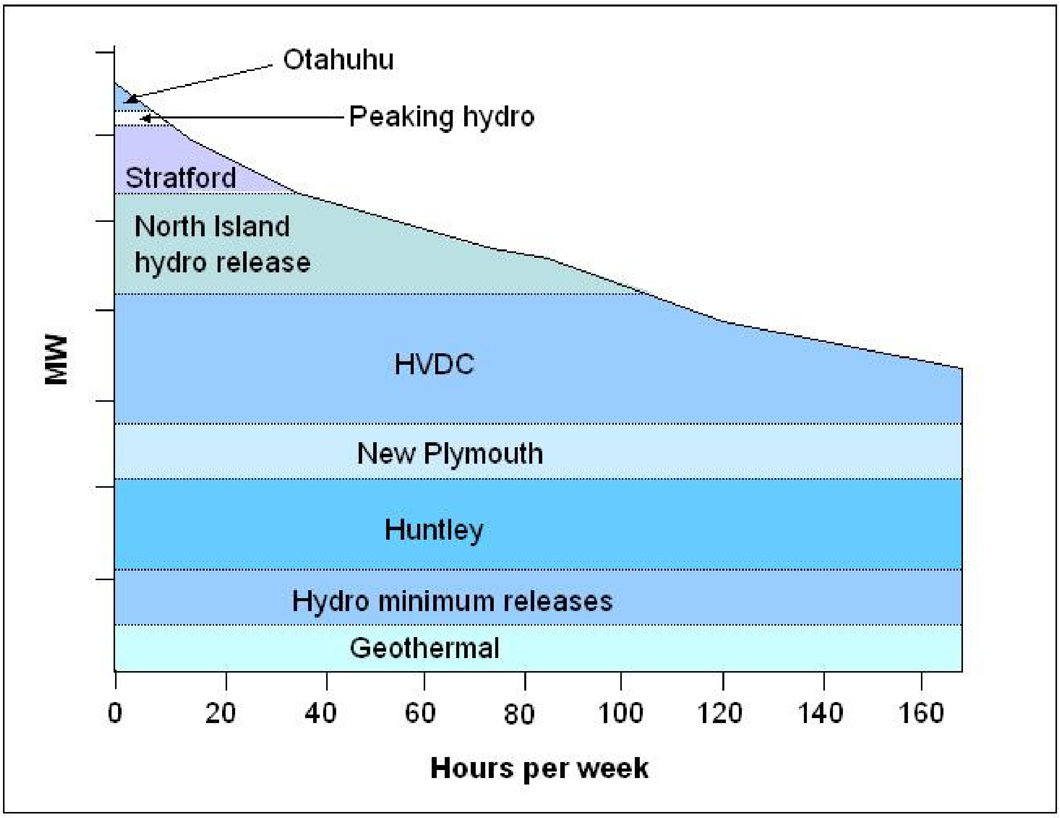

Figure 5: Load Duration Curve for the North Island of New Zealand (CENTRE OF ADVANCED ENGINEERING (1993), P. 284)

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[29] See CENTRE OF ADVANCED ENGINEERING (1993), p. 11.

With regard to electricity generation, figure 5 illustrates that to satisfy the electricity demand the cheapest power plants are loaded first. But it has to be noted that only fuel costs are considered, as these are the only avoidable costs. The capital as well as operation and maintenance costs are fixed in the short term. As the costs for electricity generation in the North Island are lower at the geothermal stations, they are used first followed by hydro power plants at times of minimum demand (minimum releases). Both types of power plants have no fuel costs in contrast to the coal power plant in Huntley and the natural gas station in New Plymouth that are added in when electricity demand increases. The supply of electricity is more cost-efficient with the waterpower from the South Island than with the hydro releases of the North Island. South Island hydropower is therefore put in operation first. The high-voltage direct current (HVDC) link connects the power systems between the North and South Island. At a further growing demand the gas turbines of Stratford are applied and after that, the North Island's hydro capacities for satisfying the peak loads. Finally the Otahuhu gas turbines are loaded to satisfy extraordinary demand.[30]

2.2.3 Resources and Generation of Electricity in the South Island

In contrast to the North Island, electricity for the South Island is only generated from hydropower.[31] The generation process at hydro power plants is explained by using figure 6.

The water needed to generating electricity is collected in a reservoir (=lake) behind a dam. The water falls through the intake in a pipe called penstock. The penstock carries the water from the reservoir to a turbine that activates the generator inside the powerhouse. The potential energy of water changes to kinetic energy that is converted into mechanical, rotating energy, and finally into electrical energy. After that the electricity is transmitted to a substation where transformers increase voltage so that the electricity can be delivered to the consumers by power lines.[32]

The amount of electricity that can be extracted from water depends not only on the volume of water but also on the difference in height between the water surface

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[30] See CENTRE OF ADVANCED ENGINEERING (1993), p. 284.

[31] See CENTRE OF ADVANCED ENGINEERING (1993), p. 11.

[32] See VIZCARRA (w. y. b).

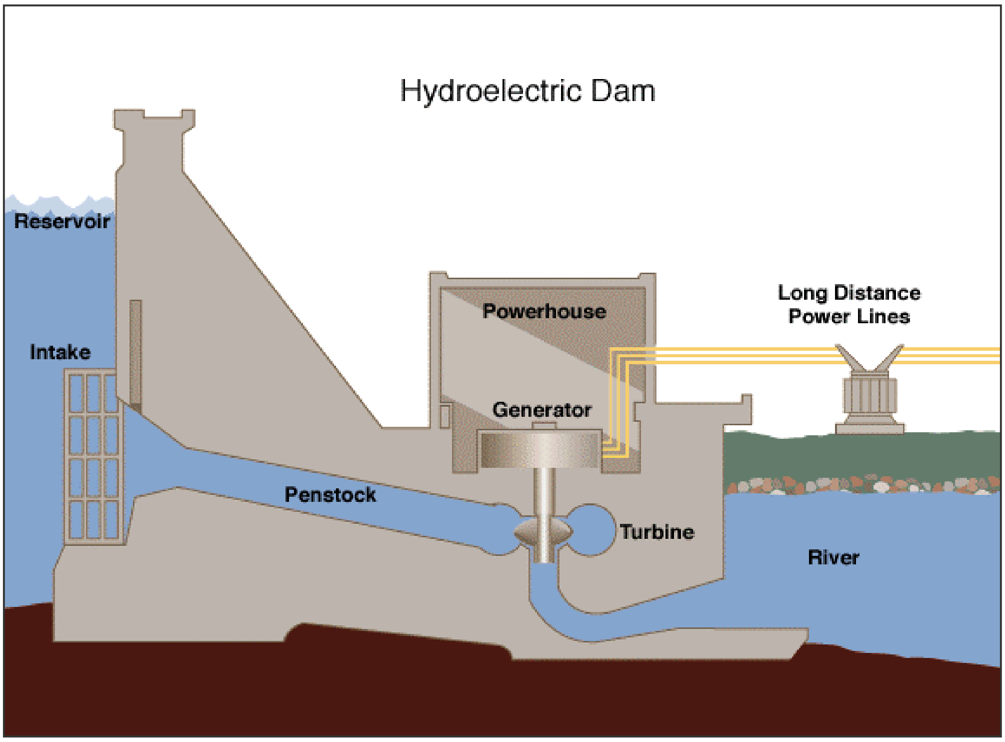

Figure 6: Hydro Power Plant (VIZCARRA (w. y. b))

and the turbine. This height difference is called the head and is directly proportional to the amount of potential energy in the water. That means that the higher the flow and the head, the greater the amount of electricity that can be generated out of water.[33] It is not possible to store large amounts of electricity but it is possible to store the water in dams to ensure the power supply. The hydro power plants run constantly but they can slightly vary the capacities on the demand by controlling the storage of water behind dams. However, the continuous operation leads to a surplus of electricity in low demand periods like during the nights. However, in a dry year the lakes are low and the supply of electricity reaches a limit, as the water resources are too little. That is exactly the problem Canterbury has to deal with.

2.3 The Electricity Grid in New Zealand

The following chapter describes the development and the design of the hydropower grid in New Zealand and introduces the local Canterbury electricity providers.

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[33] See Wikimedia Foundation (2005b).

2.3.1 Development and Design of the Electricity Grid

At the end of the 19th century New Zealand began generating electricity from hydropower. The first public supply started in 1887 by turning on the first public electricity lighting system all over Reefton on the West Coast of the South Island. While in the first years the inhabitants were very sceptical, the acceptance of electricity had become widespread by the 1920s.[34] In about 1922 the first storage lake scheme was completed at Lake Coleridge in Canterbury.[35]

As already mentioned, the electricity market in New Zealand was determined by a system of monopoly providers of generation, transmission, distribution and retailing. But during the 1990s many government reforms have led to the separation of the generating and retailing monopoly to create a framework for a competitive electricity market. For example the ELECTRICITY REFORM ACT (1998) required New Zealand's integrated electricity companies (of which there were some 36) to functionally separate their electricity network and electricity retail businesses and divest either the network or retail businesses.[36] In this connection it should be pointed out, that the present capacities of the hydropower plants, of 220,000 volts were largely built in the 1950s. Since that time no changes in the capacities seemed to be necessary, but full capacities are now approaching in places.[37]

The present structure of the electricity grid is shown in figure 7. As can be seen, the hydro-based electricity grid of New Zealand and therefore of Canterbury generally consists of five elements: The Generators, the Transmission, the Linescompanies, the Retailers and above all, the Customers. These are explained separately by showing photos of each institution:[38]

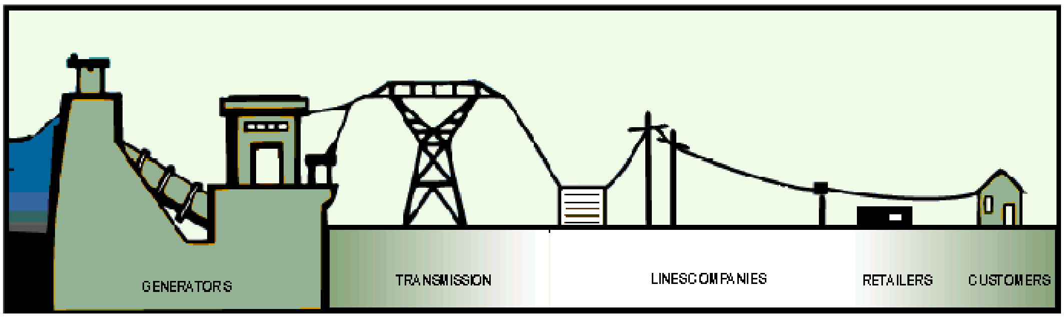

Figure 7: Electricity Grid in New Zealand (ORION (w. y. a), P. 4)

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[34] See Orion (w. y. c).

[35] See Meridian Energy (2005b).

[36] See ORION (w. y. c).

[37] See TRANSPOWER (w. y. b).

[38] See ORION (2005b), p. 5.

Figure 8: Generator in Canterbury

Generators are power plants that produce electricity for example out of hydropower. Regarding to New Zealand's hydro power plants there are several private and government owned companies such as CONTACT ENERGY, GENESIS POWER, MERIDIAN ENERGY, MIGHTY RIVER POWER, TODD ENERGY AND TRUST POWER.

Figure 9: Transmission in Canterbury

Transmissions are the national grid of high voltage power lines and tall pylons that transport electricity from the generators to key points around the country. The key points are major substations, which are mostly near towns and cities and are known as grid exit points. New Zealand's grid is operated by the state-owned enterprise called TRANSPOWER.

Figure 10: Powerline and Grid-Exit Point

Linescompanies distribute the electricity from the major substations (grid exit points) to the homes and businesses by lower voltage overhead lines and underground cables. They are also responsible for the construction and maintenance of an efficient and safe electricity network. In New Zealand there are 28 electricity distributors, including the network company ORION NEW ZEALAND LIMITED that serves the greater Christchurch urban area and large surrounding rural areas in Canterbury.

Figure 11: Retailers in Canterbury

Retailers are companies that sell the electricity direct to households and businesses. In central Canterbury there are five electricity retailers, Contact Energy, Genesis Power, Meridian Energy, Mighty River Power, and Trust Power. The retailers are charged by the linescompanies for delivering the energy. The retailers then bundle up the charges for the generation, transmission, distribution and retailing of electricity, and invoice the end users.

Figure 12: Customer in Canterbury

At the end of New Zealand's electricity infrastructure there are the **Customers**, consist of households, businesses and industrial electricity users. The customers get the electricity from the linescompany but they are charged by the retailers.

The dominant companies in Canterbury are Meridian Energy Limited, which acts as a generator as well as a retailer, the state-owned enterprise Transpower that is responsible for transmission and Orion New Zealand Limited that owns and operates the electricity network in the most part of Canterbury.

2.3.2 Meridian Energy Limited

Meridian Energy Limited (`Meridian´) is the largest state-owned electricity generator in New Zealand. It produces the largest amount of electricity and satisfies approximately one-third of the country's power needs of about 12,000 GWh [Gigawatthours] per year. In the South Island the company owns and operates nine hydroelectric generating stations: eight on the Waitaki River and the country's largest hydroelectric station, the Manapouri Power Station that is located on Lake Manapouri in the south of the island. In line with a commitment in 2004, MERIDIAN has started to build new generation capacities by developing only renewable forms of power generation. Consequently it now generates electricity from windpower as well as from of hydropower.[39]

MERIDIAN also operates as a retailer of electricity, selling power to approximately 230,000 residential, industrial and commercial customers that are primarily located in the South Island. In the Canterbury area, MERIDIAN serves about 90,000 to 100,000 customers.[40]

2.3.3 Transpower New Zealand Limited

TRANSPOWER NEW ZEALAND LIMITED (`TRANSPOWER´) is a state-owned enterprise. It owns and operates New Zealand's high-voltage electricity transmission network and links the generators with the distribution companies and major industrial users. The transmission grid comprises approximately 12,000 km of transmission lines and 170 substations and switchyards that provide a capacity of 220,000 Volt.[41] Data specific to Canterbury was not available.

As electricity is an instant connection from source to switch that cannot be stored TRANSPOWER ensures its lines deliver a continuous volume of electricity. Therefore it works in collaboration with electricity generation companies as well as with linescompanies. Overall, TRANSPOWER acts as a system operator and "keeps the right amount of the energy flowing, 24 hours a day, 7 days a week" so that a safe, secure and continuous supply of electricity should be guaranteed.[42] Moreover, TRANSPOWER is responsible for the real-time coordination of the electricity transmission in New Zealand and provides for the scheduling and the dispatching of the services. As a result, the generating companies offer the electricity at a price of their choice and the retailers make bids to buy certain quantities at different prices. TRANSPOWER then works out the amount of electricity that needs to be

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[39] See WIKIMEDIA FOUNDATION (2005c).

[40] See E-Mail ALAN SEAY MERIDIAN ENERGY at 14.11.2005.

[41] See TRANSPOWER (w. y. c).

[42] TRANSPOWER (w. y. a).

Figure 13: Network Area of Orion New Zealand Limited (ORION (w. y. a.), P. 2)

generated for a particular half-hour period, so that the supply will equal the demand.[43]

2.3.4 Orion New Zealand Limited

As a linescompany ORION NEW ZEALAND LIMITED (`ORION´) is responsible for the construction and maintenance of an efficient electricity network. It distributes electricity from ten major substations to homes and business within the Canterbury area (shown at figure 13). For that, ORION'S network covers 8,000 km² in central Canterbury and delivers 2,800 GWh per year. [44] It can supply a maximum demand of about 700 MW [Mega-Watt].[45]

Ultimately Orion is owned by the Christchurch City Council (87.625%), Selwyn District Council (10.725%) and Banks Peninsula District Council (1.650%) (see figure 14).

For delivering the electricity, ORION has agreements with five retailers, CONTACT ENERGY LIMITED, GENESIS POWER LIMITED, MERIDIAN ENERGY LIMITED, MIGHTY RIVER POWER LIMITED and TRUST POWER LIMITED.[46] In addition to the

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[43] See TRANSPOWER (w. y. c).

[44] See ORION (w. y. a), p. 2.

[45] See E-Mail GLENN COATES ORION at 15.11.2005.

[46] See ORION (w. y. b).

network management it should be emphasized that ORION also has investments in a number of energy-related services and technology companies.[47]

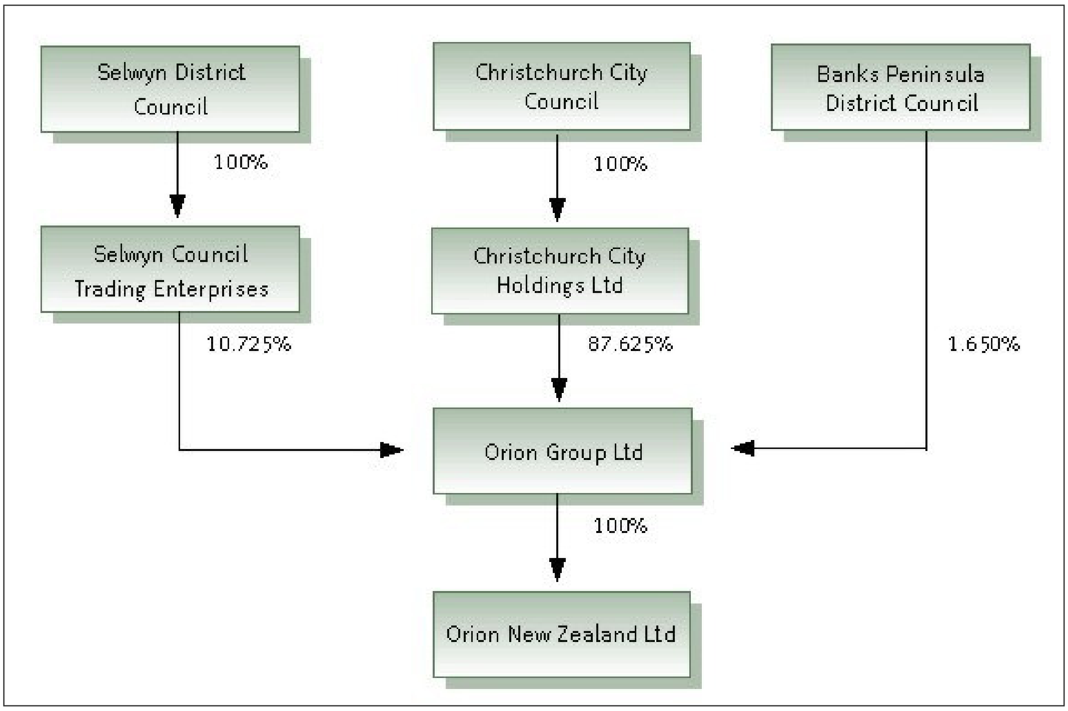

Figure 14: Ownership of Orion New Zealand Limited (ORION (w. y. d))

As already mentioned, the capacities of New Zealand's hydropower plants have not changed since the 1950s and the South Island in particular is highly dependent on water resources for generating electricity. Taking into account the identified growth in population and the economy at chapter 2.1.4 and chapter 2.1.5 it can be assumed that electricity consumption will increase during the coming years. This will require management of the limited water resources and an adaptation of the capacities at every power company. Because of that, the following literature review will now show the circumstances in Canterbury's electricity market for supporting the development of a sustainable economic model to match that resource-constrained region.

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[47] See ORION (w. y. a), pp. 5ff.

3. LITERATURE REVIEW

This chapter outlines the reviewed and analysed literature in the framework of this diploma thesis. The circumstances of the electricity market in Canterbury in the operating area of ORION are shown. To identify approaches to dealing in a resource-constrained market, the meaning of sustainability will be analysed. Further, theoretical and practical economic approaches will be presented.

3.1 Circumstances of the Electricity Market in Canterbury

The development of electricity consumption in Canterbury is analysed by showing different statistics of electricity demand. The data focuses on the general development of electricity demand as well as the overall maximum demand trends within the network area of the linescompany ORION. A discussion with an expert confirms that this data is representative for the entire Canterbury region.[48] Additionally the electricity consumption on a winter day is shown with reference to the time as that season is expected to be the main driver of the load factors at the hydro power plants.

3.1.1 Electricity Demand Trends

The averaged annual energy trends in the electricity market in the network of Canterbury's dominant linescompany ORION is shown in figure 15.

The evolution of the averaged demand in GWh/year between 1975 and 2005 is depicted. To illustrate the expected future demand up to the year 2015 the figure includes a projection of the 30 years history as well as an expected electricity demand, which could result from the CLEAN AIR PLAN for Christchurch. The CLEAN AIR PLAN is being "implemented in the context of a national air quality standard" and "provides for restrictions on the use of non-complying burners (…) and conversion to `clean´ heating appliances."[49] Therefore the inhabitants should avoid heating appliances like open fires and secondarily log burners because of their high rates of emissions that pollute the environment and reduce the quality of life.[50]

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[48] See meeting with DR. SUSAN KRUMDIECK at 07.09.2005.

[49] ORION (2005a), p. 57.

[50] See BURTON; KRUMDIECK (1998), p. 7.

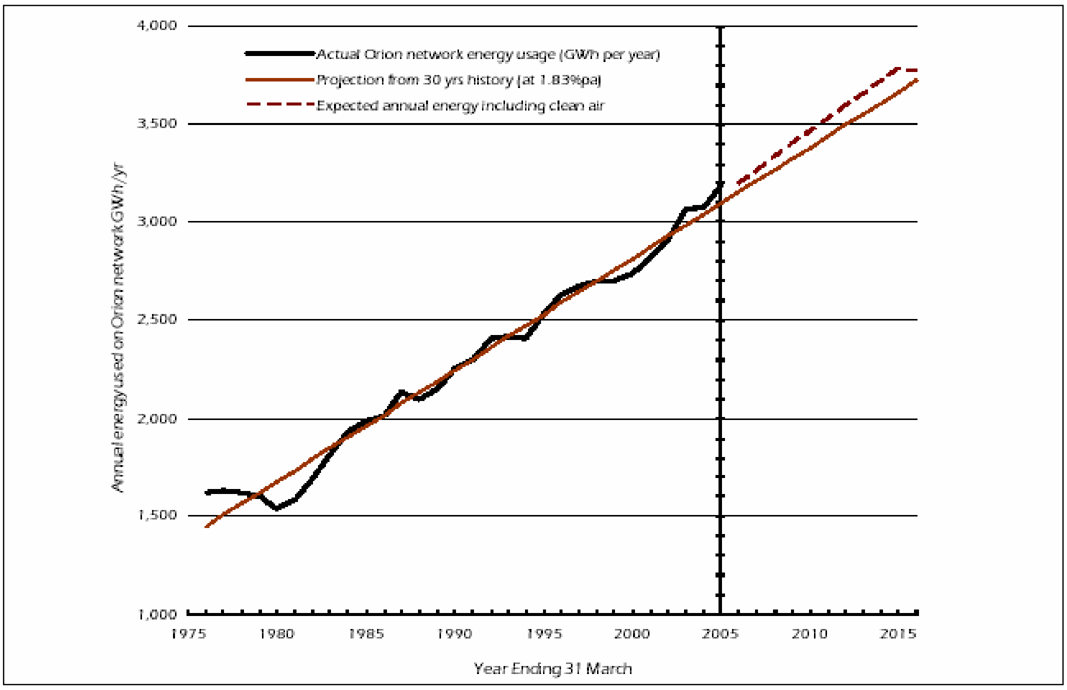

Figure 15: Annual Electricity Trends (ORION (2005a), P. 52)

Figure 15 shows, that electricity consumption within ORION'S network area is characterised by a trend of an increasing demand. The electricity throughput for the year ending at 31 March 2005 increased by 3.7% to the previous year and reached about 3190 GWh. According to the projection of the 30 years history, ORION estimates an average growth rate of electricity demand of about 1.83% per year. Taking into account the CLEAN AIR PLAN for Christchurch, ORION expects a growth rate of electricity demand of about 2.0%.[51]

The expected growth rate because of the CLEAN AIR PLAN is based on a strong impact of climatic variations on electricity demand, which may result in a higher use of electric heaters during the winter. A further reason for the increasing electricity demand seems to be population growth. All above, the growth in commercial and industrial output as well as the changes in land use in the rural sector can cause a higher demand for electricity.[52]

3.1.2 Overall Maximum Demand Trends

It can be assumed that the major driver for load factors in the electricity network is the maximum demand. Therefore figure 16 shows the overall maximum demand trends within the ORION network. It includes the evolution of the actual

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[51] See ORION (2005a), p. 52.

[52] See ORION (2005a), p. 13.

maximum demands in Canterbury to 2005 and a projection of the 30-year history until 2015. It depicts the estimated development of potential cold snap peaks that indicate periods of very cold weather. In addition to that it considers the future development of electricity demand with and without the effects of the Clean Air Plan.

In figure 16 the overall maximum demand of electricity clearly shows a rising trend. The long-term trends suggest a growth rate of 1.24% per year. According to Orion's investigations, the maximum demands substantially depend on the vagaries of winter weather. Therefore the maximum demand for the year ending 31 March 2005 was 577 MW, which corresponds to a growth rate of about 2% from the previous year. The peak in 2002 was caused by a very cold snap and reached a demand of about 600 MW.[53]

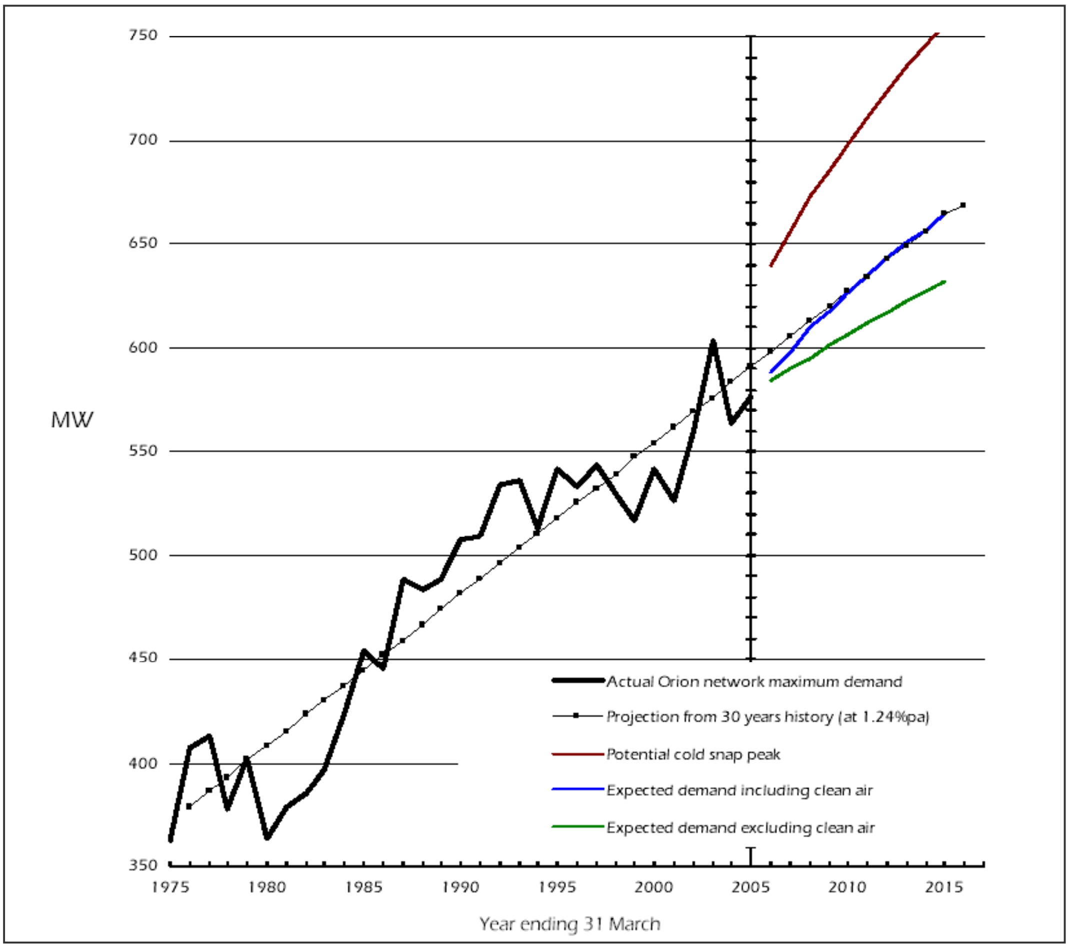

Figure 16: Overall Maximum Demand Trends of Electricity (see Orion (2005a), P. 53)

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[53] See Orion (2005a), p. 53.

Taking into account the expected demand during a potential cold-snap peak, the forecast is based on events like the very cold winter in 2002.[54] If this were to every year, then the demand is estimated to grow up to an amount of 750 MW in the year 2015. The forecast of the maximum electricity consumption excluding the CLEAN AIR PLAN is based on a continuation of medium term trends and is likely to lead to an increasing demand of an estimated 1.2% per year. In contrast to this, the expectations of maximum demand including the CLEAN AIR PLAN are based on medium term trends. A growth rate of about 1.3% is forecast.[55] The higher demand predicted as a result of the Clean Air Plan is probably based on the assumption that as people are required to avoid emissions they will increasingly use electric heaters.

3.1.3 Winter Daily Demand

From the two previous figures 15 and 16 it can be estimated that the rising electricity demand is caused by the peak demand during the winter. To define the winter peaks more exactly, figure 17 is shown. It depicts the run and the forecast of the winter daily load profile for Christchurch and the Upper South Island for the years 2005, 2010, 2012 and 2015. The curves are determined by the time and the amount of the electricity demand. In addition to that, the capacity limit of approximately 1350 MW is shown. It has to be noted, that figure 17 considers Christchurch and the Upper South Island, as data for ORION'S network area were not available. However, as ORION'S network area comprises Christchurch and a part of the upper South Island the curves are expected to pinpoint identical load factors. Consequently, the use of figure 17 is valid.

Figure 17 shows that the demand during the winter will grow from 2005 up to 2015. It is obvious, that the amount of the different winter demands are all similar and that they are all characterised by identical peak-times. The first peak can be seen at 8 am, when people turn on electric heaters and appliances for preparing breakfast to start their day. The second peak demand can be recognized at 6 pm, when people use electric heaters and equipment for preparing dinner when they come home from work. Comparing the forecasted peak times of the different years with the capacity limit, it becomes apparent that the capacity will first be

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[54] See ORION (2005a), p. 53.

[55] See ORION (2005a), p. 53.

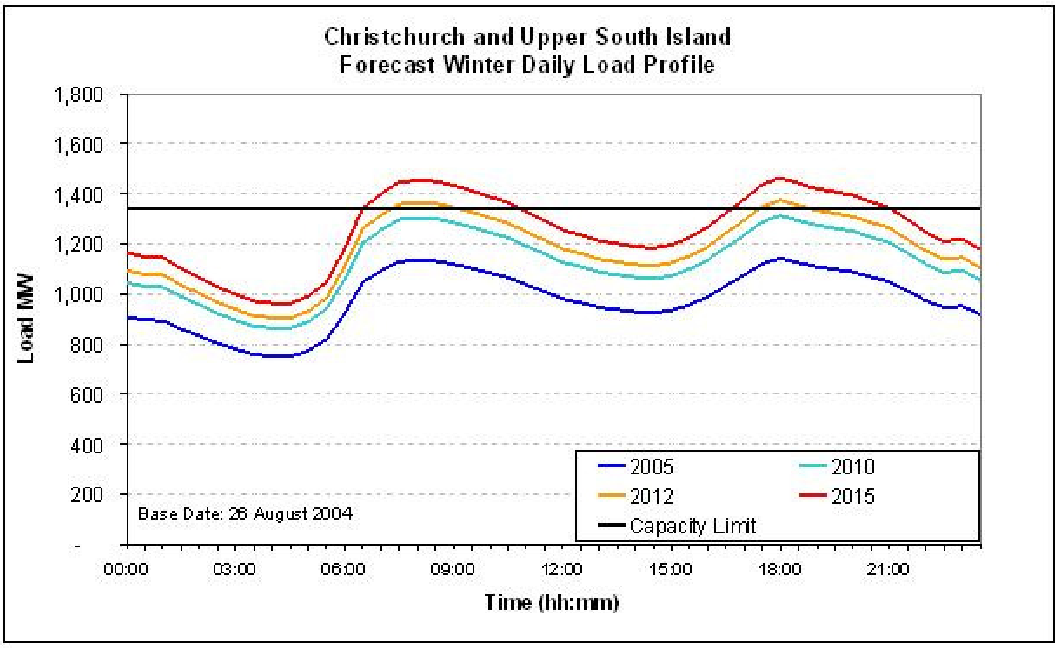

Figure 17: Forecast of the Winter Daily Load Profile for Christchurch and the Upper South Island (E-Mail Chris Roberts at 10.11.2005)

exceeded within the peaks during 2012 and 2015. Therefore it can be stated, that without changes in Canterbury's electricity market with respect to Orion's network area the demand cannot be satisfied anymore during the two winter peak times in the year 2010.

3.1.4 Summary

As illustrated in the previous figures, electricity demand is predicted to rise during the next years. The maximum peaks, which are mainly caused by the winter weather, will also increase. The essential drivers for this development seem to be climatic variations, the expected growth rate of population as well as commercial and industrial outputs. In addition to this, changes in land use in the rural sector may also have an impact on electricity demand.

Because New Zealand, and with the considered region of Canterbury, is resource-constrained, it could happen that the increasing demand for electricity can no longer be satisfied. Without any increase in capacities or changing the management of the resource-constrained electricity market or the demand, this would first occur in the morning and afternoon peaks during the winter of 2010. In the case of low lake levels it could possibly happen earlier. Electricity importing is very difficult because of the remote geographical position of New Zealand. It is theoretically possible to build additional power plants (like nuclear power plants). As the theme of this thesis underlined, if these options are ignored, other ideas have to be developed that show how acting in a resource-constrained market may be possible.

In different discussions, the word sustainability seems to be the key for solving that problem. The next section analyses the meaning of sustainability and considers economic approaches. The results could support the design of a sustainable economic model for a resource-constrained market.

3.2 Analysis of Sustainability

The technology and economic infrastructure of the current energy system were based on the assumption of available energy resources. However, the focus of present research activities must increasingly consider the problem of the foreseen shortage of resources. Currently offered solutions mainly investigate the integration of renewable energy resources like sun or wind. Unfortunately a methodology of dealing in resource-constrained markets without the necessity for alternative energy sources still seems to be missing. It is well known that fossil fuels are limited on earth but that renewable energy resources do not have such a reliable energy-output as fossil fuels do. Therefore it is necessary to integrate "a sustainable energy and environment architecture, where the daily activities of individuals and businesses are carried out within environmental constraints."[56] In discussing a sustainable society, it is important to define what sustainability exactly means and to identify which tools already exist to generate it.

3.2.1 Approaches and Methods of Sustainability

Six different publications that deal with the state of sustainability are discussed below.

3.2.1.1 Limits to Growth

In 1963 the CLUB OF ROME started to investigate how the interdependent components of economics, politics, nature and society determine the global system.[57] In LIMITS TO GROWTH, the authors MEADOWS ET AL (1972) argued that unlimited

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[56] KRUMDIECK (2004), p. 1.

[57] See MEADOWS ET AL (1972), p. 9.

material growth does not meet the physical reality. Focussing on the fact that the Earth's finite resources and space are running out, the publication modelled the consequences of a rapidly growing global population by the so called world1- and world2-model. The interactions between population, pollution, industrial growth, food production as well as non-renewable resources and limits in the ecosystem were considered and consequences of interactions between the Earth's and the humans´ systems were shown.[58] As a result, it is postulated that society must reach an equilibrium state to avoid a collapse, for example by stopping exponential growth.[59] MEADOWS ET AL (2004) published an up to date state of the environment by developing the world3-Model, in which the equilibrium state was renamed as a sustainable system.[60] Summarized, MEADOWS ET AL (1972) can be seen as the beginning of sustainability discussions.

3.2.1.2 Brundtland Commission

In 1983 the United Nations appointed an international commission to propose strategies for sustainable development of the environment. The goal of the meeting was the establishment of the BRUNDTLAND COMMISSION that focuses on strategies to strengthen efforts to encourage sustainable and environmentally friendly development.[61] For sustainable management of climate change the BRUNDTLAND COMMISSION recommended a "low energy future, one that is grounded firmly in energy-efficiency, conservation and the aggressive development of new and renewable resources."[62] It considers ways that the international community can act more efficiently, for example by producing more with less.[63] The most well-known result from the commission meeting seems to be the definition of sustainable development as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs."[64]

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[58] See MEADOWS ET AL (1972), pp. 123ff.

[59] See MEADOWS ET AL (1972), pp. 170f.

[60] See MEADOWS ET AL (2004), pp. 235ff.

[61] See BRUNDTLAND CITY ENERGY (w. y.).

[62] KING (1989), p. 27.

[63] See KING (1998), p. 28.

[64] KING (1998), p. 7.

3.2.1.3 Industrial Ecology

JELINSKI ET AL (1992) proposed that "Industrial ecology is a new approach to the industrial design of products and processes and the implementation of sustainable manufacturing strategies. It is a concept in which an industrial system is viewed not in isolation from its surrounding systems but in concert with them."[65] They argue that global sustainability can be reached by providing this framework concept to businesses that are expected to follow the strategies of general energy and material conservation goals as well as redefining commodity markets and product stewardship relations. If businesses do not follow this, they will loose their market access due to inevitable loss of interest in their products.[66]

3.2.1.4 The Natural Step

With the NATURAL STEP, ROBÉRT (2002) derived four system conditions from the laws of thermodynamics that have to be fulfilled to achieve a sustainable society.[67] The system conditions are stated as follows:[68]

"In a sustainable society, the nature is not subject to systematically increasing…

- …concentrations of substances extracted from the Earth's crust;
- …concentrations of substances produced by society;
- …degradation by physical means and,
- in a sustainable society human needs are met worldwide."

The four system conditions are equally important and if even one is unfilled, society cannot be sustainable. As a result, symptoms "resulting in a systematic accumulation of (…) waste and (…) pollution" will occur.[69]

For strategic planning for sustainable development five different levels have to be fulfilled:[70]

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[65] See JELINSKI ET AL, (1992), p. 793.

[66] See GRAEDEL; ALLENBY (1998), p. 20.

[67] See ROBÉRT (2002), pp. 36ff.

[68] ROBÉRT (2002), pp. 68ff.

[69] ROBÉRT (2002), p. 210.

[70] See ROBÉRT (2002), pp. 249ff.

- Level 1- System Definition: Articulation of how the system is constituted.
- Level 2 - Identification of Outcomes and Success: Principles for setting the vision and guiding strategy.
- Level 3 - Strategies: A means of moving purposefully toward the vision.
- Level 4 - Actions: Concrete measures that will lead to the desired outcomes.
- Level 5 - Toolbox: Means of assessing, managing and monitoring actions.

The concept of the NATURAL STEP is frequently applied to businesses. For example, the world's largest furnishing retailer IKEA adopted this concept and completely rethought all its value and supply processes. As a result IKEA became more sustainable (and more profitable).[71]

3.2.1.5 Collapse

DIAMOND (2005) examined how and why western civilizations developed the technologies and immunities that have allowed them to dominate much of the world. By analysing the past and present situations of different societies the following FIVE-POINT FRAMEWORK that contributes to a society's failure or success was developed:[72]

- environmental damage,
- climate change,
- hostile neighbours,
- friendly trade partners,
- society's response to environmental problems as a part of the local and central monitoring of the environment.

All of these factors are indicators that have a strong influence on reaching a successful and sustainable environment.

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[71] See ROBÉRT (2002), pp. 76ff.

[72] See DIAMOND (2005), p. 11.

3.2.1.6 Theory of Behaviour of Complex Systems

BURTON; KRUMDIECK (1989) developed the THEORY OF BEHAVIOUR OF COMPLEX SYSTEMS by designing a Continuity Energy-Environment-Economic System Model, in which the present regional energy and environment system behaviour as well as the desired state of sustainability can be shown. The initial point of the model (see figure 18) is the so called Model Environment that includes a possible future scenario based on the Continuity Model. The Continuity Model describes the steady state system response that can be interpreted as the balance between natural cycles in use of resources and impacts on natural systems.[73] Therefore the Continuity Model is a shared vision of the "right way to do things" to reach sustainability. The Social, Economic and Energy Architecture consist of discrete subsystems, which include cultural requirements of the society for a high quality of life, the relationship between consumers and producers (including income etc) that determines the Economy, as well as the built Environment that depends among other things, on innovations or controlling systems. The economy and the built environment are shaped by the cultural, technological and environmental context of the civilization. Individual people and businesses represent the system's control elements that can only utilize the existing built environment. The model has three levels of feedback, the availability of energy, the performance

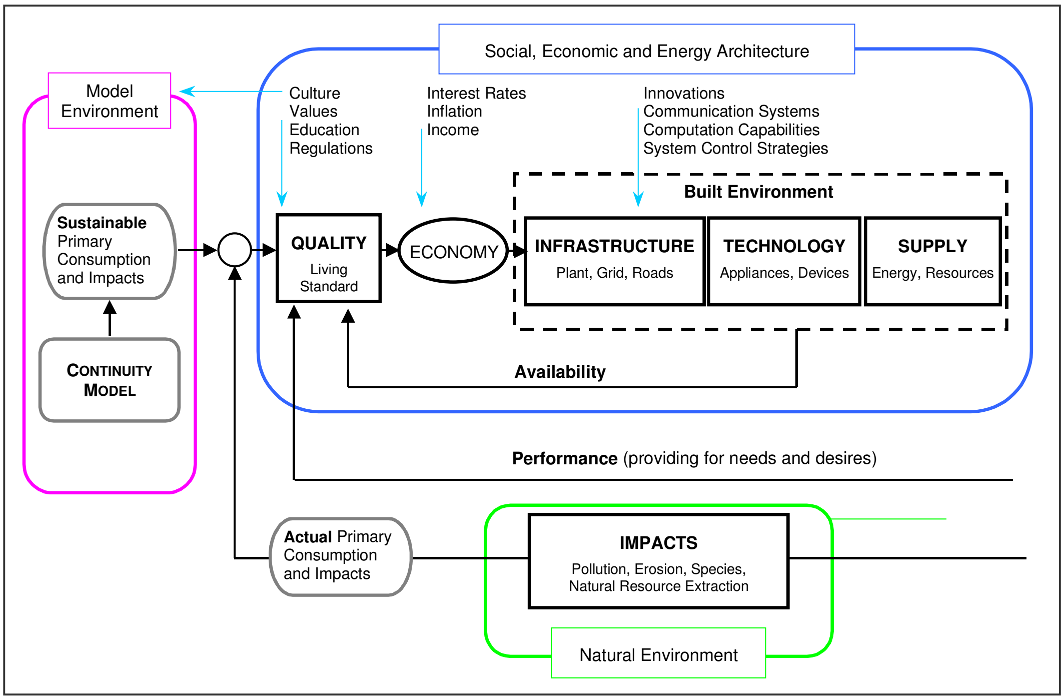

Figure 18: Continuity Energy-Environment-Economic Model (KRUMDIECK (2004), P. 3)

that considers the needs and desires and environmental impacts that could disturb the sustainable state of the system. The "system control is accomplished through cumulative individual decisions made in the cultural, regulatory, and economic context."[74] Decisions can be generalized to maximize utility within the context of what is available, allowable, and affordable. People typically follow social and government rules, and access technology, goods, services and energy through the economy. Summarized, the model "shows the role of continuity model as providing a sustainability reference for the energy system for system design, development, and day-to-day operation." [75]

KRUMDIECK (2004) later described the approach of the Continuity Energy-Environment-Economic Model as "Systems Approach to Posing Problems and Finding Sustainable Solutions.[76] This clarifies that with the THEORY OF BEHAVIOUR OF THE COMPLEX SYSTEM a special regional topic can be understood by using a simplified structure like the one illustrated at figure 19.[77]

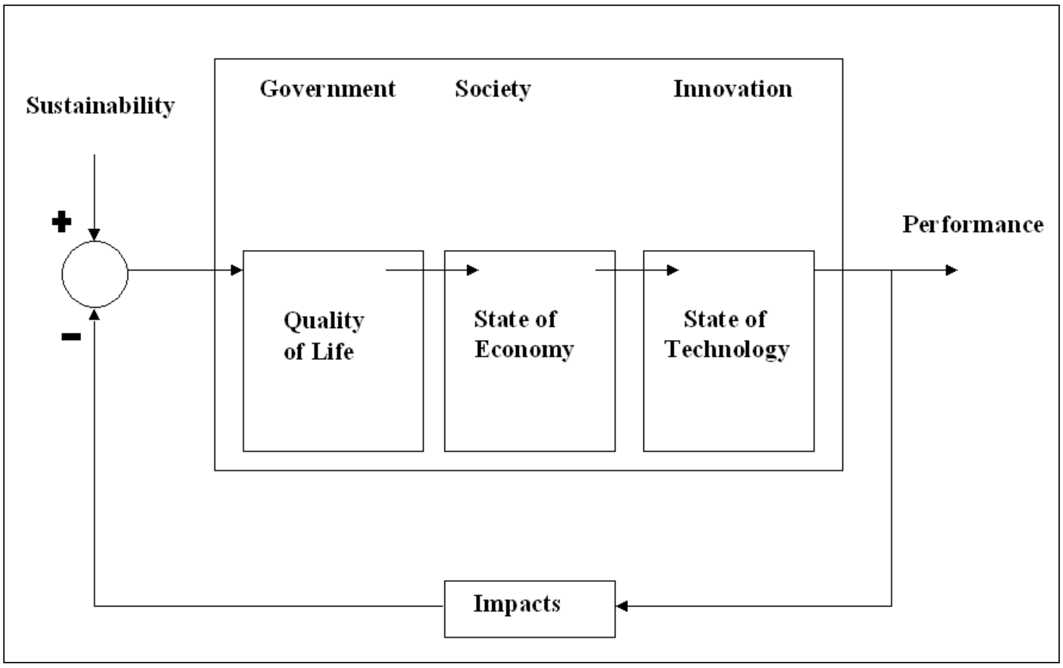

Figure 19: Regional Energy-Environment-Economic Model (see BURTON; KRUMDIECK (1998), P. 8

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[73] See BURTON; KRUMDIECK (1989), p. 5.

[74] KRUMDIECK (2004), p. 3.

[75] BURTON; KRUMDIECK (1998), p. 6.

[76] See KRUMDIECK (2004), p. 1.

[77] See BURTON; KRUMDIECK (1998), p. 8.

By using the model at figure 19, an idealised, sustainable state of a regional energy system can be investigated. The role of the community, that means government and society, and innovations must be challenged and the influence of different factors like the quality of life, the state of economy as well as the state of technology must be analysed. Out of this, the performance objectives can be recognized and negative impacts on the system can be identified. The resulting findings support the understanding of a regional system.[78]

3.2.2 Sustainability Tools

Different tools that are recommended to achieve sustainability are outlined below.

3.2.2.1 Life Cycle Assessment

Assessment of the LIFE CYCLE has become a widely accepted methodology for sustainability analysis. This assesses the environmental impact of a product or service throughout its lifespan. The lifespan refers to the production of the raw material, the manufacturing, the distribution, the use as well as the disposal including all integrated transportation steps. The goal is the identification of the most environmentally friendly product by comparing different products and services according to environmental aspects. The results allow the environmental performance of a company to be optimised by eliminating failures and identifying the best products and services.[79]

3.2.2.2 Ecological Footprint

The ECOLOGICAL FOOTPRINT methodology was developed by MATHIS WACKERNAGEL in the 1990s and is used as a resource management tool for the evaluation of the ecological impact of human activities. It measures how much land and water area a human population is using for producing the required resources and to maintain a given population at a given lifestyle. In addition to that it considers how much land and water the population needs for absorbing its wastes by the prevailing technology.[80] Therefore the measurement of the ecological footprint is based on the population's use of energy, food, water and building material as well as other consumable goods. The methodology can be used to design a concept for

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[78] See BURTON; KRUMDIECK (1998), pp. 5ff.

[79] See ROBÉRT (2002), pp. 258f.

[80] See MEADOWS ET AL (2004), p. 3.

renewing resources and the level at which the resources can be more efficiently used. The WORLD FUND FOR NATURE publishes the ECOLOGICAL FOOTPRINT of some nations twice a year.[81]

3.2.2.3 Triple Bottom Line Accounting

The idea of a TRIPLE BOTTOM LINE refers to ethical business practices and gained attention with the publication of the British edition of CANNIBALS WITH FORKS: THE TRIPLE BOTTOM LINE OF 21ST CENTURY BUSINESS.[82] Advocates of the TRIPLE BOTTOM LINE paradigm encourage managers not to think only in terms of the financial bottom line. They should think of the TRIPLE BOTTOM LINE by adding the social and environmental line to the financial one.[83]

3.2.2.4 Factor Four

V. WEIZSÄCKER ET AL (1998) constitutes an approach to ensure the quality of life. The FACTOR FOUR means that a bisected consumption of natural resources will double human prosperity as resources are saved. Fifty hypothetical examples emphasize today's possibilities as to how the world's resources could be matched more sustainably.[84]

3.2.3 Summary

The previous literature review covered the analysis of sustainability by describing different approaches as well as some tools to reach sustainability. Different views of the definition of sustainability obviously exist, which are concluded at table 2.

Study	Understanding of Sustainability	Proposed Solution
Limits to Growth, MEADOWS ET AL (1972)	State of global equilibrium	eg. Stopping of exponential population growth.

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[81] See MEADOWS ET AL (2004), pp. 291f.

[82] ELKINGTON (1998).

[83] See NORMAN; MACDONALD (2003), p. 2.

[84] See WEIZSÄCKER, V. ET AL (1998), p. xiii.

Brundtland Commission, King (1989)	Meet the needs of the present without compromising the ability of future generations to meet their own needs.	Increase in resource efficiency.
Industrial Ecology, Jelinski et al (1992)	If businesses follow the same strategies as industrial ecology, global sustainability will result.	The industrial system must integrate all surrounding systems.
Natural Step, Robért (2002)	In the sustainable society nature is not subject to systematically increasing concentrations of substances produced by society, degradation by physical means and that the society needs worldwide.	Define the system, identify the outcome and success, develop strategies, transfer them into practice and assess the result.
Collapse, Diamond (2005)	Not to collapse	Five-Point Framework: Take care of environmental damage, climate change, hostile neighbours, friendly trade partners, society's response to environmental problems.
Continuity Model for Energy System Sustainability, Burton; Krumdieck (1998)	Climax phase of anthropogenic continuity.	Sustainability must be translated into a framework of constraints for the consumption and the engineering of our built environment.

Table 2: Approaches and Methods of Sustainability

According to the research results, a common theme in all approaches is the fact that human-caused environmental or social problems can be unsustainable. However, the exact boundaries of sustainability are hidden. In the easiest case, special parts of the society system are analysed. If a disadvantage for the human being or the environment occurs, then this factor is called “unsustainable”. Through different solutions for eliminating the “unsustainable” factor the changed system is called sustainable. An example would be the suggestion of stopping the exponential population growth in the book LIMITS TO GROWTH (1972).

Overall it seems that the tools discussed focus on these approaches. They all deal with suggestions to eliminate present “unsustainable” aspects. While the LIFE CYCLE ASSESSMENT recommends a benchmark of environmental performance, the TRIPLE BOTTOM LINE theory points out that social and environmental aspects must also be considered. In contrast to this, FACTOR FOUR underlines that present consumption is too high and has to be halved.

The initial point of all statements was the resource constraints. Overall the common content of all analysed approaches is the fact that sustainability depends on the continuity of human beings´ behaviour and environmental impacts. However it was conspicuous that while all approaches aim foe sustainability, none of the approaches gave a detailed explanation of how sustainability works It is now apparent, that sustainability can be understood as provident, resource-matching and environmentally conscious action within resource constraints.

3.3 Analysis of Economic Approaches

Economic approaches to sustainability of resources are analysed in the following chapter.

3.3.1 Theoretical Economic Approaches

3.3.1.1 Economia

By taking a broader view and enquiries to deeper levels of society, DAVIS (2004) analysed the problem of sustainability by showing reasons why economic systems do not serve the real needs of society. His criticism was that economic systems are unstable, resource-inefficient and do not integrate scientific research from other disciplines. In particular, he saw the neoclassical theory of markets as an inadequate way to sustainability as it simplifies a system.[85] To reaching sustainability, he suggested that the design of economic systems needs to be perennial in the same sense as the living systems of the Earth.[86]

3.3.1.2 Economics and the Environment

Dealing with the four questions, "How much pollution is too much? Is Government up to the Job? How can we do better? How can we resolve global issues?", GOODSTEIN (2005) offered an analysis of environmental policy debates and how economists approach environmental issues and present a sustainable development. As a result, price politics seems to be not sustainable. But at the use of energy, the management of the demand side is recommended that includes the promotion of more efficient technologies.[87]

3.3.1.3 Demand for Electricity and Appliances in Swiss Households

The high demand for electricity by Swiss households was studied in the dissertation ELEKTRIZITÄTSNACHFRAGE UND GERÄTENACHFRAGE VON HAUSHALTEN IN DER SCHWEIZ (DEMAND FOR ELECTRICITY AND APPLIANCES IN SWISS HOUSEHOLDS) by BONOMO (1998). The aim of the study was the examination of the price-influences on to the demand for electricity and appliances by Swiss households. The study showed that the price elasticity of (electricity) demand is inelastic. That means that in consequence of rising prices the demand would decrease underproportionally and that only a part of the households would adapt the electricity demand to the prices. The effect of higher electricity prices to the appliances could not exactly be proved. [88]

The research report was supplemented by BONOMO ET AL (1998) in the study NEUE AUFSCHLÜSSE ÜBER DIE ELEKTRIZITÄTSNACHFRAGE DER SCHWEIZERISCHEN HAUSHALTE (NEW EVIDENCE CONCERNING THE DEMAND FOR ELECTRICITY OF SWISS HOUSEHOLDS). As a result of identifying peak demands in Switzerland, that mainly occur during morning and noon in summer, possibilities for reaching a

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[85] See DAVIES (2004), p. 62.

[86] See DAVIES (2004), pp. 433ff.

[87] See GOODSTEIN (2005), p. 416.

[88] See BONOMO (1998), pp. 185ff.

more equal distribution of demand were investigated. It was identified that different time-based price tariffs could support this aim. It seems that increasing prices during peak loads has a similar effect to decreasing prices during a low demand period.[89]

For both studies it seems that permanent equal prices do not have such a strong impact on demand than different time-based prices.

3.3.1.4 Architecture of Power Markets

Using the assumption that the liberalisation of infrastructure industries shows the economic issue about how organization and procedure affect market performance, WILSON (2002) analysed the efficiency and incentives in wholesale power markets. He reflected that there is an increasing role of economics as an engineering discipline for providing guidance on details of a sustainable market design.[90] As a consequence forward planning as well as real-time operations of power supply are recommended.[91]

3.3.1.5 The Power to Choose: Demand Response in Liberalized Electricity Markets

JONES (2003) generally argued that the end-users need to play a greater role in the operation and development of the systems that provide them with energy services. Otherwise the aggregate system will be more redundant and more costly than it need to be. Because of that fact, a better price responsiveness by end-users that can operate either through automation or conscious involvement would be necessary. Additionally, a system for pricing methodologies was recommended that could reflect their real-time status of energy demand in a better way.[92]

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[89] See BONOMO ET AL. (1998), p. 415; p. 429.

[90] See WILSON (2002), pp. 1299f.

[91] See WILSON (2002), pp. 1305f.

[92] See JONES, M. (2003), p. 61,

3.3.2 Implemented Approaches in Practice

3.3.2.1 Orion New Zealand Limited

As the biggest linescompany in Canterbury, ORION researches ways to reduce peak loads so that power black-outs and additional power plants can be avoided. To manage this problem the company uses two strategies. On the one hand ORION introduced price signals, where the company charges the retailers every half hour. The prices are higher during periods of high electricity demand and lower during lower demand periods. This approach should lead the retailers to encourage their households and business customers to reduce electricity consumption when the network is heavily loaded.[93] On the other hand ORION implemented "´ripple control´ to turn off household electric hot water cylinders automatically."[94] In this case, the company is allowed to switch off the hot water cylinder during peak times. The customer has to agree but gets the benefit of lower price rates at the retailer.[95] For their contribution to reducing peak demand in Canterbury and for the resulting savings in natural resources ORION was honoured with the Green Ribbon ´Business Caring for the Environment Award´ in 2001.[96]

3.3.2.2 Meridian New Zealand Limited

MERIDIAN is – apart from its function as a generator - one of the retailers in Canterbury. It is also working on strategies that could lead to reduced electricity consumption by offering different price rates. For corporate customers, there are the so called Option 48 and Option 144.[97] "Option 48 calculates the electricity prices by a day-time rate and a night-time rate, for a business day and non-business day. The rates change each month of the year. Four time periods a month, multiplied by 12 months, equals 48" different price rates.[98] In contrast to this "Option 144 breaks the day into smaller time periods. There are six per business day, and six more per non-business day, each with its own price. The 12 time periods a month,

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[93] See ORION (2005b), p. 7.

[94] ORION (2005b), p. 7.

[95] MERIDIAN ENERGY (2005b), pp. 1ff.

[96] See ORION (2005b), p. 7.

[97] Structure of the price rates are shown at appendix 1.

[98] MERIDIAN ENERGY (w. y. a).

multiplied by 12 months, equals 144" different price rates.[99] For domestic customers there are also about 26 different price rates, which generally differ between Low Users that demand less than 8,000 kWh per year and the Standard Users with a higher amount. Different sub-groups specify these two classifications. Examples are the Night/Day Rate with different tariffs during night and day supply, the Anytime Rate that is for users who prefer a continual supply of electricity and the Economy24 Rate that includes an interruption of the hot water cylinder or storage heater during peak times.[100,101]

3.3.3 Summary

The literature review regarding theoretical economic solutions for sustainability and resource-constrained markets demonstrates the controversial attitudes of the scientist. Options differ, especially about the neoclassic theory of price politics. In contrast to BONOMO (1998) and BONOMO ET AL (1998) who estimated that time-based price rates could influence demand more than constantly fixed prices, DAVIS (2004) described price systems as unstable since they do not meet the real needs of the society. GOODSTEIN (2005) held the opinion that price politics is not sustainable and that instead of this demand side management could lead to efficient energy use. The demand response is analysed by JONES (2003). There it was emphasised that the end-users have to play an important part in the energy services they use. For better price responsiveness, automatic or conscious systems are recommended that reflect the real time status of the customer's power demand. In addition to that, WILSON (2002) pointed out that it is necessary that economists and engineers work together to provide guidance and details of a sustainable market design as a forward scheduling.

In New Zealand price signals have already been implemented to influence customers´ electricity demand. However, for this to be effective it is important that the retailers pass the price rates they get from the linescompany down to their customers. While the linescompany charges the retailers every half hour according to the amount of electricity demand, MERIDIAN, as retailer, has fixed price rates. It only differentiates between night and day tariffs, but offers, for example, cheaper

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[99] MERIDIAN ENERGY (w. y. a).

[100] See MERIDIAN ENERGY (2005a), pp. 1ff.

[101] Structure of the price rates see appendix 2.

tariffs for “Low Users”. According to BONOMO (1998) and BONOMO ET AL (1998) only a few users will be likely to follow this “permanent” price rate. But MERIDIAN supports the regulation of peak loads by offering the customers a cheaper price rate if they allow the linescompany to manage the hot water cylinder or the storage heater by ripple control. While this type of price differentiation makes it possible to regulate peak loads by interrupting the supply, it does not really avoid a peak load. As already mentioned, the peak loads are usually during the mornings and afternoons in the winter after a dry year. None of MERIDIAN’S rates reflect this period. Therefore, consumers do not have a monetary incentive to reduce electricity demand during that time. Above all, the price is not used as a signal to make it obvious to the customers that electricity consumption during a special period should be reduced.

For designing a sustainable economic system it is now obvious that the consumers have to play a greater role in the electricity market. In addition to that they must surely know about the peak times so that they can adapt their consumption. With the integration of real-time signalling or forward planning, the resources could be matched sustainably.

4. RESEARCH OBJECTIVES

With regard to the previous chapters a short overview of the findings is given and the present situation of the electricity market in Canterbury is clarified by the design of the Energy Environment Economic Model. In consequence the research objectives are derived.

4.1 Overview

The literature review pointed out that electricity demand, especially in the network area of the linescompany ORION, is likely to rise in the coming years. The essential drivers for this development are climatic variation, population growth as well as rising commercial and industrial outputs and changes in land use of the rural sector. As Canterbury is resource-constrained, there may be the risk that the increasing demand for electricity cannot be satisfied anymore. The electricity black-outs, which happened during the winter of 2003, underline this assumption. At that time electricity consumption was so high that the power companies could not generate and supply as much electricity as was needed. It is obvious that Canterbury needs approaches and solutions for reducing electricity consumption that reflect its unique hydropower resources. Research should therefore be focused on the winter peak demands as in a dry year the shortage of electricity happens there first and possibly 2010.

According to the literature review, the key to solving this problem seems to be sustainability. However, the research pinpointed that there is no consistent perception of its meaning. Nevertheless a common approach could be identified: Sustainability depends on the continuity of human beings´ behaviour and environmental impacts. Therefore, sustainability can be understood as a provident, resource-matching and environmentally conscious action within the resource constraints of the environment for present and future generations.

The literature review evinced that economic approaches for sustainability and resource-constrained markets differ. Especially the neoclassic theory of price politics was criticized as unstable and not sustainable and therefore it was suggested to change it into a demand side management that could lead to an efficient energy use. In contrast to this the Swiss research recognized that peak loads could be influenced by peak-based prices. For a sustainable market design it was also recommended that economists and engineers work together so that technical solutions like real-time operating can be developed in an economically useful way. In the Canterbury power market the criticised price politics is prevalent. The different opinions and lack of direct approaches for the design of a sustainable economic energy system suggest that further research is necessary.

4.2 Energy-Environment-Economic Model of Canterbury

As already described in chapter 3.2.1.6, BURTON; KRUMDIECK (1998) prove that a regional system can be understood by using a simplified structure of the complex Continuity Energy-Environment-Economic Model.[102] Relating to this, figure 20 was developed for the present situation of Canterbury's resource-constrained electricity market. In that way the problems in satisfying the winter peak demand are considered. Actually, the initial point of the following elaboration is to identify the failures in the present electricity system and to suggest improvements so that a sustainable economic model for Canterbury's electricity market can be designed.

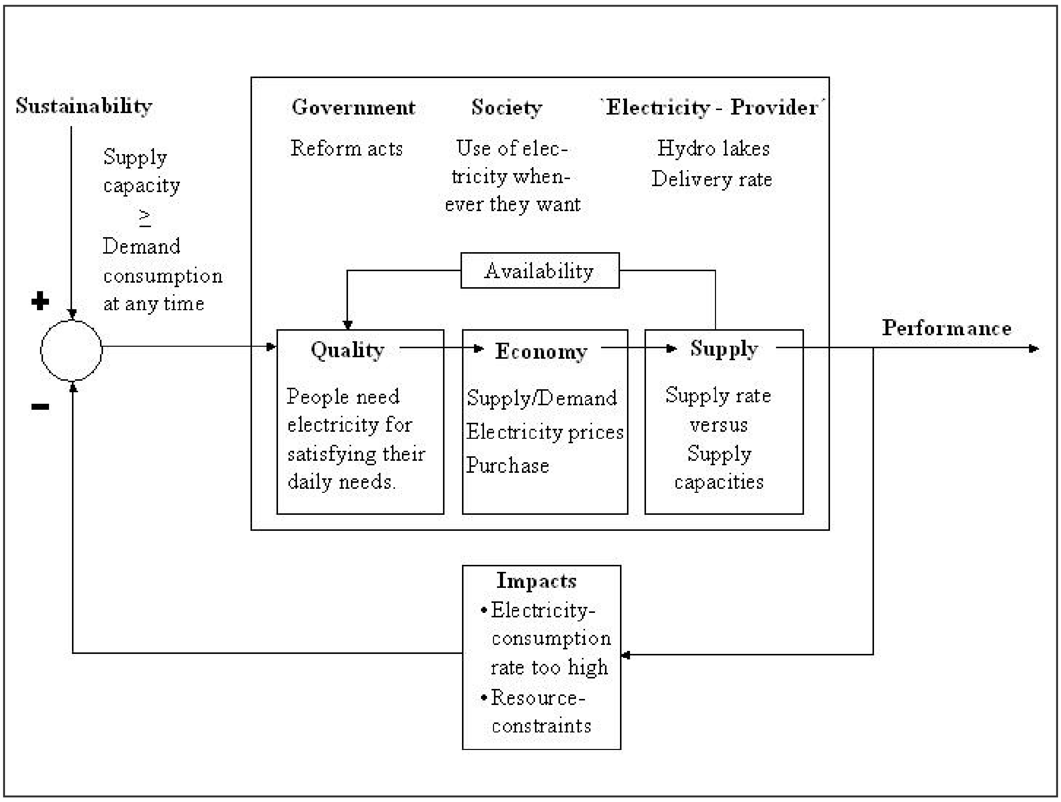

Figure 20: Regional Energy-Environment-Economic Model of the Electricity Market in Canterbury (See BURTON; KRUMDIECK (1998), P. 8)

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[102] BURTON; KRUMDIECK (1998), p. 8.

As figure 20 depicts, the ideal, sustainable state of the electricity system in Canterbury would be the satisfaction of customers´ electricity demand at any time. To achieve this, supply capacities must at least meet demand consumption.

In figure 20 the community comprises the Government, Society and the Electricity Providers. It can be recognized, that the Government enacted different reform acts. But Acts like the ENERGY COMPANY ACT and the ELECTRICITY ACT in 1992, the ELECTRICITY REFORM ACT (1998) and the ENERGY EFFICIENCY and CONSERVATION ACT (2000) do not have impact sustainability.[103] They all relate to the creation of a framework for a competitive electricity market and do not consider the controlling of electricity supply or electricity demand as a consequence of the deregulation in the 1990s. Society currently uses electricity whenever it wants and that the `Electricity Providers´ generate the electricity out of the hydro lakes and deliver it to the customers.

In a sustainable economic system the people's Quality of life must be ensured, by guaranteeing that their daily electricity needs will be met. However, this can only be achieved if the supply is available, which depends on the supply capacities determined by the head of the hydro lakes. In addition to this, the Economy influences supply and demand as it determines the electricity prices that people have to pay to purchase power.

The sustainability of the Canterbury electricity market is negatively impacted by the same conflict between peak electricity demand and finite generation and supply. The aim of a sustainable system therefore requires a change in people's electricity consumption behaviour is necessary as the resources are a given. This exigency can be underlined with the fact that - in contrast to the resources - the population as well as the economy will both increase. If the people use electricity during that winter peaks any longer and in a rising amount the Supply of electricity and consequently if Quality of life is to be guaranteed.

Sustainability requires not so much a reduction of demand but a change in the time of power use. The high drain on resources during peak times could be avoided if demand was distributed more evenly. Surplus electricity during low load periods could be used and a sustainable disposition of the constrained water resources can be achieved.

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[103] See DEPARTMENT OF THE PRIME MINISTER AND CABINET (w. y.).

Consumers have shown they are willing to change their consumption, as was demonstrated in the cold winter of 2003. At that time, lake levels were low and the supply of electricity was insecure in a time of extremely high demand. To avoid power cuts the media requested people to reduce their consumption and society did change its demand until the media gave the all-clear.[104] This example shows that the integration of the people is an important part of a sustainable system. Thus, there must be continuous communication between the consumers and providers so that the consumers know about the problem of shortage and will change their consumption behaviour.

The current system therefore requires more that the soft an unstable control of supply and demand. An efficient and effective sustainable economic model should incorporate an information system, which advises customers as to availability, and have hard and stable controls through technology up-grades, which maintain reliability and security of the system. To reach that goal it is essential that economists and engineers work together and that forward scheduling as well as the integration of the real time status of the power demand can be realised.

By considering these approaches, the research objective of this diploma thesis is to develop a sustainable economic model for the electricity grid in Canterbury that makes dealing in resource constrained markets possible. This model has to be focused on matching the winter peak demand that becomes a problem after a dry year when water resources are insufficient to satisfy the demand. The model must have no disadvantages in terms of the quality of life for people so that they can go about their daily activities. In addition to that it has to be observed that a certain kind of growth in energy supply is not necessary, inevitable, desirable or sustainable.

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[104] See Meeting with DR. SUSAN KRUMDIECK at 07.09.2005.

5. METHODS OF ACHIEVING OBJECTIVES

Given that it would be technologically possible to control the complex and diverse demand to match electricity availability during the winter, this chapter investigates different solutions to create a sustainable economic energy system for the electricity market in Canterbury. The theory of supply and demand is included to clarify the controversial attitudes shown in the literature review. In addition to that technologies that signal the shortage of electricity to the consumers are focused on considering different options if consumers ignore the signal. Above all, the idea of introducing Electricity Supply Chain Management is integrated. The conventional Supply Chain and its Management is analysed and transferred to the electricity market before it is specially adapted in the resource-constrained electricity market of Canterbury.

5.1 Option 1: Supply and Demand

The following chapter deals with the influence of supply and demand on market prices. The basics of the market mechanism will be explained with reference to the electricity market in Canterbury wherever possible.

5.1.1 Assumptions and Definitions

Supply (S) is the quantity (Q) of a good that the producers are willing to sell at a given price (P). This is influenced by the market price of the good and the costs of producing it. In contrast to this, demand (D) can be described as the quantity of a good that consumers want to buy and have the capacity to buy at a given price. The main determinants of the quantity customers are willing to purchase will be the price of the good, the level of income, individual tastes and the price of substitute and complementary goods.[105] When the price equals the quantity supplied and the quantity demanded the market clears, or is in equilibrium (E).[106]

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[105] See BEGG ET AL (1991), pp. 32f, pp. 37ff.

[106] See BEGG ET AL (1991), p. 46.

5.1.2 The Law of Supply and Demand

To explain the law of supply and demand different illustrations will be used for explaining the movements on and the shifts of supply and demand curves. The course of the supply and demand curves are simplified as straight lines and the exact shapes differ for every market.

5.1.2.1 Movements on the Supply and Demand Curves

As can be seen with figure 21, the demand curve shows the relation between the price and the demanded quantity of a good. The movement on this curve indicates that at lower prices a greater quantity of the good will be demanded. Above or below the demand curve the producers are not willing to make goods available. In contrast to this, the supply curve depends on the price and the supplied quantity of a good. By moving on the supply curve it can be recognized, that with an increasing price the producers will generally be willing to produce more. But above or below the supply curve the consumers are not willing to make a purchase. The intersection of the supply and demand curves is called the equilibrium point (E). At this point the market clears, as the supply is equal to the demand. Consequently, the producers supply the amount of Q to the price P while the consumers demand to the price P exactly this quantity Q of goods.[107]

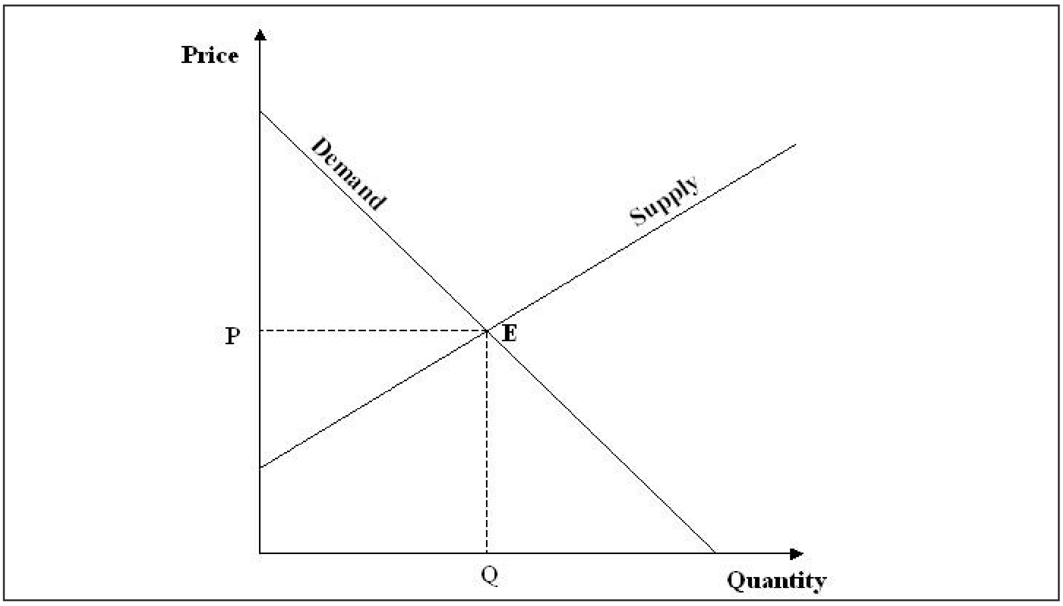

Figure 21: Supply and Demand (see BEGG ET AL (1991), P. 35)

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[107] See BEGG ET AL (1991), pp. 32ff; See HERRMANN (2001), pp. 30ff.

Generally, movements along the demand curve only depend on the amount of a good that is demanded at any special price. Other factors like individual tastes are assumed to be constant (ceteris paribus) and do not influence the customer in changing their behaviour. Movements along the supply curve depend on the quantity of a good that is supplied at any special price. Factors like costs of production are also assumed as constant and do not influence the producers in implementing goods.

Applying to the electricity market in Canterbury, further supply of electricity (assuming others sources like hydropower) is generally not possible within a short term, as new power plants would have to be built. Only in a long term expansion of electricity generation would be possible, but additional sources have to be avoided in this research.

As Canterbury will soon reach the limit in electricity supply from hydropower, the use of the ceteris paribus technique implies that higher electricity prices would lead to a reduced demand. But as electricity demand as well as electricity supply are determined by additional factors like limited resources (water) or individual desires (behaviour in heating during the winter) further theories of supply and demand have to be considered.

5.1.2.2 Shifts in the Demand Curve

In contrast to movement on the demand curves, the curve will shift if factors other than price influence the demand (for example individual behaviours). Assuming a growing population and economy increases the use of electric heaters during the winter, the demand for the good electricity will increase. In this case the individual needs for a warm house influence the demand instead of the price for electricity. Consequently, the demand curve will shift to the right, as a higher quantity of electricity is demanded independently from the price. This example is illustrated in figure 22.

Figure 22 depicts an increase in demand (electricity) from Q_0 to Q_1 by a right shift of the demand curve D_0 to D_1. As it is more important for the consumers to satisfy their requirements not to freeze during the winter, they do not consider the price of electricity and consume the higher quantity Q_1 to the risen price P_1. As a consequence, the equilibrium is changed from E_0 to E_1.

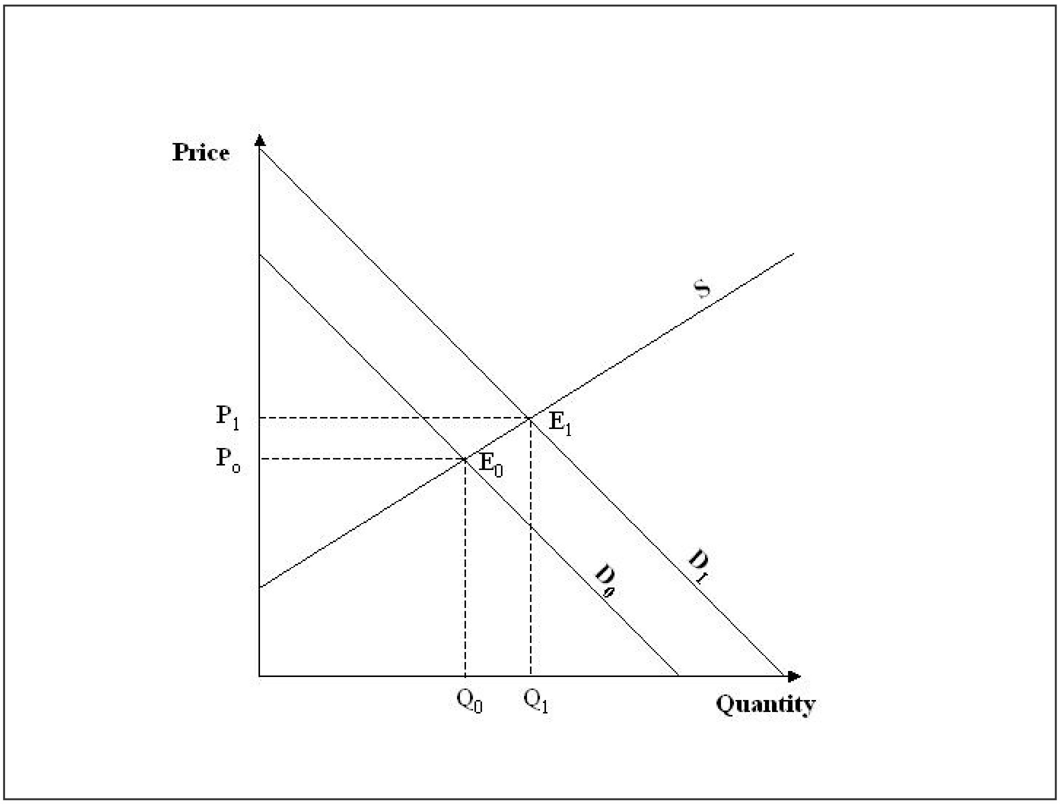

Figure 22: Shift in the Demand Curve (see BEGG ET AL (1991), P. 37)

If demand decreases from Q_1 to Q_0 (for example at summer time when electric heaters are not used) the opposite will happen. A left shift from D_1 to D_0 shows that the price will decrease from P_1 to P_0 and that the point of equilibrium will be reached at E_0.[108]

In the Canterbury electricity market this would mean that a rising demand for electricity would lead to a rising quantity of supply but also to increasing electricity prices. As the electricity market in Canterbury is resource-constrained, supply cannot be exceeded. As a result it is likely that higher prices would not necessarily reduce the demand if the consumers´ desire to use electricity is stronger incentive than the price they have to pay. The risk that it is possible that electricity demand cannot always be satisfied is obvious.

5.1.2.3 Shifts in the Supply Curve

Similar to the demand curve, the supply curve shifts if factors other than the selling price influence the quantity of supply (like limited generation capacities for electricity). In Canterbury, the supply of the good electricity will decrease if the lakes are low. In this case the resource-constraints determine the quantity of the

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[108] See BEGG ET AL (1991), pp. 37f; See HERRMANN (2001), pp. 32ff.

supplied good instead of the selling price. Consequently, the supply curve will shift to the left, as a lower quantity of electricity is supplied independently from the price. This example is illustrated in figure 23.

Figure 23: Shift in the Supply Curve (see BEGG ET AL (1991), P. 40)

As can be seen in figure 23, a sinking quantity of supply will lead to a left-shift of the supply curve from S_0 to S_1. To reach the point of equilibrium E_1, the reduced quantity of the good, electricity, from Q_0 to Q_1 would be sold at the increasing price P_1.

Assuming that the amount of supply will increase from S_1 to S_0, the equilibrium E_0 because of the increased amount from Q_1 to Q_0 would be reached at the lower price P_0.[109]

Applying this to the electricity market in Canterbury, a dry year would lead to reduced capacities in generating electricity and a reduced quantity of electricity supply. By following the explanation given, this would lead to increasing prices when the equilibrium is reached.

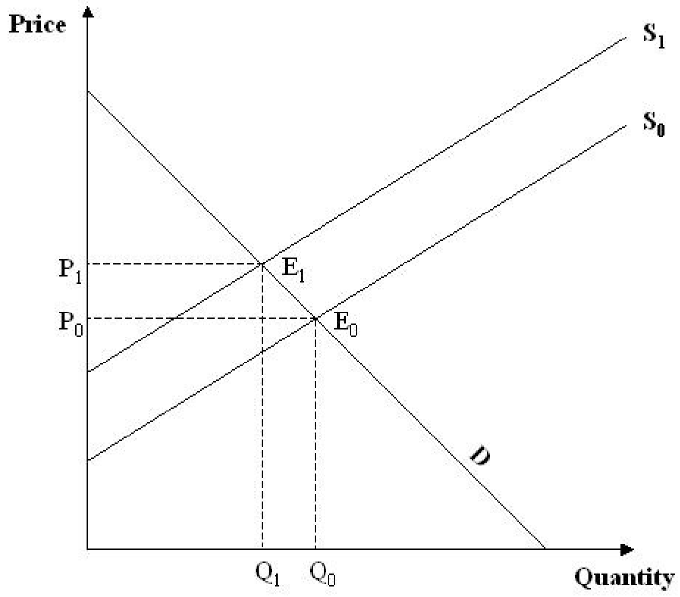

Figure 23: Shift in the Supply Curve (see BEGG ET AL (1991), P. 40)

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[109] See BEGG ET AL (1991), pp. 38ff; See HERRMANN (2001), pp. 31ff.

5.1.2.4 Change in Demand at a Constant Quantity of Supply

A producer may have a constant and fixed quantity that is supplied in the market. For example, a limited amount of electricity can be generated at hydropower plants. It is hoped that exactly as many electricity is sold as is produced. In this case, the price at which the customers are willing to buy cannot influence the supplied quantity of the electricity. The generators will supply all the electricity but cannot raise the supply as a result of growing market prices. An extra supply would mean an extension to the hydropower plants and that cannot be created.[110]

In this case, the supply curve is vertical, which is depicted at figure 24. Figure 24 illustrates a vertical supply curve that is determined through an absolutely fixed quantity of supply that cannot be influenced by the market price.

Assuming that a very cold winter would lead to rising demand, people are willing to pay higher prices for electricity. As the demand is influenced by the desire to use electricity independently of the price, this can be illustrated by a right shift of the demand curve from D_0 to D_1. The equilibrium E_1 of the market will only be reached by a price rise of the electricity from P_0 up to P_1 and not by a change to

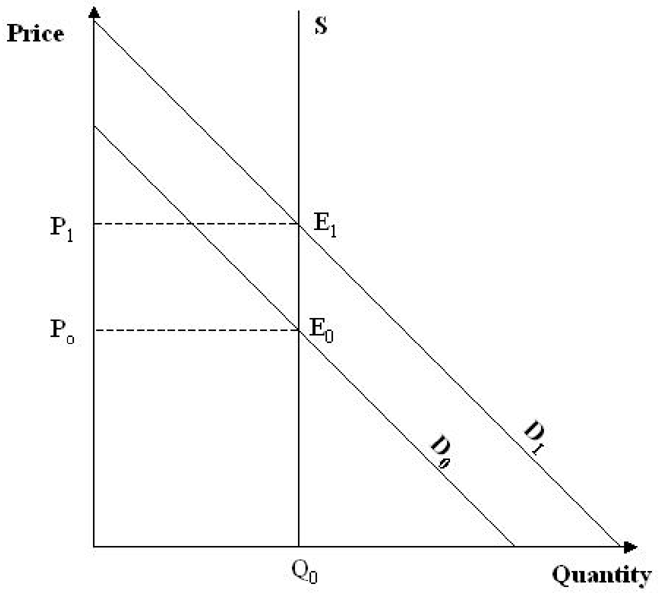

Figure 24: Vertical Supply Curve (see HERRMANN (2001), P. 43)

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[110] See HERRMANN (2001), pp. 43f.

the quantity of supply. While the equilibrium price will therefore be reached at P_1, the equilibrium quantity will stay at Q_0 because it is impossible to change the supplied amount of electricity in a short term.

As the hydropower plants in Canterbury can marginally vary the electricity output, this case is not relevant for pricing policies in that electricity market.

5.1.3 Elasticity

A substantial concept in understanding supply and demand theory is `elasticity´. Elasticity refers to how supply and demand vary in response to different influences like the price. Generally there are different types of elasticity: the price elasticity of demand, the price elasticity of supply, the income and the cross elasticity of demand. Because of the fact, that the price elasticity of demand is more interesting for the electricity market it will in contrast to the other types explained more detailed.

5.1.3.1 The Price Elasticity of Demand

The Price Elasticity of Demand (E_d) shown with equation below "is the percentage change in the quantity of a good demanded divided by the corresponding percentage change in its price."[111] Therefore, it shows how the demanded quantity of a good will change when the price varies.

$$\boxed{E_d = \frac{\text{\% change in quantity demanded of product X}}{\text{\% change in price of product X}}}$$

Equation 1: Calculation of the Price Elasticity of Demand

As illustrated mentioned, a rise in the price of a good is generally expected to lead to a decrease in the demanded quantity, so the price elasticity of demand is negative (as above). It may be possible that the demanded quantity of a good rises as its price rises, even under conventional economic assumptions of consumer rationality. This kind of good is known as a Giffen Good.[112] A Giffen Good can be

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[111] Begg et al (1991), p. 61.

[112] See Begg et al (1991), p. 87.

a staple food like bread. An increase in price of bread can lead to a rising demand in poor households. Because of the fact that poor households have not much money left for other food, they will buy more bread to provide the basic nourishment. At Giffen Goods the demand of the households also considers their income.

It should be noted, that the Price Elasticity of Demand (like every type of elasticity) could vary between the values of $- \infty \leq E_d \leq 0$. If the elasticity is more negative than -1, the demand reacts elastic. That implies that the demanded quantity of a good changes proportionally more than the price. If the Price Elasticity of Demand lies between –1 and 0, demand is inelastic. That means, that the demanded quantity changes proportionally less than the price. If price elasticity is exactly -1, the demand is unit-elastic and a change in price leads to an equal change in demand. Table 3 summarizes the individual values.[113]

- $E_d < -1$: elastic demand; a change in price leads to an over-proportional change in quantity
- $-1 \leq E_d \leq 0$: inelastic demand; change in price leads to an under-proportional change in quantity.
- $E_d = -1$: unit-elastic demand; a change in price of 1% leads to a change in quantity of 1%

Table 3: Values of the Price Elasticity of Demand

The Price Elasticity of Demand can be determined by different influences. For example vital or luxury goods react differently. Vital goods show an inelastic demand, as at rising prices the demand would - because of the necessity of the good - just be reduced to a smaller amount. In contrast to this, luxury goods have an elastic demand, as higher prices would lead to a strong reduction in demand.[114] If it is assumed that electricity is currently a vital good then it can be deduced that with higher prices the demand would only decrease by a small amount.

Overall, there are two different results of the price elasticity of demand that can be distinguished: On the one hand it can be assumed, that a reduction of demand as a consequence of higher prices would be very low in the short-term as the demand

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[113] See BEGG ET AL (1991), p. 63.

[114] See HERRMANN (2001), pp. 48 ff.

is highly influenced by the devices used. The only possibility for customers to reduce demand immediately is to avoid using the gadget at maximum capacity, for example by using only the low settings of an electric heater. The other possibility is to use the devices for a shorter period of time such as reducing heating during the time when people are out of the house. On the other hand in the long term, the price elasticity of demand could be higher, because customers have the opportunity to change their electric devices by more energy efficient ones. As such change usually only occurs when, for example, the old appliances are damaged this effect will only occur in a long term.[115]

5.1.3.2 The Price Elasticity of Supply

In contrast to the price elasticity of demand, the PRICE ELASTICITY OF SUPPLY (E_S) measures the responsiveness of the quantity supplied of a good to its price.[116] It can be calculated by using the equation below:

$$\boxed{E_s = \frac{\text{\% change in quantity supplied of product X}}{\text{\% change in price of product X}}}$$

Equation 2: Calculation of the Price Elasticity of Supply

Just as the price elasticity of demand, the price elasticity of supply could also vary between the values of $- \infty \leq E_S \leq 0$. If the elasticity is more negative than -1, the supply reacts elastically. That implies that the supplied quantity of a good changes proportionally more than the price. If the price elasticity of supply lies between –1 and 0, supply is inelastic. That means that the supplied quantity changes proportionally less than the price. If the price elasticity of supply is exactly -1, the supply reacts unit-elastic and changing prices lead to equally changing supply. By changing the demand to the supply Table 3 could be used to check the individual correlations of price elasticity of supply.[117]

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[115] See BONOMO (1998), p. 35.

[116] See HERRMANN (2001), p. 50.

[117] See BEGG ET AL (1991), p. 60.

5.1.3.3 Other Types of Elasticity

As already mentioned, there are additional types of elasticity, which will be discussed in this chapter.

One factor that can be considered in relation to elasticity is income. The so called income elasticity of demand measures how the demand for a good (such as electricity) would change if income varies. For example, how much the demand for electricity would increase if the average income increased by 10%. This can be calculated by dividing the percentage change in quantity demanded of product X (electricity) to the percentage change in income. If the result were positive, than the demand for electricity would rise.[118]

Another possibility for considering elasticity is the cross elasticity of demand. In this case, the responsiveness of the demanded quantity of a good to a change in the price of another good would be measured. This is often considered in the case of complement and substitute goods. Complement goods are goods that are typically utilized together (cars and fuel) and substitute goods are those, which can be replaced with others (such as diesel and bio diesel). The cross elasticity of demand can be measured by the quotient of the percentage change in quantity demanded of product X and the percentage change in quantity of product Y.[119] For an example with a complement good, if, in response to a 10% increase in the price of fuel, the quantity of new cars demanded decreased by 20%, the cross elasticity of demand would be –20%/10% = –2. Therefore the demand is inelastic, which means that a change in fuel price leads to an under-proportional change in new cars. As electricity cannot completely be substituted this calculation would not make sense for the electricity market.

Regarding the possible values the meaning of the elasticities table 3 can be used by modifications in the terms of demand.

5.1.4 Summary

The previous chapter explained that not only the price of a good but also factors like constrained resources or individual desires can influence supply and demand. Actually, the price as a signal seems to be fundamental to the operation of markets

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[118] See BEGG ET AL (1991), p. 69.

[119] See BEGG ET AL (1991), p. 69.

but with the electricity market it has to be recognized that the price elasticity of demand stated that in the short time a higher and constant price would lead to little reduced demand. It seems likely that power demand will only reduce in the long term, when customers change their electric appliances into more energy-efficient ones.

Relating to the electricity market in New Zealand and Canterbury, some hold the opinion that, "Giving customers price signals and improving their capability to respond to (…) price signals will lead to a more efficient market. Insulation of customers from price signals leads to the potential of short-term rationing and ultimately the potential for even higher prices in the future."[120] This would mean that electricity consumption generally could be influenced by the price. According to this, the literature review pointed out that price rises, that then remain constant would not lead to a permanent reduction in demand, as consumers lose their sensitivity after a short time. In contrast to this, different price rates could lead to a reduced demand if they differ between peak times with higher rates and lower prices at times of a lower demand.

However, different price rates are already implemented in Canterbury's electricity market. As shown in the literature review (see chapter 3.3.2.1), the linescompany ORION charges retailers according to the quantity of demand every half hour. But for this concept to lead to a change in demand, the retailers have to pass on the prices to their customers. The literature review also showed that the retailer MERIDIAN introduced different price rates as well, though MERIDIAN'S price system for households does not signal the peak times to the consumers. The prices only differ between night and day tariffs and between low users and other consumer groups. Therefore the peak times - which happen during the winter mornings as well as afternoons - are not obvious enough to customers. Consequently, the current signals that should inform the customers about peak times are insufficient and have to be improved.

In summary supply and demand according to constant price rates seem to be not capable of leading to sustainability. Looking at the resource-constrained electricity market in Canterbury it is obvious that a cooperative service and availability information system must be part of the electricity market and that price adjust-

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[120] GILBERT; LAUN (2004), p. 5.

ment alone will not work. Only when customers know about the peak times do they have the signal to adapt their demand. Overall, the aim of the signal should be, that the constrained water resources could be matched sustainably. Thereby it would be desirable to reach a more evenly instead of a varying demand as the capacities can be adjusted. What a signalling system could look like and that it does not have to be focused on the price alone will be shown in the following chapter.

5.2 Signalling the Shortage of Electricity

As already mentioned, it is essential in a sustainable system that customers are informed about the critical peak times so that they can align their demand. In addition to that, it is possible for the future that consumers get a real time signal when the electricity supply gets short. This would be important if water resources run out in a dry year and only a limited amount of electricity can be generated and supplied. Assuming that the integration of real time signalling is technologically feasible, this methodology can be developed by various possibilities:

- At present all customers have an electricity meter in their electricity counter that shows the individual use of electricity. The first suggestion to signal a shortage of electricity is that the customers have a second meter that shows the current demand of the entire electricity network area. Assuming that customers know about the maximum amount of supply (as the supply depends on the water resources which the media could report) they could regularly compare the common measured values with the maximum of the present load factor. In this way, the shortage of electricity supply becomes obvious and the customers can change their own consumption by reducing the demand until the common electricity demand goes down. It is also possible that the meter is set so that it makes a signal itself when a fixed value is exceeded.

- The second solution can include the second meter but does not have to. The idea is that retailers inform the customers about the shortage of electricity. That means that the retailer urges the customers to reduce consumption by sending an audible signal through the meters as soon as the peak load is apparent.

- Another approach is that the signal is not only sent out of the meter but in addition to this (or only) when each appliance is plugged in. Thereby the signal could start at every socket when an electric device is going to be put into operation.

With regard to the translation of the signalling methodology into practise, the subchapters will now deal with different options that could follow if the customers ignore the warning signal. These options include the absence of penalties as well as higher prices and power cuts in general, but is not considered in every given idea of the signalling design above.

5.2.1 Option 2: Signalling without Penalties

In the case of a signal without any penalties, the system does not include any consequences if the consumers do not react to the shortage information.

As can be seen with figure 25, individual consumption of electricity is determined by the lifestyle of the people and the signal of shortage. Whether people will change their consumption as a consequence of the peak-load signal or not, no penalties will occur. For example, customers do not have to pay higher prices for the electricity if they do not reduce their consumption to a determined level (that has to be contracted with the consumers) during the peak time.

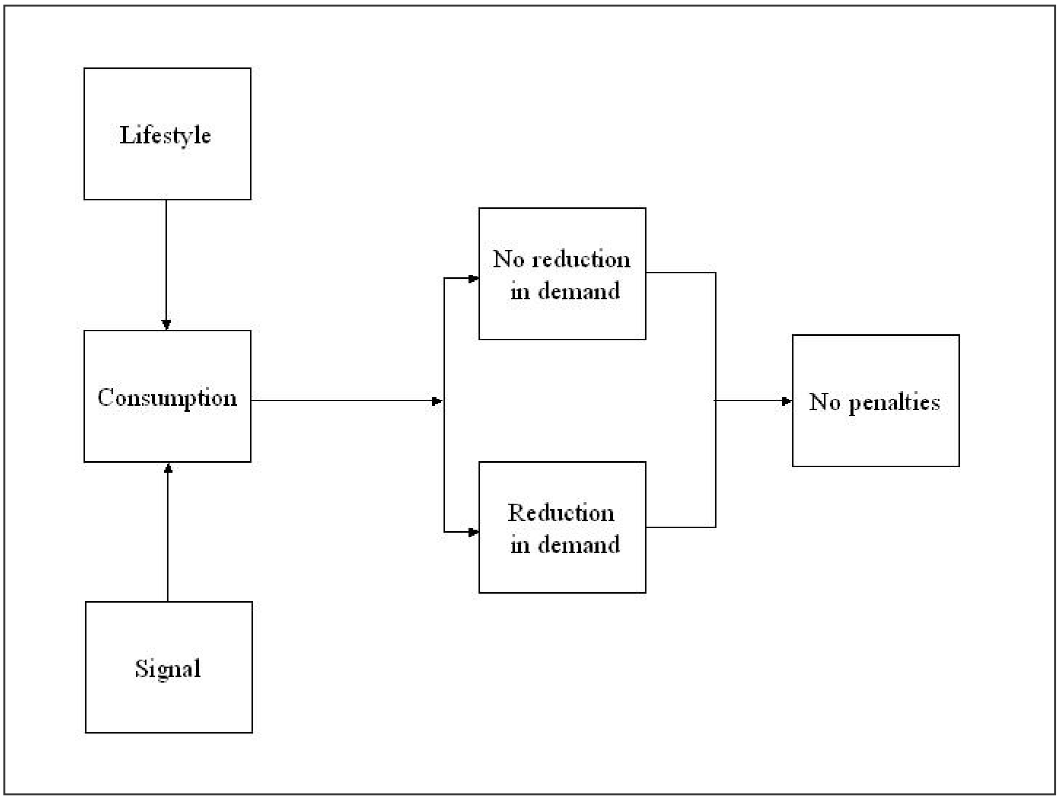

Figure 25: Signalling without Penalties

As a consequence, the system highly depends on the customers´ individual sense to save the resources and to avoid a power cut. Assuming that living in a community should entail mutual respect and sense of responsibility, the consumers are expected to reduce their consumption. How far this approach will meet the reality cannot be forecasted in this thesis but, realistically, the system depends too much on people's personal attitudes.

5.2.2 Option 3: Signalling with Costs

In contrast to Option 2, that avoids any negative factors to the customers, Option 3 includes different price rates for the electricity consumption during peak times.

Like Option 2, this figure 26 shows that electricity usage is influenced by individual lifestyles and the peak-load signal. In this option if people do not reduce their electricity demand to a determined value (that has to be published by the retailers or is individually contracted with every consumer) even though the signal informs them about the shortage, then they have to pay higher prices for electricity during that signalled peak period. If they reduce their demand no penalties will occur. The electricity supply will be provided for as long as possible but because of the

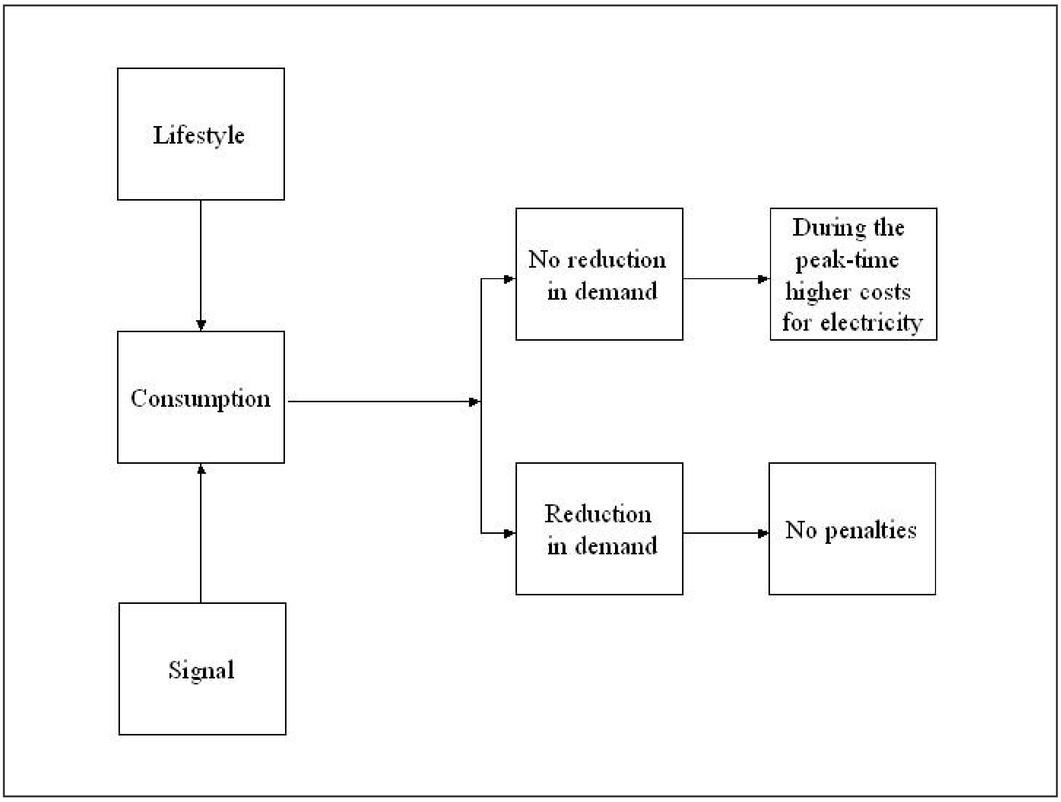

Figure 26: Signalling with Costs

shortage, at apparently higher costs for the customers who do not reduce their demand to the determined limit.

It can be recognized that Option 3 does not rely solely on the customers` good sense, as it integrates a cost penalty. This option depends on the customers´ attitude and how much money they are willing to pay for the electricity. The individual control of every household would be necessary so they can be charged with the different prices according to their consumption behaviour during the peak time. This would also have a strong impact on the present calculation of power bills as the individual reactions of consumers would have to be monitored. However, taking into consideration of the price elasticity of demand it is likely that long-term success will only come when people take the electricity consumption of the electric devices into account at initial purchases.

5.2.3 Option 4: Signalling with Loss of Service

Option 4, Signal with Loss of Service, is characterized by a very strong penalty for customers – a power cut. Figure 27 shows how personal consumption of electricity is determined by the individual lifestyle and the signal of the peak loads. If consumers do not reduce their demand to a determined value after the shortage-

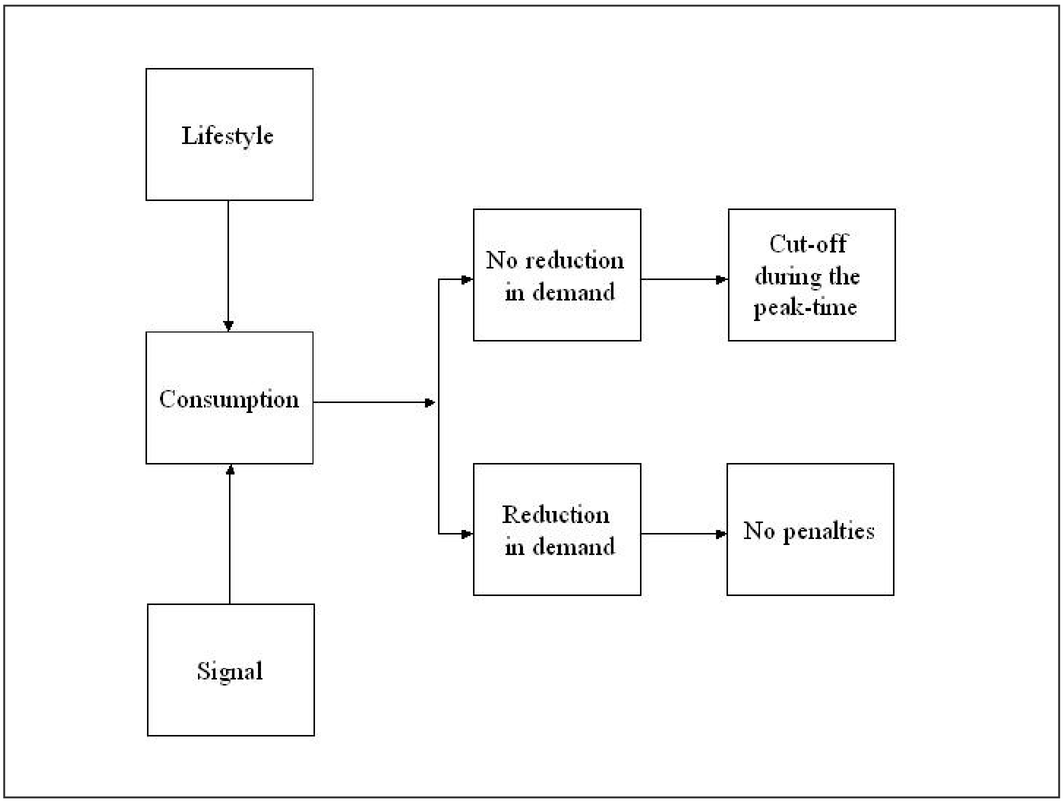

Figure 27: Signalling with Loss of Service

signal sounds, then they will be cut off during the peak-time. If they comply with the signalled request to reduce their electricity consumption to the specified amount, no penalties will occur.

As in Option 3, this approach will also require the individual controlling of every single consumer, so that only those who do not reduce demand have their supply cut. The extent to which this option would lead to reduced electricity consumption within the peak time would require a long-term study, but it is likely that such a heavy penalty will change electricity consumption, as the people will avoid being cut off.

5.2.4 Summary

As shown in this chapter, there are generally different possibilities to influence the demand for electricity during the peak periods. According to the theory of supply and demand a sustainable system cannot based only on prices. The price alone could not steer a market when the resources are not available and all above the price could not steer demand when customers are not directly informed about different price rates and peak load times. Therefore it is necessary for power companies to directly cooperate with the customers by providing load transparency through intelligent information technologies. To influence the customers´ reaction to the peak load signals it is possible to use different price rates or very serious consequences like a power cut in addition to the signalling methodology. The power cut is not recommended as, for example, emergency calls would not be possible, as telephones need electricity to work.

Unfortunately it is impossible to estimate what the different signal methodologies might achieve. Therefore a long-term study should take place to investigate the likely success of each option. In this context the ripple control that is used from the linescompany for matching the peak load periods is relevant (see chapter 3.3.2.1). The ripple control is not an a priori signal for the shortage of electricity, it is a current action that follows from it. Some domestic electricity accounts are configured so that it is possible for the network company to switch the water cylinder or storage heater on and off at set times. This may be done through a ripple relay that is an electrical switch what is remotely controlled by putting a coded signal into the electrical network.[121] However, while the ripple control influences

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[121] See MERIDIAN ENERGY (w. y. b).

the extent of the peak demand it does not make a contribution to reducing peak demand in advance.

5.3 Option 5: Supply Chain Management

This chapter deals with the integration of a forward scheduling system regarding peak load periods in the Canterbury electricity market. In the economic context this concept is generally known as Supply Chain Management. For identifying how this concept could apply to the electricity market, the basics of conventional Supply Chain Management will be explained first. By identifying its objectives, goals, procedures and characteristics, its application within an electricity market can be explored and applied to transforming the Supply Chain Management for the electricity market in Canterbury.

5.3.1 Supply Chain Management

5.3.1.1 Definition

In order to explain the Supply Chain Management the structure of a Supply Chain is first clarifyed:

A Supply Chain emerges from a chain of multi-level customer-vendor-relationships. It can be external kind, as in sales and supply markets, or internal, as in members of the value chain within an enterprise. In its broadest sense the Supply Chain starts at the sources of raw material and ends with the delivery to the end-customers. The individual members of the Supply Chain are connected by logistics service-providers.[122]

The Supply Chain is also defined as “all activities associated with the flow and transformation of goods from raw material stage (extraction) through the end user, as well as the associated information flows.”[123]

Both statements indicate a connection to the logistics that is cross-enterprise (= integrated) management of the entire goods- and information-flow. It can take

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[122] See HAHN (2000), p. 12.

[123] KOTZAB (2000), p. 24.

place within one enterprise or between an enterprise and its vendors or its customers.[124]

Because of the strong relation between a Supply Chain and logistics, the management of the Supply Chain could be compared to the achievements of logistics. This idea is supported by a scientific investigation of KOTZAB (2000) that did not identify any mayor differences between logistics management and the management of a Supply Chain.[125] Therefore the Supply Chain Management can be interpreted as an alternative explanation of integrated logistics management.[126] Above all, it is a strategic, cooperation-based and cross-enterprise (= integration-based) (logistics-) management conception that leads to an improvement of logistical achievements at all stages of the Supply Chain.[127]

5.3.1.2 Objectives, Goals and Processes of Supply Chain Management

To show how an electricity-based Supply Chain works the following chapter introduces the objectives, goals and processes of Supply Chain Management.[128]

The OBJECTIVES of Supply Chain Management include all activities with regard to the material- and information-flow between the manufacturer and the end-user. To achieve GOALS like the synchronization of the material flow with the customers´ desires, the achievement of competition advantages for the value and supply chain as well as the more evenly or reduced resource-consumption, the application of the SCOR-Model (Supply Chain Operation Reference Model) is being recommended.[129] The SUPPLY CHAIN COUNCIL developed and endorsed this model as the cross-industry standard diagnostic tool for managing a Supply Chain. SCOR enables the users to address, improve and communicate Supply Chain Management practices within and between all interested parties.[130] The SCOR-Model is divided into the four consecutive management PROCESSES of Plan, Source, Make and Deliver that are illustrated at figure 28:

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[124] See KOTZAB (2000), p. 23.

[125] See KOTZAB (2000), pp. 33ff.

[126] See KOTZAB (2000), p. 40.

[127] See KOTZAB (2000), P. 27.

[128] See KOTZAB (2000), p. 34.

[129] See BLECKER; KALUZA (2000), p. 134.

[130] See SUPPLY CHAIN COUNCIL (w. y.).

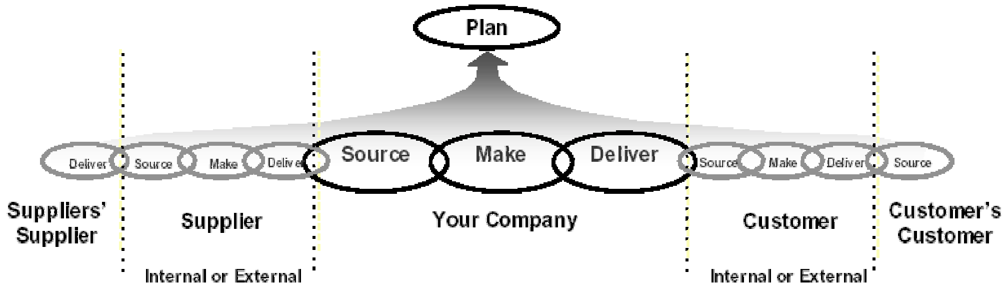

Figure 28: Supply Chain Operations Reference Model (see BOLSTORFF (2001), P. 2)

"The integrated processes of Plan, Source, Make and Deliver, spanning your suppliers' supplier to your customer's customer."[131] The term of PLAN encompasses the scheduling of procurement and production. In addition to that the distribution of orders and the assignment of resources have to be considered between all involved enterprises of the Supply Chain. The SOURCE step integrates acquirement of external goods and services, the MAKE process contains the actual production. Every single enterprise within the Supply Chain must therefore organize its production by considering the resources of the other Supply Chain partners. Above all, the integrated enterprises have to define criteria that lead to an order release. The main tasks of the management process DELIVER are the coverage of demand, the commission of the orders as well as transport, order picking and warehousing.[132]

5.3.1.3 Characteristics of Supply Chain Management

From the objectives, goals and processes described in the previous sub-chapter, the Supply Chain Management can now be characterized through four different principles considering the terms of integration/cooperation, marketing, postponement and information.[133]

The principle of INTEGRATION AND COOPERATION allows a continuous run of the Supply Chain by bringing cross-department and cross-enterprise integration into

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[131] BOLSTORFF (2001), p. 2.

[132] See BLECKER; KALUZA (2000), pp. 134ff.

[133] See KOTZAB (2000), p. 35.

the entire enterprise processes. In the best case the final customer steers and determines the whole Supply Chain. Consequently, the customers´ desires have to be identified in the course of the MARKETING PRINCIPLE. Actually a holistic view of the Supply Chain is necessary so that potentials for optimising it can be recognized and realized. Consideration of the principle of POSTPONEMENT should lead to converse specific customer requirements only towards the end of the Supply Chain. Preliminary processes of the Supply Chain can therefore be accomplished without some restructuring of previous phases. According to the information principle the design of an information system is very important to link all Supply Chain partners. Only when all partners get the information in time is an efficient and effective realization of the Supply Chain Management possible.

The previous elaboration of the Supply Chain Management reveals that the application of Supply Chain Management within electricity markets would need several adjustments. These will be covered in the following chapter.

5.3.2 Supply Chain Management within Electricity Markets

5.3.2.1 Definition

To underline the fact, that the following chapter is focussed on the case of electricity, the name Supply Chain (Management) will be extended to Electricity Supply Chain (Management).

As well as the basic conditions of a conventional Supply Chain described in the previous chapter, the Electricity Supply Chain also consists of a customer-vendor relationship. It starts, at is broadest, at the extraction of energy resources and ends with the electricity consumption at households or industries. The individual members of the Electricity Supply Chain are connected by logistical systems.

The management of the logistical requirements relating to the electricity market is obviously called Electricity Supply Chain Management. It has to be pointed out, that a detailed definition of Electricity Supply Chain Management seems not to exist. Research shows only one linescompany (UnitedNetworks) in New Zealand denotes the electricity distribution system as an Electricity Supply Chain.[134] How-

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[134] See UNITEDNETWORKS (w. y.).

ever, an exact description was not available. The term Electricity Supply Chain Management does not seem to be used.

This highlights the necessity to define the Electricity Supply Chain Management uniformly and exactly. This is the content of the following chapter.

5.3.2.2 Objectives, Goals and Processes of Electricity Supply Chain Management

The objectives, goals and processes of the Electricity Supply Chain Management are similar to those of the illustrated Supply Chain Management at chapter 5.3.1.

The OBJECTIVES of Electricity Supply Chain Management are again all activities related to the material and information flow between the producer and the final customer. In respect of the electricity content, the material flow relates to the energy resources like water, coal or gas that are transformed into electricity and delivered to the households. The information flow should be focussed on the supply and demand of electricity. But with regard to electricity markets, it is remarkable that there is generally a lack of information flow. Consumers are informed about the supply of electricity and reasons for power cuts but in contrast to this, the enterprises of the Electricity Supply Chain are not informed about individual and time-based electricity demands. This leads to the fact that constrained resources are actually used for generating electricity also during times when electricity is not demanded in a congruent amount. This is neither an even disposition of the resources nor resource saving or sustainable.

Different political discussions make it clear that the GOAL of the Electricity Supply Chain is to deal with the constrained resources in a sustainable way. This means to save energy resources and manage their shortage without negative effects on (future) customers. Energy should be available, prices should be affordable and the use of energy should be environmentally friendly. This results in synchronizing the supply and demand and in creating a service and availability market where the consumers know about the availability of electricity. Therefore logistical and process engineering techniques have to be developed that realize the real-time signalling. On the economic side, the following processes of the Electricity Supply Chain Management can provide an opportunity to reach sustainability.

The SCOR-Model is published as the best practice model for managing the management PROCESSES within a Supply Chain, so it is logical to also use it for the Electricity Supply Chain. As already illustrated in chapter 5.3.1.2, the SCOR-Model is based on a cross-industry assumption and contains the entire chain from the (supplier's) supplier to the (customer's) customer. Moreover it contains the four processes of Plan, Source, Make and Deliver.

For synchronizing the customers´ need for electricity with the availability of it, the PLAN step contains the identification of the customers´ consumption behaviour relating to the time of use. To coordinate forward scheduling of the procurement of the resources, the generation of electricity as well as the distribution of the orders and the assignment of resources within the electricity market it would be conceivable to found a "common office" that supports the coverage of this data. All people who want to get electricity would have to register there and have to notify their expected electricity consumption. This procedure could be realized by an electricity audit at which all consumers have to fill out a questionnaire that includes specific electrical devices. For example, by declaring the estimated period and time (per week) for using the appliances, the average electricity demand and possibly the resulting prices for using the electricity would become transparent. The "common office" would sum up and calculate all the customers´ demands and report this to the other Electricity Supply Chain partners so that the electricity can be generated at the adjusted amount. The "common office" could select between different electricity sources. During the windy time of autumn and winter, the electricity could, for example, be generated from windpower plants, while during the spring the hydropower plants seem to be efficient because of the snowmelt. In contrast to this, photovoltaic-systems seem to be a good source during the summertime. The Management of an Electricity Supply Chain should determine the optimal source-mix for generating electricity during specific times. If the "common office" registered all the customers´ electricity requirements it seems to be the most suitable way of selecting and ordering electricity from different sources and enabling economic and environmental point of views to be considered.

In the SOURCE step the Supply Chain integrates the procurement of external goods and services. The partners in the Electricity Supply Chain have to consider the amount of the required resources that are needed to MAKE (generate) the required electricity. In consequence, the make step also includes the alignment of the power plant capacities. The forecast of future electricity consumption makes it possible to generate and DELIVER just as much electricity as is really needed. Thereby the deliver step comprises the procedures of transmission and transport of the electricity to the customers.

Because not everybody can exactly estimate their electricity needs, a safety stock has to be generated. This should guarantee that customers could use the power whenever they really need it and not only during the notified times. This is very important as, for example, emergency calls cannot be predicted but require electricity.

5.3.2.3 Characteristics of Electricity Supply Chain Management

In reference to the described objectives, goals and processes Electricity Supply Chain Management can now be characterized by different principles:

To ensure continuous operation of the Electricity Supply Chain the principle of INTEGRATION AND COOPERATION of all acting partners has to be kept in mind as they all depend on each other. Because of the fact that the Electricity Supply Chain is influenced by the end-users, their consumption behaviour must be identified by the MARKETING principle, by an electricity audit. The results have to be integrated in the organization of the entire Electricity Supply Chain via IT-technologies. That underlines the importance of eliminating the lack of information identified from consumers to the electricity providers and that cross-enterprise procedures have to be considered across the whole Supply Chain. In the context of the POSTPONEMENT principle, it was explained at chapter 5.3.1.3 that specific customer requirements should only be realized towards the end of the Supply Chain (like the integration of special features in a car). This is to avoid the restructuring of preliminary processes. The postponement principle cannot directly be transferred to the Electricity Supply Chain, but it could be applied so that a continuous level of demand should be predicted that the power plant capacities do not have to be changed too often. Consequently the peak loads must be eliminated to a minimum or disposed more evenly as they make an alignment of the power plant capacities necessary. A time-based price policy that is obvious for the customers when they notify their electricity needs is likely to influence demand as well as the implementation of signalling methods that inform about peak times and the shortage of electricity. Although the effect of prices was already doubted, it seems to make sense if used in combination with the report of future demand as well as the signalling methodology. This monetary influence could lead to a decision analysis where the consumers rethink their electricity demand in detail. Combined with the INFORMATION principle it has to be considered that all integrated companies of the Electricity Supply Chain have to know the electricity needs so technological changes at the power plants can be arranged. For that, the integration of information systems is necessary. When all Electricity Supply Chain partners get the information, the constrained resources can be matched in a sustainable way by synchronizing supply and demand. A complete elimination of the peaks will never be reached, but it seems to be possible to reduce them by transferring a part of the demand in times of lower electricity use. As long as the peaks are within the possible load factor of the power companies the availability of electricity can be guaranteed. Therefore the information systems should also include ways to signal customers that a peak occurs respective that their demand is (soon) exceeded.

In summary the process of notifying the estimated consumption to the electricity generators can be represented as a system that consists of several elements. These elements contain the steps of Plan, Source, Make and Deliver and are being controlled by Electricity Supply Chain Management.

Therefore, Electricity Supply Chain Management can be defined as a strategic, cooperation-based and cross-functional management conception. It is based on the electricity- and information-flow and contains the steps of Plan, Source, Make and Deliver. The Electricity Supply Chain Management makes a point of dealing in resource-constrained markets and pursues the goal of sustainable electricity management by matching the constrained resources.

5.3.3 Electricity Supply Chain Management in Canterbury

The Canterbury electricity market is characterised by peak demands during winter mornings and afternoons. For that reason Electricity Supply Chain Management for Canterbury is going to be developed for matching the higher demand that will become a problem in the year 2010 or even earlier if the year is dry. If there is not enough water in the lakes, the supply of electricity is limited and all electricity usage will need to be controlled.

5.3.3.1 Electricity Supply Chain in Canterbury

To clarify the suggestions concerning the establishment of Electricity Supply Chain Management in Canterbury, that process is briefly restated.

The Electricity Supply Chain in Canterbury consists of a customer-vendor relationship that comprises five elements. These are the Generators that produce the electricity out of hydropower, the Transmissions that increase the voltage of the power and transport the electricity from the generators to grid-exit points, the Linescompanies that maintain the power lines and distribute the power from the grid-exit points to the consumers, and the Retailers that charge the consumers as the last members of the Electricity Supply Chain for the use of electricity. The Electricity Supply Chain starts at the Generators and ends with the electricity-consumption by single customers. Logistics service providers like the linescompany ORION connect the individual members of the Supply Chain.

5.3.3.2 Objectives, Goals and Processes of Electricity Supply Chain Management in Canterbury

The following chapter points out the special objectives, goals and processes of Electricity Supply Chain Management in Canterbury.

The OBJECTIVES of this concept comprise all activities related to the electricity- and information- flow between the generators and the customers. For reaching the GOAL of matching the local water constraints during the winters, peak demands have to be replaced by a more linear lapse. Consequently the realisation of Electricity Supply Chain Management in Canterbury can be focused on shifting a part of the demand into periods of a generally lower consumption rate so that resources are saved as the surplus of electricity generated during the low load periods is used. Again, the peaks will never be totally eliminated, but the goal is to reduce the total and to keep electricity demand within the load factors of the power plants. To reach this, individual electricity usage during the times of the extremely high demand has to be identified and a change in consumption behaviour must be effected.

A recommendation as to how this could be realized can be given by investigating the processes of the Electricity Supply Chain Management.

As already mentioned, the processes of the Electricity Supply Chain Management consist of the steps Plan, Source, Make and Deliver. Chapter 5.3.2.2 showed that for planning electricity capacities the identification of the customers´ consumption behaviour regarding to the time of use should take place. This underlines the importance of the information flow from customers to the power companies. As the research within this diploma thesis only focuses on the winter peak times in Canterbury, the identification of total electricity demand suggested at chapter 5.3.2.2 has to be substituted by the exploration of over-proportional electricity demand during the winters. This present information gap could be closed by the integration of an electricity audit. It is recommended that this be done by surveying each customer via questionnaire so that reasons for the disproportionate peak demand can be discovered. As the questionnaire cannot consider every single electric device it should be focused on those that consume the most electricity and those that can be substituted or being used out of the peak times.

To enable the replacement of peak loads with a more linear lapse of demand, the survey should include consulting in the timely use of electricity. It is therefore recommended that the retailers like MERIDIAN organize the electricity audit as they already know about the problems and are already connected with the customers. Above all, the company knows about their different price rates and is able to support the consumers in their decision analysis to reduce their electricity demand. Assuming that the customers are willing to save money, the retailers should offer consumers that agree with the contraction of a limited amount of electricity use during the winter peak times cheaper price rates. This would reduce the high peak demands in winter and the customers get the benefit of saving money. The plan step ends with the calculation of the new peak loads by the retailers and the reporting of it to the partners of the Electricity Supply Chain via IT-tools.

On the basis of the information out of the electricity audit the enterprises of the Electricity Supply Chain are able to control the water resources that are needed for the generating of electricity in the SOURCE step.

So that the electricity can be sustainably generated during the process of MAKE the alignment of the power plant capacities at every Supply Chain partner on the new and lower peak loads also take place. When the electricity is generated the step of DELIVER follows that includes the transmission and the transport of electricity to the grid exit points and to the customers.

To support the fact that the single peak loads should be as small as possible by distributing demand more evenly, the implementation of a controlling system – in addition to the audit – is also suggested. This system could be based on intelligent IT-technologies. The technology should monitor the individual electricity consumption and report the real time and the real amount of use to the consumers as well as to the retailers. These meters can possibly be installed at the customers´ electricity counters and should also be controlled by the retailers. To avoid exceeding the individual contracted winter demands, as well as a power cut caused be unforeseen peak demands, the retailers should use the IT-Tool for communication with customers. They could send an (acoustic) signal to customers that informs them that demand has to be changed. To encourage users to reduce their demand, higher prices for electricity during the peak times are envisioned. A price adjustment makes sense in combination with the recommended Electricity Supply Chain Management for Canterbury. At present, the price policy of the power companies can indeed be gleaned (for example at the internet homepages of the retailers) but sometimes they are too complex to memorise. In this connection MERIDIAN'S 48 and 144 different price rates are an example, although they do not integrate peak-rates. Therefore prices should be determined in an accessible way and be reported within the electricity audit. Overall, the generation of electricity should not be at the same level retailers forecast it on the basis of the electricity audit. It is recommended to produce low safety stock that avoids a power cut if the consumers exceed their demand, for example in extremely cold winters.

5.3.3.3 Characteristics of Electricity Supply Chain Management in the Area of Canterbury

In reference to the described objectives, goals and procedures the Electricity Supply Chain Management of Canterbury can now be characterized like the Electricity Supply Chain Management in chapter 5.3.2.3.

For sustainable Electricity Supply Chain Management in Canterbury the INTEGRATION AND COOPERATION of all Supply Chain partners is a precedent condition. The single enterprises depend on each other and all have to take part in meeting the electricity demand. To forecast the amount of the peak loads, the peak-based usage behaviour of the customers has to be identified within the MARKETING principle. The desired decrease of the present peak loads in favour of a more balanced demand can be summarized with the POSTPONEMENT principle, as the operation of the Electricity Supply Chain is more sustainable when the load factor is more continuously on the basis of lower and forecasted peak demands. The integration of IT-systems, required at the INFORMATION principle, has to ensure the connection of all members of the Electricity Supply Chain and has to support sustainable operation of the Electricity Supply Chain. Only when all members of the Electricity Supply Chain get the necessary information can the constrained water resources in Canterbury be matched in a sustainable way and the electricity supply be guaranteed by eliminating the risk of power cuts. In this context is especially important, that the power companies should permanently stay in contact with consumers by informing them about the used demand and the existence or absence of a peak load. Hence the tools should be used to signal consumers that demand has to be controlled.

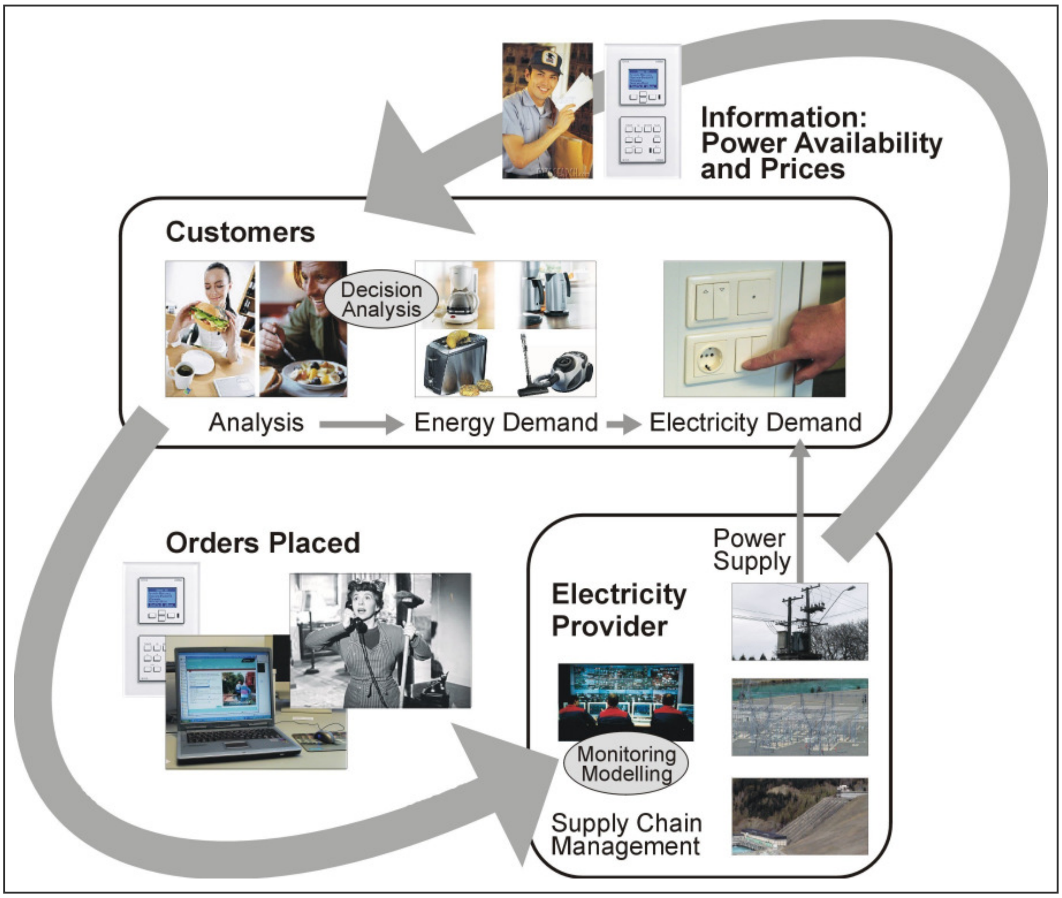

Figure 29: Electricity Supply Chain Management

To make the concept of Electricity Supply Chain Management clear all elements are shown at figure 29.

5.3.4 Summary

It is obvious that the integration of the developed Electricity Supply Chain Management for Canterbury would be a substantial contribution to dealing with that resource-constrained market. By replacing the peak loads with a more linear lapse of the demand, Electricity Supply Chain Management would lead to a sustainable matching of Canterbury's constrained water resources as the electricity-surplus during low load factors are used. Customers have to reconsider their electricity usage by filling out an audit questionnaire to identify reasons for the high winter demand and offering possibilities to reduce it by consulting with the retailers. Overall lower price rates should be offered for those consumers who decide to reduce their electricity demand during the known peak times and contract to use not more than a fixed electricity amount. On the basis of the electricity audit the retailers can calculate the new amount of the peak periods. So that the sustainable operation of the Electricity Supply Chain Management can be realized, the retailers have to pass this information to all Supply Chain partners via IT-tools. The partners can then align their capacities and can guarantee the supply of electricity. To avoid exceeding of the contracted demand, the retailers should use the IT-technologies to inform the users that their electricity consumption has to be controlled, for example when the demand is exceeded or unforeseen.

By analysing the electricity grid in Canterbury it can be identified that the infrastructure to translate Electricity Supply Chain Management into practise already partially exists. Only the recommended electricity audit has to be introduced and the interviewing institution has to be chosen. The IT-tools have to be implemented to guarantee the information flow between all partners of the Electricity Supply Chain and signal the consumers that their demand has to be controlled so that no unforeseen shortage occurs. If the consumers ignore that signal, as their demand will be inconsistent with the one contracted to in the electricity audit, it is recommended that customers pay much more for that additional amount of electricity as they potentially provoke a power cut. In this connection it is also possible that consumers could be contracted to follow the signal in case of any unforeseen peak demand.

6. RESULTS

After a short review of the different designed ideas for reaching a sustainable economic model the utility analysis is used to identify the most suitable solution.

6.1 Review

In the previous chapters different ideas for matching the constrained water resources and guaranteeing sustainable and reliable electricity service in Canterbury were analysed and developed. The supply and demand option showed that an advance in power prices seems likely to lead to a more even demand only in a long term. Although the influence of different time-based prices could not explicitly be demonstrated it is assumed that the price alone would not lead to a sustainable and reliable electricity service. As a consequence, a cooperative service and availability concept was examined by integrating signals that inform consumers about the availability of the electricity service. The consequences of ignoring the warning sign comprise the absence of penalties, higher costs or a total power cut if people ignore the (acoustic) shortage signal and do not reduce their power consumption. In contrast to the signalling methodology that seems to be sustainable if people follow the signal, the design of an Electricity Supply Chain Management was derived from conventional Supply Chain Management. This approach seems to be sustainable if people decide to change their consumption behaviour during the winter peak loads as a result of an electricity audit and the signalling. Unfortunately, it is not possible within this thesis to forecast the success of the individual solutions. But with the accomplishment of a utility analysis in the next chapter a recommendation can be made by evaluating and comparing the different approaches on selected criteria.

6.2 Recommendation on the Basis of the Utility Analysis

Generally the objective of the utility analysis is the recommendation of the most suitable approach to achieve a defined target system. By exposing key aspects for reaching the target, the maximum expected utility of every developed approach can be identified. These key aspects are given a weight factor from 1 (low) to 10 (high) that underlines their importance in achieving the target as well as the preferences of the decision-maker. In addition to that, the key aspects are assessed with values from 1 (low) to 10 (high) according to the individual degree of performance at every single approach. To calculate the utility value, the key aspect is multiplied with the corresponding weight factor. To identify the total utility value of every considered solution, its single utility values are summed up. The approach with the highest total utility value can then be recommended as the best analysed solution.[135]

As the utility analysis is well appropriate for decisions that cannot be measured in monetary terms it is now used for the assessment of the "soft facts" to reach the aspired sustainable economic system for the resource-constrained electricity market in Canterbury.

Table 4 below shows the utility analysis for the target system of a sustainable economic model. The researched approaches of Supply and Demand, Signalling without Penalties, Signalling with Costs and Signalling with Loss of Service as well as Electricity Supply Chain Management are considered. As key aspects the criteria of `Matching the Resources´, guaranteeing `Quality of Life´ as well as the `Time to Success´ appraise the value of utility.

The criteria of `Matching the Resources´ is the aim of a more uniform allocation of the resources for the generation of electricity, where high peak loads have to be avoided, as during that time an over-proportional amount of resources is needed. Because of the fact that the matching of the resources is a very important part of a sustainable system it has a weight factor of 10. In `Quality of Life´, the effect of the possible solutions on consumers is considered. That includes the reliability and availability of electricity as well as changes in electricity prices. As the requirement for the design of the system was avoiding disadvantages to the `Quality of Life´, the weight factor is assessed at 8. The criterion of `Time to Success´ depends on the period until the approaches will show first positive results. In that way a more even allocation of the resources as a result of a more even demand, available resources and a reliable electricity service are considered. Assuming that the `Time to Success´ is not as important as the success itself, it is given the weight factor of 6.

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[135] See WIKIMEDIA FOUNDATION (2005d).

Possible Solutions	**Key Aspects**	**Degree of Performance**	**Weight Factor**	**Value of Utility**
Supply and Demand	Matching the Resources	2	10	(2x10 =) 20
	Quality of Life	2	8	(2x8 =) 16
	Time to Success	1	6	(1x6 =) 6
				Σ 42
Signalling without Penalties	Matching the Resources	3	10	30
	Quality of Life	9	8	72
	Time to Success	3	6	18
				Σ 120
Signalling with Costs	Matching the Resources	4	10	40
	Quality of Life	2	8	16
	Time to Success	4	6	24
				Σ 80
Signalling with Loss of Service	Matching the Resources	10	10	100
	Quality of Life	1	8	9
	Time to Success	9	6	54
				Σ 163
Electricity Supply Chain Management	Matching the Resources	9	10	90
	Quality of Life	9	8	72
	Time to Success	7	6	42
				Σ 204

Table 4: Utility Analysis

With regard to the Supply and Demand approach, table 4 let recognize that the key factor of `Matching the Resources´ is given a performance factor of 2. As electricity is an essential element it can be assumed that neither general nor time-based changes in the prices would lead to an obvious change in the time and amount of power consumption. In contrast to this, this key factor could marginally be rated higher for the ideas of Signalling without Penalties and with Costs as the signal - at the latter combined with a conscious prise rise - makes the shortage of electricity obvious to the consumers. If the customers follow the shortage signal, the resources could be matched as high peak loads are avoided. With the concept of Signalling with Loss of Service the performance factor of `Matching the Resources´ could be assessed at 10. As in this case ignoring the warning signal interrupts the electricity supply, the over-proportional high peak load is definitely avoided. In Electricity Supply Chain Management the performance factor of `Matching the Resources´ could be estimated at 9. As the consumers are consulted and contracted to spread their demand more evenly the aim of `Matching the Resources´ can be reached all the better as more consumers take part in shifting their demand by getting lower price rates.

The performance factor `Quality of Life´ the solutions of Supply and Demand as well as the Signalling with Costs is rated at 2 as rising power prices have a negative impact on the consumer. For the concept of Signalling with Loss of Service the performance factor is very low, at 1. There the negative impact on the consumers caused by a total power cut is obvious. In contrast to this, the performance factor `Quality of Life´ at Signalling without Penalties as well as Electricity Supply Chain Management could be stated at 9. A possible implementation of that approach would not cause many disadvantages for consumers. But one negative result of Signalling without Penalties could be a power cut if people ignore the electricity shortage warning. In case of the Electricity Supply Chain Management the customers only have to distribute their demand more uniformly so that the peak demands can be reduced. For doing that, the consumers get lower price rates. If they do not agree with contracting the maximum demand during the peak time and the consideration of the signal at unforeseen shortages they have to stay at the higher prices they presently pay.

While the `Time to Success´ of Supply and Demand is, because of its doubtful effect, only given a performance factor of 1 the idea of Signalling without Penalties as well as Signalling with Costs could also be rated with a low performance factor of 3 and 4 as the success is too insecure. The approach Signalling with Loss of Service could be valued with 9 as a fast implementation can be expected. Electricity Supply Chain Management could be assessed with 8, as its implementation will take longer as, for example, the electricity audit has to be done with every household.

Table 4 shows that the use of the utility values identifies Electricity Supply Chain Management as the most promising approach. With a total utility value of 204 it can be highly recommended in contrast to Supply and Demand that has only a utility value of 42. As Electricity Supply Chain Management allows a limited amount of electricity demand during the peak times and guarantees lower prices when a part of the peak demand is shifted in times of a general lower demand (like the nights), people's quality of life is secured. Overall the Electricity Supply Chain could be assessed as better than other approaches as it offers a high potential in matching the resources supported by personal consulting. In conclusion, Electricity Supply Chain Management seems to be the best way to realize a sustainable economic model in resource-constrained markets.

How the Electricity Supply Chain Management could be implemented in the Canterbury area will be shown in the following chapter.

7. DISCUSSION AND INTERPRETATION

In this chapter the results of the utility analysis are briefly discussed and the significance of Electricity Supply Chain Management in Canterbury is emphasised. A possible way to integrate this approach into practise in Canterbury will be shown. On this basis it is possible to show a sustainable economic model for Canterbury's resource-constrained electricity market.

7.1 Discussion of the Results of the Utility Analysis

The utility analysis at chapter 6.2 showed that the implementation of Electricity Supply Chain Management is the most appropriate solution to make the resource-constrained electricity market in Canterbury sustainable. All the chosen criteria in the utility analysis that support the aim of sustainability are met by Electricity Supply Chain Management very well. As the options of supply and demand as well as most of the signalling approaches had deficits in the aim of matching the constrained resources, keeping the quality of life as well as the time to success, the concept of the Electricity Supply Chain could satisfy these criteria. The significance of Electricity Supply Chain Management in the resource-constrained market of Canterbury is pinpointed again below and the way of realizing it is explained by focusing on the consumer group of private households and the winter afternoon peak.

7.2 Significance of Electricity Supply Chain Management in Canterbury

The hydro power plants in Canterbury have to deal with constrained water resources. To avoid future power cuts Electricity Supply Chain Management has to be implemented in Canterbury at least before 2010. The aim is to trim the winter peaks down in favour of a more balanced distribution of demand by realising the electricity audit and the signalling methodology. As electricity is an instant connection from source to switch that cannot be stored, a continuous volume of electricity is always delivered in the lines.[136] Consequently, with a change in the customer behaviour the constrained water resources can be matched in a sustainable way when the surplus of electricity at low load periods is used.

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[136] See TRANSPOWER (w. y. a).

7.3 Way to Realize Electricity Supply Chain Management in Canterbury

To realise sustainable Electricity Supply Chain Management in Canterbury the customers´ behaviour that causes the peak loads in the winter afternoons must be identified. In addition to this, private households have to be convinced to take part in avoiding a power cut by distributing their demand more evenly (for example by using the dishwasher during the night). These steps were already recommended to fulfil by a questionnaire-based electricity audit with each customer. As consumers can mainly be influenced with monetary benefits, the retailers should carry out the audit. As they charge the consumers for the electricity use they are in the position to consult in aspects of the electricity use and can offer different price rates for reducing electricity demand at peak times and the agreement to attend the signal. Figure 30 shows the resulting tasks of retailers within the Electricity Supply Chain Management.

As can be seen from figure 30, retailers have to carry out the electricity audit of customers. They would consult them regarding possibilities to deliver their demand more evenly and offer better price rates if the private households contract to use a maximum amount of electricity during the winter afternoons or additionally the agreement to follow the signal in cases of unexpected power shortage. After that, the retailers have to estimate the future run of electricity demand and must report it to all Electricity Supply Chain partners. On the basis of this information, the necessary capacities for the generation and the supply of electricity can be aligned. Overall the retailers have to control customer demand via IT-tools in order to avoid a power cut and have to charge them for their demand. Therefore, for

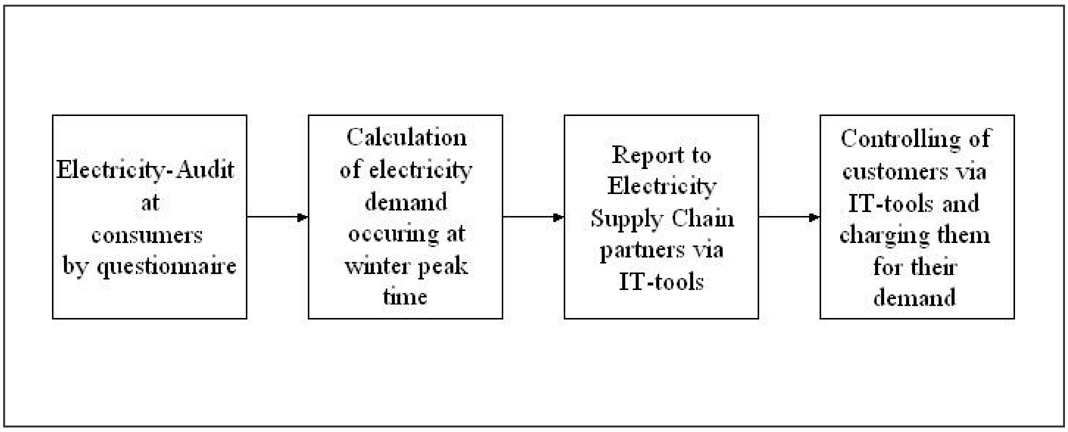

Figure 30: Tasks of Retailers

sustainable running of the Electricity Supply Chain IT-tools have to be implemented that support the communication between all Electricity Supply Chain partners.

So that the electricity audit can be realized a questionnaire has to be developed and IT- as well as controlling tools must be implemented. This is the content of the next sub-chapters.

7.3.1 Electricity Audit of Consumers

The aim of the electricity audit is to investigate the individual electricity demands at the peak times that occur in the winter afternoons. Above all it includes the conviction that consumers should transfer a part of their peak demand to times of lower demand. As the results of the audit are essential for sustainable Electricity Supply Chain Management it is necessary that every customer take part in the survey. So that information about individual electricity behaviour during the winter afternoon peak can be acquired in a short time, it seems useful to carry out the audit via questionnaire. The design of the questionnaire must be meet empirical needs, including the following general requirements. On this basis, a possible opinion poll can be designed.

7.3.1.1 Design of the Questionnaire

The design of a questionnaire generally consists of five different steps:[137]

(1) Containment of the subject area and clarification of the inquiry subject.

(2) Formulation of the questions and possible responses.

(3) Structuring of the questionnaire.

(4) Examination of the questionnaire.

(5) Preparation of the main investigation.

These steps are used for the design of the electricity audit questionnaire.

(1) At the beginning, the degree of standardisation of the questionnaire has to be fixed as well as the form of the interview. After analysing the topic of the audit,

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[137] See WELLENREUTHER (1982), p. 179.

the content of the questions is specified.[138] As already mentioned, the aim of the electricity audit is the identification of reasons for the high winter afternoon demand at each household. As these questions are the same for every household the opinion poll is completely standardised and equal for every respondent. To emphasise the importance of the audit and to reach every household it is recommended to complete the questionnaire with a personal interview. To influence consumers to deliver their electricity usage more uniformly, the audit should allow the calculation of the individual present and peak-based electric rate scales. Therefore the subject area of the audit is confined to electricity devices that are the main cause of peak loads during the winter afternoon and high costs for the customers. As it is not possible to cover all electric equipment, the questionnaire has to be focussed on selected devices with an particularly high power consumption (like hot water cylinders), devices that can be substituted (electrical heating by heating with pellets) and all above appliances that are suitable to use in periods of generally lower electricity demand (like using the dishwasher during the night). Customer behaviour can be identified and changes in peak electricity usage can be suggested. Showing the customers their present peak costs and offering them a better price rate when electrical use during peak times is reduced should influence their usage behaviour. Therefore customer representatives of the retailers seem the most appropriate people to do the audit, as they know the price system of their company.

(2) The questions and possible responses must be formulated so that everybody can understand them. This means a simple structure with a clear content. If specific terms are necessary then they should be explained within the questionnaire or in a separate glossary. Cross-references should be avoided, as they could lead to confusion.[139] There are two possible forms of questions, the closed questions and the open questions. In closed questions the respondents have a given number of predetermined answers what makes the completion of the questionnaire easier and faster. But they are more difficult to prepare, as possible answers have to be anticipated in advance. However they are easier to interpret because standardized answers can be analysed statistically. In contrast, open questions expect the respondents to answer in their own words. They can provide a useful set of re-

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[138] See WELLENREUTHER (1982), p. 162.

[139] See FRIELING; SONNTAG (1999), pp. 67f.

sponses and are used if individual opinions are essential for the survey, however, analysis of the different statements is difficult.[140] As the electricity audit should give an overview about the reasons behind peak consumption, open questions are not suitable. Respondents would not be less motivated to take part in the survey as, for example, the enumeration of the exact time of use of selected electric devices during the afternoon peak would take time and may not be particularly accurate. So it seems to make sense, to prepare the questionnaire for the electricity audit with closed questions that provide a certain leeway by choosing a value out of the rating-chart.

(3) The structure of a questionnaire should start with notes on completing it. General questions and those that can be answered easily should follow.[141] The interviewing customer representative should emphasise that the information the customer representative will allow the calculation of the individual electric rate scale and offers possibilities to get a better rate. The general questions should include the name, address and contact details so the individual household can be registered. Subsequent, questions are concerned with concrete subjects. Difficult, critical and sensitive questions should be placed towards the end of the questionnaire. The respondents are by then familiar with the topic and more likely to give comments to critical aspects.[142] For example, a question about how often the washing machine is used between 5 pm and 7 pm should be placed at the end of the questionnaire as some people could misunderstand this as invasive. Like every survey, the electricity audit has to be closed with thanks for participation and advise of a contact address for further inquiries.[143]

(4) Before the survey can be done, a pre-test should be conducted. In this a group of different people fills in the questionnaire and assesses it according to clarity, understanding and the existence of sufficient possible answers. On the basis of the feedback the quality of the questionnaire can be improved.[144] With the electricity audit, the pre-test could take place with selected employees of the generating and transmission companies as well as the linescompanies and retailers. Because of

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[140] See FRIELING; SONNTAG (1999), pp. 67f.

[141] See WELLENREUTHER (1982), p. 174.

[142] See WELLENREUTHER (1982), p. 174.

[143] See WELLENREUTHER (1982), p. 174.

[144] See WELLENREUTHER (1982), p. 176.

their technical knowledge they are particular suited to assess the selected electric devices and the possible answers. In addition to this a small sample number of customers should complete the questionnaire and comment on the clarity and the understanding of the survey as well as problems in answering any questions.

(5) Training of the interviewers is an important part of preparation for a survey by personal interview. In order to achieve a high participation rate, the respondents have to be informed about the reason (and aim) for the investigation. Personal delivery of the questionnaires could also lead to a high response.[145] The customer representatives have to be coached in interviewing and consulting the consumers. This must include learning the price structure of their retailing enterprise and how to calculate the different price rates for each household. They must also know how to suggest changes in electricity use. To ensure households are informed about the reason and goals of the survey, the media should report about the necessity to match the resource constraints in advance. They should point out that this can only be done if everybody supports the electricity audit. Furthermore, this information should be given in a personal letter that can be included in the power bills a few weeks before the personal audit starts. Overall, households have to be informed that they will benefit from the audit from suggestions to get a better price rate for electricity that would save their money.

Before closing this chapter, the attitude of New Zealanders regarding surveys should be stated. The author of this thesis recognises that New Zealanders attitude is market by an appreciation of personal contact and a confiding relationship to each other. Personal interviews, either face to face or by telephone are not uncommon in New Zealand and the locals are very familiar with this procedure. So that the consumers have enough time to look for specific information and to fill in the questionnaire the electricity audit should not be done by telephone but in a personal meeting. This additionally offers the advantage that the customers get detailed information about the purpose of the audit and recognize that they are a very important part of making a sustainable Electricity Supply Chain and its management possible. Overall New Zealanders seem to be more connected to their country than other nations, so that there is only little doubt that they will support a survey with the aim of matching resources. This personal impression of the author

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[145] See WELLENREUTHER (1982), p. 160.

comes also from the fact that in 2003 calls to reduce electricity during a shortage were followed immediately.[146]

7.3.1.2 Content of the Questionnaire

This chapter explains in detail the choice of the integrated questions in the opinion poll. The questionnaire can be seen in the appendix 3.

The questionnaire starts with a short introduction regarding the aim of the electricity audit and notes about completing the survey. The customers are requested to take part on the survey and to fill in the questionnaire together with a customer representative of their retailer. They are informed that their electricity rate scale will be calculated on the basis of their stated electric usage and that the customer representative will consult on changes in electricity usage and that by the integration of the signalling a better (cheaper) price rate can be achieved.

So that the registration of every single household as well as contracting for monitored electricity demand is possible, the first of the two parts of the survey deals with the gathering of general information. There, the respondents have to state their name, address and contact details, such as telephone-number and e-mail address if available.

The “Peak Use Survey” is the second part of the questionnaire. That way the extent of electricity use during the winter afternoon is ascertained by mainly closed questions that can be answered with yes or no and statements about to the number of the electric devices used. As already mentioned, the survey focuses on selected electric appliances that are characterised by extremely high power consumption, possibilities to substitute and/or possible use at periods of generally lower electricity demand. The questions are in seven different groups that are classified regarding to the activity or location of use. The groups comprise Household, Hot Water, Kitchen, Cooking, Electrical Heating, Laundry and Lighting. The associated electrical devices are now pinpointed by including the purpose of the stated questions.

- Within the `Household´ group the customers have to name the number of members living in the household and the size of their living area in square metres. These are the only open questions in the survey as these factors differ at every household and are expected to influence the amount of the electricity demand.

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[146] See Meeting with DR. SUSAN KRUMDIECK at 07.09.2005.

- In the `Hot Water´ group respondents are asked whether they have a hot water cylinder. In most households the electric hot water cylinders run continuously and need, with an average volume of 80 litres, about 537 kWh/year.[147] As the electric hot water cylinder is necessary to heat the water (for having a shower, cleaning etc) its use cannot completely be avoided. But to reduce this very high amount of electricity it is possible to switch the hot water cylinder off at particular times without any disadvantages in having hot water. In some households this concept is already realized by the ripple control, when the linescompanies cut off the hot water cylinder for 15 minutes during peak times. In addition to that, the linescompanies offer to run the hot water cylinder only during the night.[148] As a consequence the households do not need electricity for the hot water cylinder during the daily peak time and get the benefit of a cheaper night rate tariff. If every household used this system, the peak times would rapidity be reduced. To consult and calculate a better price rate for the households it is important to know if they are currently on the night rate tariff.
- In the `Kitchen´ group the use of an automatic dishwasher as well as the number and age of refrigerators is important. An automatic dishwasher needs in daily use about 395 kWh/year.[149] It can be substituted by washing the dishes in the sink and can easily be used out of the afternoon peak. Although continuous running of refrigerators cannot be avoided, its demand on electricity can generally be reduced. As well as the number of refrigerators, the age determines the electricity needs. While newer refrigerators use an average of 283 kWh/year, older ones (as those from 1999) often need more than 330 kWh/year.[150] Potential exists here to reduce the number of refrigerators as well as to substitute the older ones with more energy efficient ones. The latter would only occur when the old refrigerators break down and a new one has to be bought, but it makes sense that consumers be informed that they have to be conscious of energy efficiency ratings when making initial purchases.
- The `Cooking´ group includes questions on using an electric hob, an electric oven and a microwave. Using those electric devices out of that time can gen-

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[147] See COMMONWEALTH AUSTRALIA (2005a).

[148] See MERIDIAN ENERGY (2005a), p. 3.

[149] See ASUE (2005), p. 14.

[150] See COMMONWEALTH OF AUSTRALIA (2005b).

erally reduce the electricity demand during the afternoon peak. But if people have to prepare dinner during the afternoon peak, they could substitute the electric hob (with a consumption of 365 kWh/year) and the electric oven (with an usage of 548 kWh/year) with a microwave that has a lower estimated electricity consumption (about 180kWh/year).[151] It is also possible to cook with gas instead of electricity, in which case the electric oven as well as the electric hob and the microwave could be substituted.

- For \`Electrical Heating´ the daily period of heating as well as the number and type of electric heaters are important factors. As heaters have different qualities in heating it is possible to substitute them with those that better satisfy consumer needs and also need less electricity. For example, the radiant heater, which radiates heat from a red-hot heating element best to people or objects in front of it, is very inefficient in heating the air in a room. For heating a huge room the column heater would be the best.[152] As a consequence the period of heating as well as the number of heaters can be reduced.
- Within the \`Laundry´ group are questions about the use of an electric clothes drier. As the drier needs a very high amount of electricity (1570 kWh/year at a daily use) it could be substituted by drying the laundry in the air.[153] Using a drier during the afternoon peak time can be easily avoided. To demonstrate the potential cost savings, the number of days a week when the drier is used during the peak period has to be identified. The time of use is also important with regards to the washing of laundry, as this could also easily be done during the night.
- In the last group, \`Lighting´, the respondents have to state the type of lighting they use. So the electricity demand can be calculated and changes can be suggested the number and the wattage of the bulbs are further important factors. Fluorescent lamps are more energy efficient than incandescent lamps. Overall the number of bulbs as well as the wattage of the bulbs can be reduced by using more eco bulbs, which lower electricity consumption.

On the basis of the identified composition and reasons for the electricity demand the resulting prices can be determined. Assuming that the households are sensitive

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[151] See MARKET TRANSFORMATION PROGRAMME (2005).

[152] See AUSTRALIAN CONSUMERS´ ASSOCIATION (2004).

[153] See ASUE (2005), p. 12.

to possibilities to save money and willing to change their demand the customer representative can show possibilities to deliver the demand more evenly. Each question has to be discussed and the advantage of changing the time of demand can be underlined by the offer of lower price rates. This kind of price signal can cause a rethinking of consumption behaviour and a reduction of the afternoon peak demand. After the households make sure of their `new´ electricity demand and the times of use, they can contract for the maximal peak demand, the possible agreement to consider the signal whenever necessary and the new price rates. If they exceed their demand during the contracted peak time, they will automatically be charged higher prices.

7.3.2 Implementation of IT- and Controlling-Tools

For sustainable running of the Electricity Supply Chain all partners of the Electricity Supply Chain must get the information about the changed demand and the extent of the identified winter afternoon peaks. Therefore IT-tools have to be implemented that make the connection and information flow between the Electricity Supply Chain partners possible. This is very important as the capacities of the generators, transmission companies as well as the linescompany and the retailers must be aligned on the demand. That means in detail the storage of water in the dams for the generators and for the transmission the adaptation of the high voltage power lines and tall pylons that transport the electricity from the generators to the grid exit points. In addition to that the linescompanies have to check the reliability of the present overhead and underground cables and the retailers have to align their price calculation system with the customer's behaviours. And of course, the customers have to change their demand according to the time of use and avoid electricity consumption during the winter afternoons.

The IT systems should also work as a controlling system. To ensure that the single winter afternoon peaks are be kept within the contracted demand, the implementation of a controlling system should maintain a permanent contact between the retailers and the customers so they can signal the consumers their winter afternoon demand as well as any exceeding of the contracted amount of use. The consumers then know if they have to change their demand.

Information about problems at any Electricity Supply Chain partner, for example low lake levels, damage to the power lines or unexpected peak demands that could interrupt the supply, must be available for all the integrated power companies and consumers. This allows the Electricity Supply Chain partners to align their processes and the consumers get to know what happened and demand can be reduced.

This can be realised by one of the signalling methods explained in chapter 5.2. Generally it is recommended that the retailers send a signal to the consumers, as a “self check” by comparing the entire demand with the load capacity is not reliable enough. However, it is possible that the consumers would ignore it after a time. Consequently, the signal should be obvious for the customers and can range from an acoustic signal up to a newsletter via E-mail. The investigation of the signalling methodology also considered different possibilities that could follow if consumers ignore the requirement to reduce consumption. Where a cost- or cut-off penalty is implemented, the controlling tools must be able to figure out the individual use of electricity. People who exceed their contracted winter afternoon demand as well as those who do not reduce their consumption to the determined value must be cut off or charged with different prices from those who followed the signal.

7.4 Sustainable Economic Model for Canterbury’s Resource-Constrained Electricity Market

In chapter 4.2 an Energy-Environment-Economic Model of the current electricity market in Canterbury was developed. This model showed that a sustainable electricity system has to work through communication between all the electricity-providers and the consumers. The consumers must be informed about the critical peak periods when the supply of electricity becomes a problem. Overall it was deduced, that the peak times should be reduced in favour of a more even demand. That way, the constrained water resources could be matched more efficiently and the quality of life could be maintained as the electricity supply can be guaranteed by using the surplus of electricity during the low load periods. As a consequence, the electricity market would be sustainable.

The development of different possibilities for how the communication between the consumers and the electricity providers could be designed, the utility analysis assessed Electricity Supply Chain Management as the best approach to reach a sustainable electricity system. A recommendation for its integration into the electricity market in Canterbury was described in chapter 7.3 where the electricity audit as well as the integration of information- and controlling-tools was seen as an important part of influencing demand. The resultant design of a sustainable economic model for Canterbury can now be depicted in figure 31.

As can be recognized with figure 31, the sustainability of the electricity system in Canterbury depends on the satisfaction of the electricity needs at any time. This requires that the supply capacities are always higher than the demand consumption.

The whole community, including Government, has a role in making the choice for a sustainable electricity system. The state of sustainability depends on the Society's commitment to it. For the limited resources to be matched, the consumers have to be willing to rethink their consumption behaviour and should deliver their demand more evenly to avoid the consumption during the peak times and use more electricity at night. To support this, the Electricity Providers have to integrate Electricity Supply Chain Management including retailers doing an electricity audit of every customer and use IT-tools to make the information flow between all Electricity Supply Chain partners possible and control consumer demand. The electricity users are consulted regarding to their consumption behav-

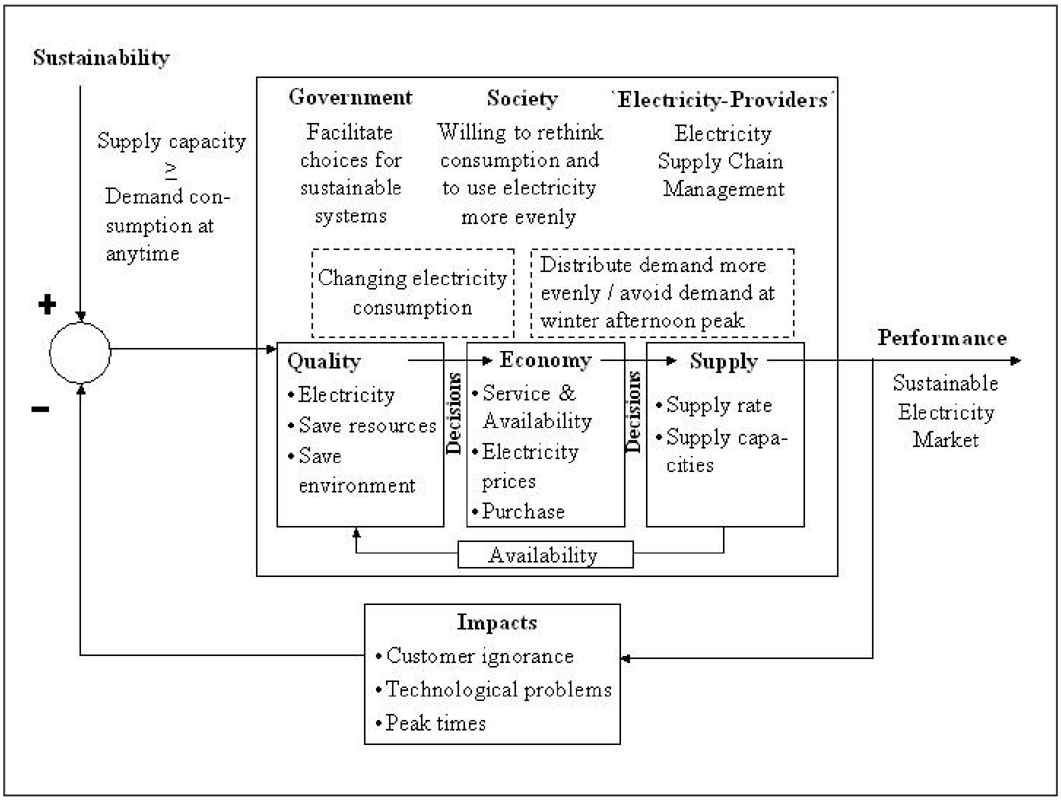


Figure 31: Sustainable Economic Model for the Resource-Constrained Electricity Market in Canterbury (see BURTON; KRUMDIECK (1998), P. 8)

iour and get lower price rates if they decide to change their electricity consumption during winter afternoons and possibly agree to consider a signal in cases of an unexpected shortage of power. Combined with the implementation of information- and controlling-tools the demand is more even and the capacities can be used more efficiently.

Consequently, the Quality of Life in a resource-constrained market can be guaranteed, as the electricity is available at any time. The supply rate and the supply capacities can be adjusted on demand and the resources but also the environment are saved as additional power plants are avoided. With regard to the economy, the consumers get the service of electricity depending on availability and have to purchase it at prices set during the electricity audit.

However, the sustainability of the model can be disturbed if the customers ignore the electricity audit and the shift in demand. To avoid the customers´ ignorance the electricity providers could integrate sanctions like higher electricity prices or the power cut also where the contracted demand is exceeded or the warning signal is not followed. However, the latter is not recommended, as emergency calls would not be possible without electricity. In addition to that, technical problems at the generation or at the supply of electricity can have a negative impact on the system, as the electricity is not available when for example the power lines break down. Regular maintenance of the equipment is the basic for preventing technical problems, but they can never be completely eliminated. It could also happen, that the customers´ electricity demand become focused on similar or the same times producing a peak load at different time. With regard to the problem of possible peak load times, the electricity provider should generally integrate time-based price rates. But there, people must know about the different price rates, which are at present not obvious enough for the households. Real-time signalling technology should be implemented that makes the shortage of the electricity supply obvious to households and orders the reduction of demand.

In summary it is important that a sustainable economic system within the resource-constrained electricity market in Canterbury has to work through cooperation and communication between the consumers and electricity providers. If there is a lack of information or/and if the consumers ignore the resource-constraints no approach will be sustainable. Therefore people’s behaviour must be influenced by introducing Electricity Supply Chain Management including an electricity audit as well as information- and controlling-tools. The electricity audit is necessary, so that the information flow from the customers to the electricity providers – that is a basic in all Supply Chain Management – can be realized and so that the capacities of the Electricity Supply Chain partners can be adapted. The necessary information- and controlling-tools should also be used to avoid power cuts as the electricity providers inform households about the shortage of electricity and call on them to reduce the current demand.

8. FUTURE WORK

The exploration of the electricity market of Canterbury is completed and a sustainable economic model for this resource-constrained area could be designed. But before the recommended Electricity Supply Chain Management can be put into practice, some engineering developments and preparations are necessary.

With regard to the engineering aspects, the design of IT- and controlling tools must take place. The IT-tools should guarantee the connection of all Electricity Supply Chain partners so that their capacities can be aligned on the "new" demand and that the customers can get informed about problems in generating and supplying electricity. The IT-tools should also be suitable for controlling customers´ demand during peak periods. In that case, the technical realisation of real-time signalling methodology regarding peak periods has to be investigated. Electricity consumers have to get a signal that the electricity supply is low and that demand has to be reduced. Different suggestions to design this concept have already been shown at chapter 5.2. A "self check" by the customers comparing the present load factor and the entire electricity consumption within the network area seems too insecure, so engineering research should be focused on the implementation of an (acoustic) signal. Engineers have to work on the development of a meter that shows the entire demand within the network area and makes a signal itself when a determined value (that must also be calculated) is exceeded. In addition to that they have to prepare a meter for every household that can receive the signal from the retailers when electricity becomes short. Another approach requires one of the two signalling meters mentioned before but also an added technology that allows the sockets to make a signal when an electric device is put into operation.

To find the best solution of the signalling approaches, a long-term study should take place that looks at choice of signalling technology as well as the consequences for the customers who ignore the shortage signal. The consequences that have to be considered are the renunciation of penalties or penalties of higher prices. The power cut is not recommended.

The controlling tools have to allow the retailers to record the individual consumptions of the households during the peak time. This is important so that the power cut and equitable charging gets possible. It is also essential in connection with the contracted consumption of the consumers from the electricity audit. The retailers must be able to monitor individual electricity consumption with focus being on the demand during the peak times. Then if the consumers exceed their contracted demand during the peak period, they have to be charged with higher prices. To make the measurement of the peak demand possible, a tool must be developed that transmits the electricity consumption especially during the peak times to the retailers. This could be done so that only when the contracted demand is exceeded the particular household become obvious to the retailers.

For efficient processing of the electricity audit, that should identify and influence a change in the electricity demand by offering cheaper price rates, the interviewers have to be coached. They must be informed about the different price rates for electricity as well as about possibilities for changing electricity consumption. They must be able to calculate and recommend better price rates for different electricity needs of customers. To make the calculation of the price rates easier, software should be developed that calculates the tariffs depending on the individual results of the audit questionnaire. The software should also be able to estimate the future likely demand and to inform all partners of the Electricity Supply Chain about it. It is important that sustainable electricity generation and supply becomes possible, so the capacities can be adapted to demand and any electricity surplus at low load periods can be eliminated.

Apart from the coaching of the interviewers and the long-term studies, it is clear, that the future work for realizing a sustainable electricity market in Canterbury now mainly depends on the engineers. They have to develop the technical realisation of the information- and controlling tools as well as the technical equipment for realizing the signalling methodology. Further research regarding to the realisation of Electricity Supply Chain Management is recommended that includes the consumer group of industry as well as consideration of the morning peak.

9. CONCLUSION

New Zealand's electricity generation is almost entirely based on hydropower. With regard to constrained water resources and presently already occurring power shortages, the electricity service, particularly the Canterbury area in the South Island of New Zealand, was examined. Thus, the major goal of this study was the design of a sustainable economic model for a resource-constrained electricity market in Canterbury, matching the constrained water resources and guaranteeing a sustainable and reliable energy supply.

A thorough review of the present energy market in Canterbury revealed the following situation:

- Canterbury generates all its electricity out of hydropower. Unlike water, electricity cannot readily be stored, so dams regulate the operation of the water resources. There is generally a constant amount of electricity in the power lines, which leads to an electricity surplus at low load periods.
- The electricity grid comprises five elements: The generators producing electricity with hydro power, the transmission agencies transporting power from the hydro plants to grid-exit points, the linescompanies distributing the electricity from the grid exit-points to the consumers and the retailers that sell the electricity to the consumers. While the generators are private as well as state-owned companies, the transmission agencies are completely government owned. In contrast to this, the linescompanies and the retailers are mainly private companies.
- In the Canterbury area, MERIDIAN ENERGY LIMITED mainly operates the generators. The state-owned company TRANSPOWER NEW ZEALAND LIMITED owns the transmission. The linescompany focused on in this thesis is ORION NEW ZEALAND LIMITED and the retailer is MERIDIAN ENERGY LIMITED.

The present and future energy demand can be described as follows:

- The entire demand in the network area of ORION NEW ZEALAND LIMITED is characterised by a rising trend until the year 2015. An average growth rate of about 2% per year is expected.
- The overall maximum demand trends determining the design of power plant capacities in ORION's network area are estimated to increase by approximately

1.2% per year until 2015. Monitoring the time dependent power profiles, peak demands during the winter mornings and afternoons could be identified.

- As population and economy are subject to growth, the power capacities will start to become severely short during the winter peak times in 2010. In case of a dry year when the lakes are low, the shortage of electricity can happen at any time and already occurred in the winter of 2003.

For solving the problems of power shortages during peak times, the following conclusions were drawn:

- For identifying the failures in the electricity market in Canterbury, a model that considers the present conditions was developed. By this means, it could clearly be recognized, that a sustainable economic model needs a change in the electricity consumption, especially as the resources are a constraint.
- Because of the highly transient demand and a surplus production of electricity at low load periods, a reduction of the entire demand is not absolutely necessary. A more even distribution of demand can lead to a sustainable disposition of constrained resources.

The theory of supply and demand, methodologies that signal the shortage of electricity to the consumers and Electricity Supply Chain Management derived from conventional Supply Chain Management were qualified for the economic realisation of a sustainable time distribution of the constrained resources. In a utility analysis of the different approaches, Electricity Supply Chain Management was assessed as the most suitable solution to a sustainable electricity market in Canterbury. Due to that, a way for implementing Electricity Supply Chain Management in Canterbury was elaborated with a special focus on the winter afternoon peaks and the consumer group of households. The following results were obtained:

- For successful implementation of Electricity Supply Chain Management, the integration of an electricity-audit as well as information- and controlling-tools are highly recommended.
- For the electricity audit, a special questionnaire for investigating the consumption behaviour of the households during the winter afternoon peaks was worked out. With this questionnaire, power shortages can be predicted and identified,

and the households can be consulted and contracted to deliver their demand more evenly.

- Information and controlling tools have to guarantee that all partners of the Electricity Supply Chain Management are informed about the predicted demand profiles, so that the capacities can be adapted. Particularly, they should be used to inform the customers about the possible peak loads and allow them to reduce their consumption. Additionally, controlling tools should make it possible for the retailers to externally shift the household's peak demands. Thus, the contracted peak demand of single households can be controlled and excess in that demand can be charged with higher prices or with power cuts, while the latter cannot be recommended.

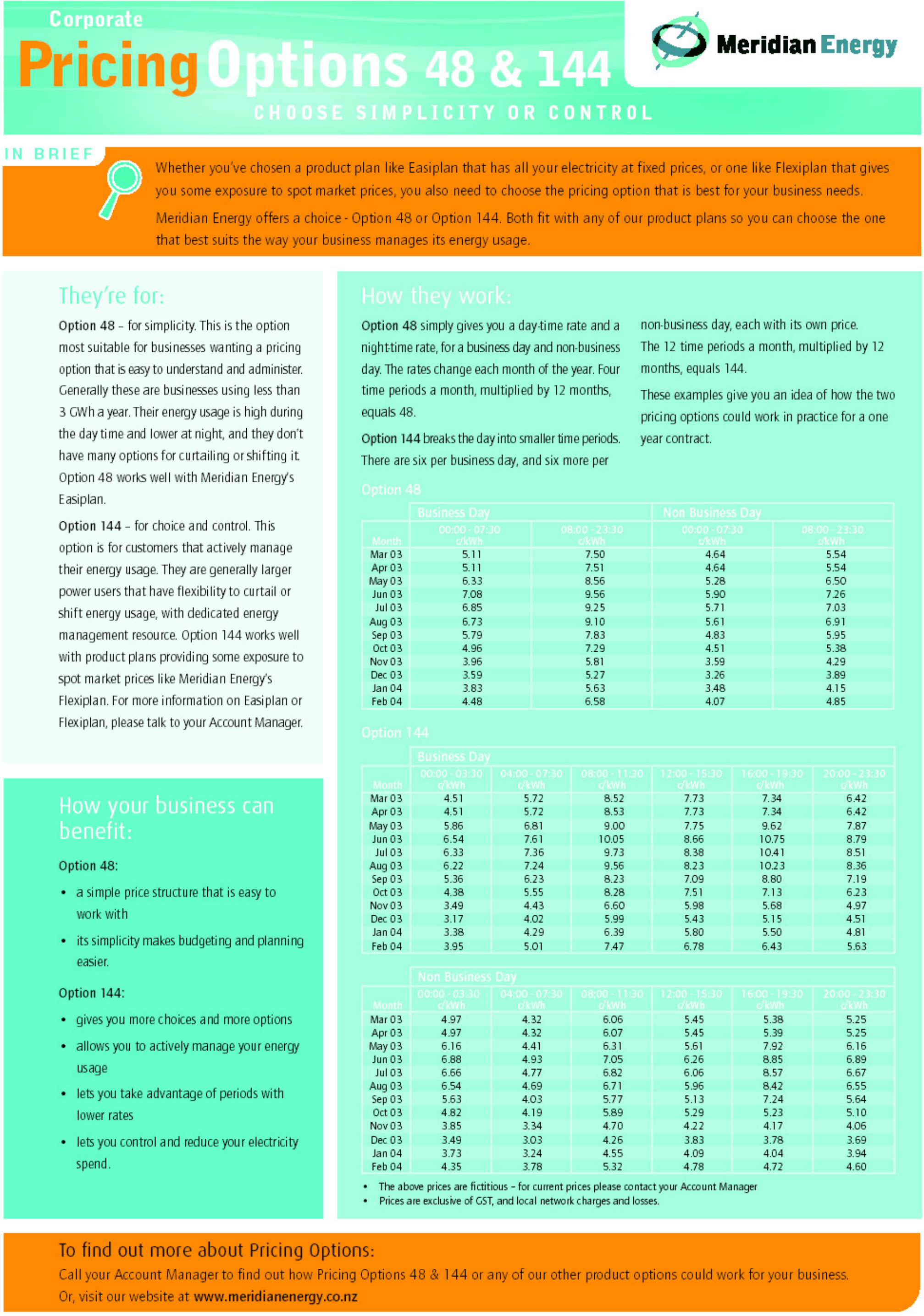
On the basis of these findings, a sustainable economic model for a resource-constrained electricity market in Canterbury could be designed. In the study, the importance of the end-users and of an information flow between all partners of the Electricity Supply Chain were found to be crucial parameters.

The results of the present diploma thesis reveal that with regard to the implementation of Electricity Supply Chain Management in Canterbury some future work has to be done. This will be in particular:

- Engineers have to develop suitable information- and controlling tools as well as technical equipment for realizing the signalling methodology.
- According to the signalling methodology, long-term studies should take place to identify optimal solutions for influencing the consumers´ reaction on peak demands.
- The interviewers for the electricity audit have to be coached in order to guarantee efficient consulting of the consumers. Special coaching programs and tools that support the calculation of the price rates therefore have to be developed.
- With the realisation of Electricity Supply Chain Management, a future development of the Canterbury electricity market towards sustainability can be expected. Adjusting the demand more evenly will save resources by using the present electricity surplus at low load periods. It is recommended to further research of Electricity Supply Chain Management by considering the electricity demand of the industry as well as the morning peaks.

10. APPENDICES

Appendix 1: Price Rates for Corporate Customers at Meridian



Corporate

Pricing Options 48 & 144

CHOOSE SIMPLICITY OR CONTROL

Meridian Energy

IN BRIEF

Whether you've chosen a product plan like Easiplan that has all your electricity at fixed prices, or one like Flexiplan that gives you some exposure to spot market prices, you also need to choose the pricing option that is best for your business needs.

Meridian Energy offers a choice - Option 48 or Option 144. Both fit with any of our product plans so you can choose the one that best suits the way your business manages its energy usage.

They're for:

Option 48 – for simplicity. This is the option most suitable for businesses wanting a pricing option that is easy to understand and administer. Generally these are businesses using less than 3 GWh a year. Their energy usage is high during the day time and lower at night, and they don't have many options for curtailing or shifting it. Option 48 works well with Meridian Energy's Easiplan.

Option 144 – for choice and control. This option is for customers that actively manage their energy usage. They are generally larger power users that have flexibility to curtail or shift energy usage, with dedicated energy management resource. Option 144 works well with product plans providing some exposure to spot market prices like Meridian Energy's Flexiplan. For more information on Easiplan or Flexiplan, please talk to your Account Manager.

How your business can benefit:

Option 48:

- a simple price structure that is easy to work with
- its simplicity makes budgeting and planning easier.

Option 144:

- gives you more choices and more options
- allows you to actively manage your energy usage
- lets you take advantage of periods with lower rates
- lets you control and reduce your electricity spend.

How they work:

Option 48 simply gives you a day-time rate and a night-time rate, for a business day and non-business day. The rates change each month of the year. Four time periods a month, multiplied by 12 months, equals 48.

Option 144 breaks the day into smaller time periods. There are six per business day, and six more per non-business day, each with its own price. The 12 time periods a month, multiplied by 12 months, equals 144.

These examples give you an idea of how the two pricing options could work in practice for a one year contract.

Option 48

	Business Day		Non Business Day	
Month	00:00 - 07:30 c/kWh	08:00 - 23:30 c/kWh	00:00 - 07:30 c/kWh	08:00 - 23:30 c/kWh
Mar 03	5.11	7.50	4.64	5.54
Apr 03	5.11	7.51	4.64	5.54
May 03	6.33	8.56	5.28	6.50
Jun 03	7.08	9.56	5.90	7.26
Jul 03	6.85	9.25	5.71	7.03
Aug 03	6.73	9.10	5.61	6.91
Sep 03	5.79	7.83	4.83	5.95
Oct 03	4.96	7.29	4.51	5.38
Nov 03	3.96	5.81	3.59	4.29
Dec 03	3.59	5.27	3.26	3.89
Jan 04	3.83	5.63	3.48	4.15
Feb 04	4.48	6.58	4.07	4.85

Option 144

	Business Day					
Month	00:00 - 03:30 c/kWh	04:00 - 07:30 c/kWh	08:00 - 11:30 c/kWh	12:00 - 15:30 c/kWh	16:00 - 19:30 c/kWh	20:00 - 23:30 c/kWh
Mar 03	4.51	5.72	8.52	7.73	7.34	6.42
Apr 03	4.51	5.72	8.53	7.73	7.34	6.42
May 03	5.86	6.81	9.00	7.75	9.62	7.87
Jun 03	6.54	7.61	10.05	8.66	10.75	8.79
Jul 03	6.33	7.36	9.73	8.38	10.41	8.51
Aug 03	6.22	7.24	9.56	8.23	10.23	8.36
Sep 03	5.36	6.23	8.23	7.09	8.80	7.19
Oct 03	4.38	5.55	8.28	7.51	7.13	6.23
Nov 03	3.49	4.43	6.60	5.98	5.68	4.97
Dec 03	3.17	4.02	5.99	5.43	5.15	4.51
Jan 04	3.38	4.29	6.39	5.80	5.50	4.81
Feb 04	3.95	5.01	7.47	6.78	6.43	5.63

	Non Business Day					
Month	00:00 - 03:30 c/kWh	04:00 - 07:30 c/kWh	08:00 - 11:30 c/kWh	12:00 - 15:30 c/kWh	16:00 - 19:30 c/kWh	20:00 - 23:30 c/kWh
Mar 03	4.97	4.32	6.06	5.45	5.38	5.25
Apr 03	4.97	4.32	6.07	5.45	5.39	5.25
May 03	6.16	4.41	6.31	5.61	7.92	6.16
Jun 03	6.88	4.93	7.05	6.26	8.85	6.89
Jul 03	6.66	4.77	6.82	6.06	8.57	6.67
Aug 03	6.54	4.69	6.71	5.96	8.42	6.55
Sep 03	5.63	4.03	5.77	5.13	7.24	5.64
Oct 03	4.82	4.19	5.89	5.29	5.23	5.10
Nov 03	3.85	3.34	4.70	4.22	4.17	4.06
Dec 03	3.49	3.03	4.26	3.83	3.78	3.69
Jan 04	3.73	3.24	4.55	4.09	4.04	3.94
Feb 04	4.35	3.78	5.32	4.78	4.72	4.60

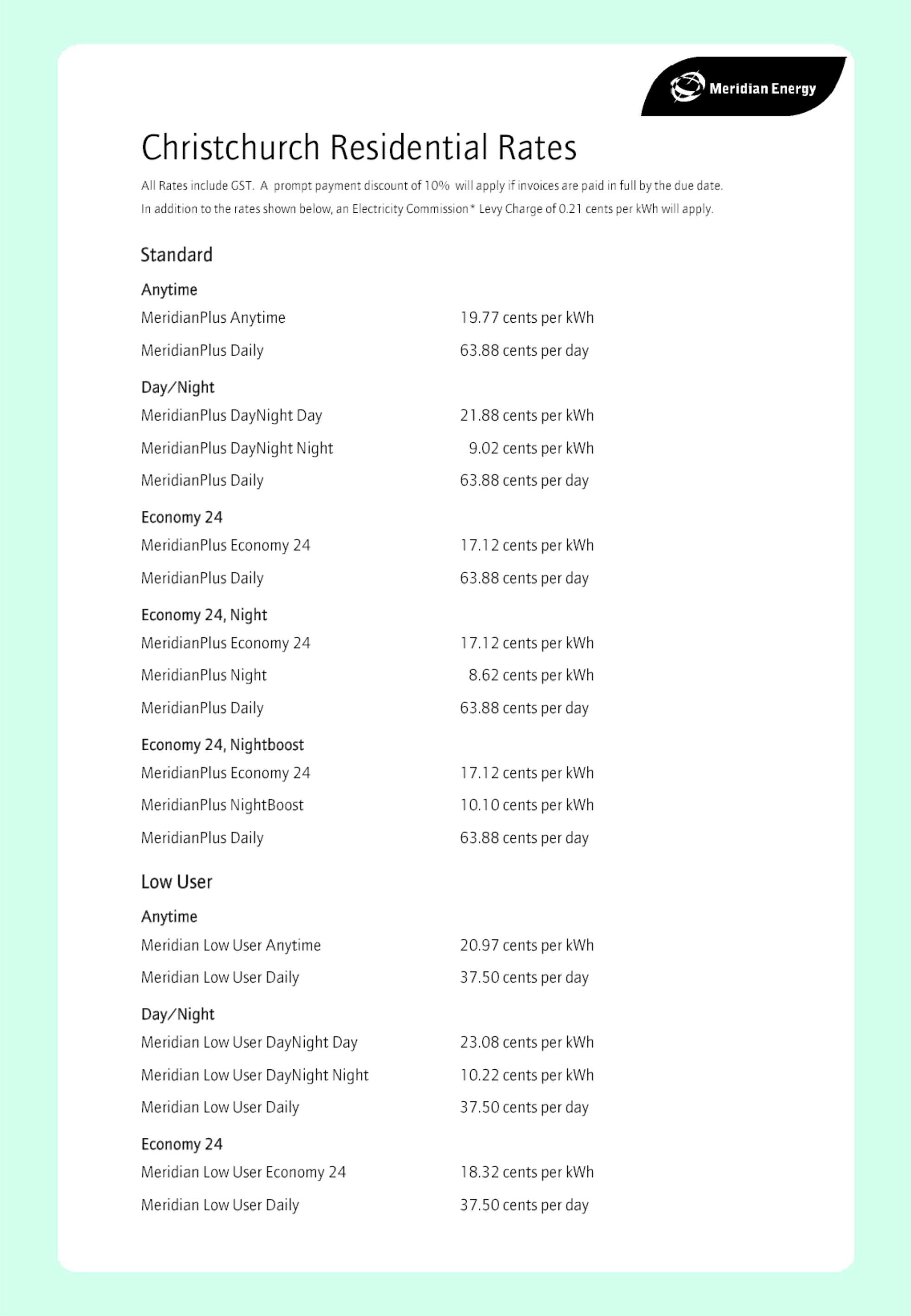
- The above prices are fictitious – for current prices please contact your Account Manager
- Prices are exclusive of GST, and local network charges and losses.

To find out more about Pricing Options:

Call your Account Manager to find out how Pricing Options 48 & 144 or any of our other product options could work for your business.

Or, visit our website at **www.meridianenergy.co.nz**

Appendix 2: Price Rates for Residential Customers at Meridian



Meridian Energy

Christchurch Residential Rates

All Rates include GST. A prompt payment discount of 10% will apply if invoices are paid in full by the due date.

In addition to the rates shown below, an Electricity Commission* Levy Charge of 0.21 cents per kWh will apply.

Standard

Anytime

MeridianPlus Anytime	19.77 cents per kWh
MeridianPlus Daily	63.88 cents per day

Day/Night

MeridianPlus DayNight Day	21.88 cents per kWh
MeridianPlus DayNight Night	9.02 cents per kWh
MeridianPlus Daily	63.88 cents per day

Economy 24

MeridianPlus Economy 24	17.12 cents per kWh
MeridianPlus Daily	63.88 cents per day

Economy 24, Night

MeridianPlus Economy 24	17.12 cents per kWh
MeridianPlus Night	8.62 cents per kWh
MeridianPlus Daily	63.88 cents per day

Economy 24, Nightboost

MeridianPlus Economy 24	17.12 cents per kWh
MeridianPlus NightBoost	10.10 cents per kWh
MeridianPlus Daily	63.88 cents per day

Low User

Anytime

Meridian Low User Anytime	20.97 cents per kWh
Meridian Low User Daily	37.50 cents per day

Day/Night

Meridian Low User DayNight Day	23.08 cents per kWh
Meridian Low User DayNight Night	10.22 cents per kWh
Meridian Low User Daily	37.50 cents per day

Economy 24

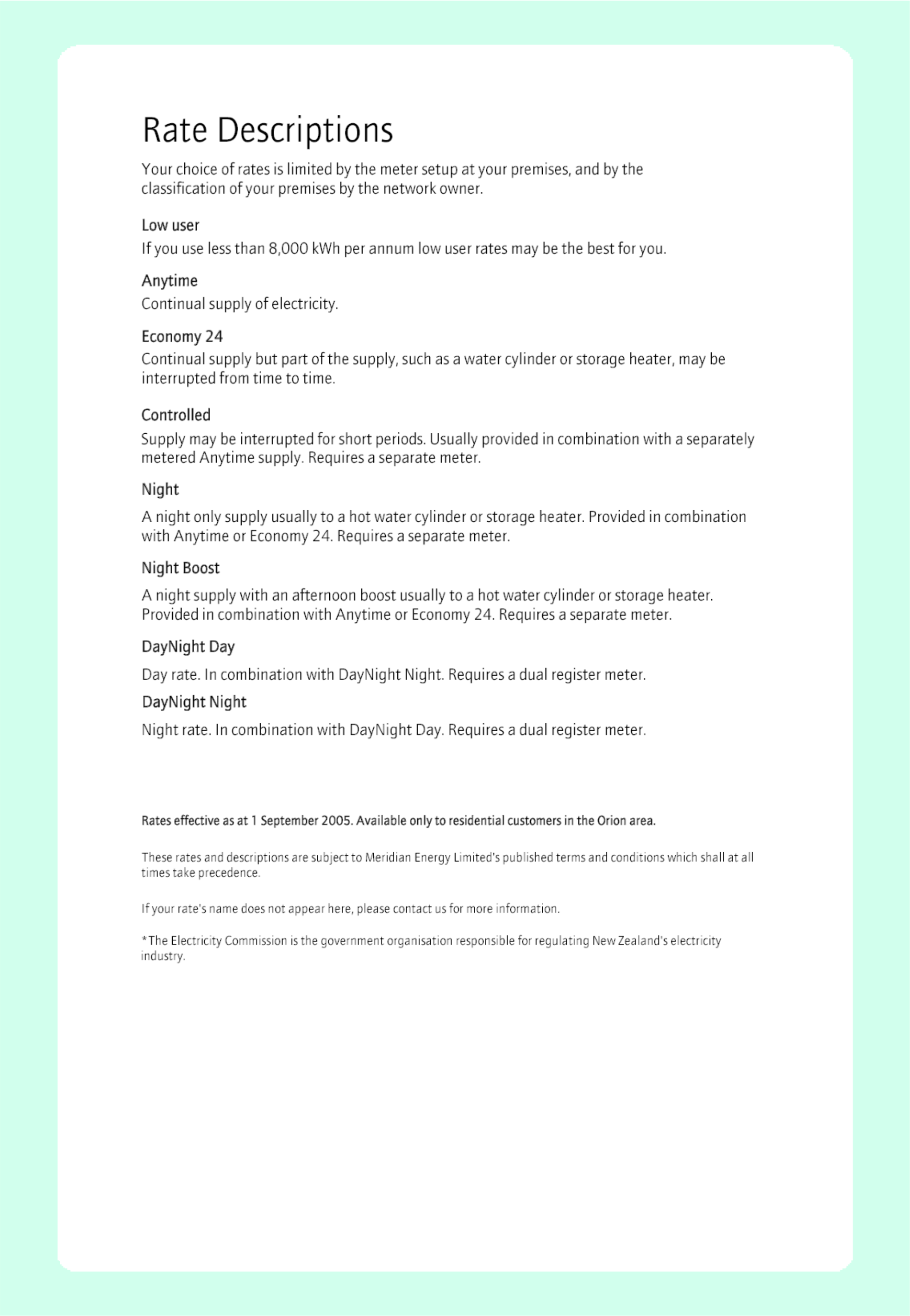
Meridian Low User Economy 24	18.32 cents per kWh
Meridian Low User Daily	37.50 cents per day

Economy 24, Night

Meridian Low User Economy 24	18.32 cents per kWh
Meridian Low User Night	9.82 cents per kWh
Meridian Low User Daily	37.50 cents per day

Economy 24, Nightboost

Meridian Low User Economy 24	18.32 cents per kWh
Meridian Low User NightBoost	11.30 cents per kWh
Meridian Low User Daily	37.50 cents per day



Rate Descriptions

Your choice of rates is limited by the meter setup at your premises, and by the classification of your premises by the network owner.

Low user

If you use less than 8,000 kWh per annum low user rates may be the best for you.

Anytime

Continual supply of electricity.

Economy 24

Continual supply but part of the supply, such as a water cylinder or storage heater, may be interrupted from time to time.

Controlled

Supply may be interrupted for short periods. Usually provided in combination with a separately metered Anytime supply. Requires a separate meter.

Night

A night only supply usually to a hot water cylinder or storage heater. Provided in combination with Anytime or Economy 24. Requires a separate meter.

Night Boost

A night supply with an afternoon boost usually to a hot water cylinder or storage heater. Provided in combination with Anytime or Economy 24. Requires a separate meter.

DayNight Day

Day rate. In combination with DayNight Night. Requires a dual register meter.

DayNight Night

Night rate. In combination with DayNight Day. Requires a dual register meter.

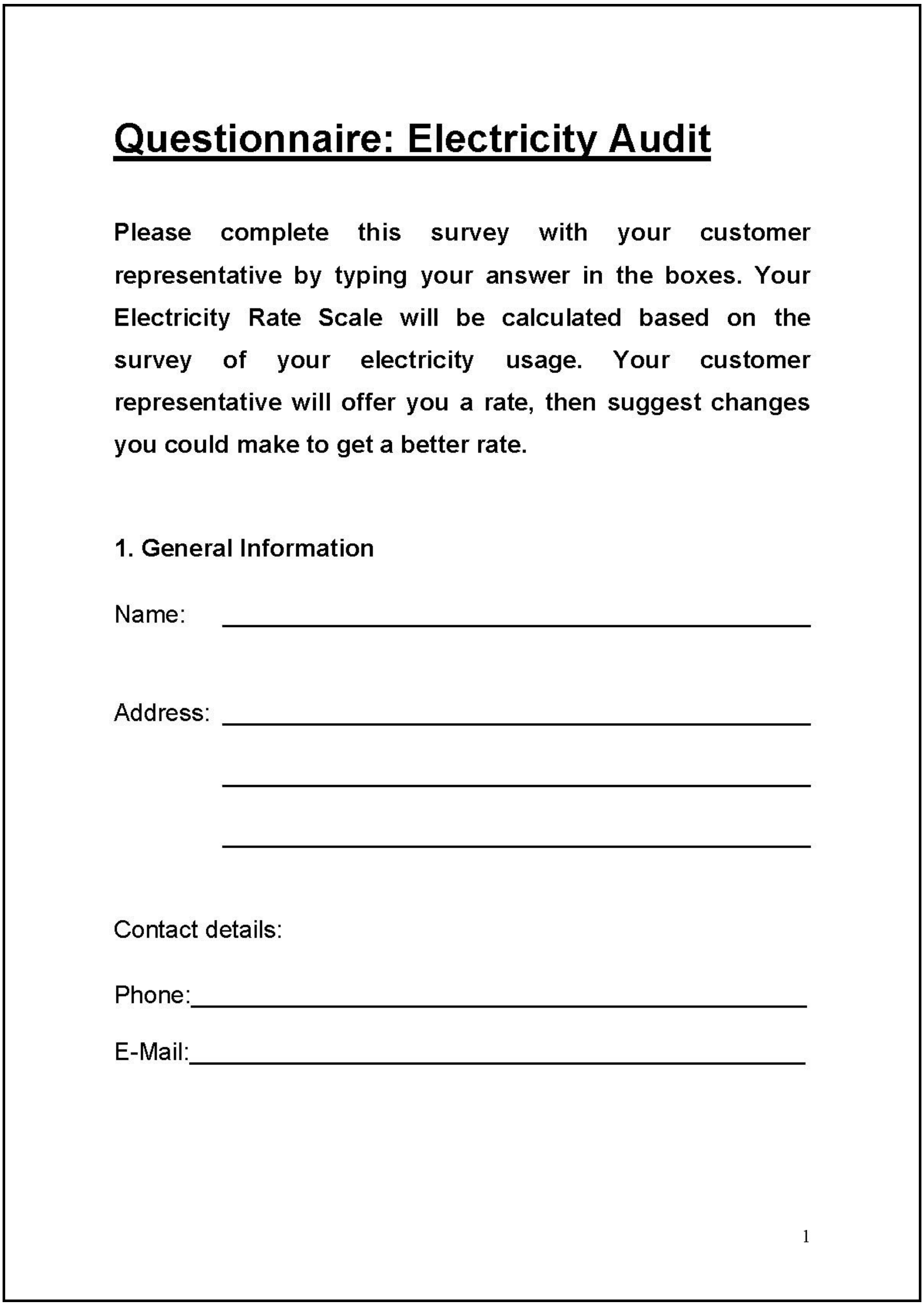
Rates effective as at 1 September 2005. Available only to residential customers in the Orion area.

These rates and descriptions are subject to Meridian Energy Limited's published terms and conditions which shall at all times take precedence.

If your rate's name does not appear here, please contact us for more information.

*The Electricity Commission is the government organisation responsible for regulating New Zealand's electricity industry.

Appendix 3: Questionnaire



Questionnaire: Electricity Audit

Please complete this survey with your customer representative by typing your answer in the boxes. Your Electricity Rate Scale will be calculated based on the survey of your electricity usage. Your customer representative will offer you a rate, then suggest changes you could make to get a better rate.

1. General Information

Name: ______________________________

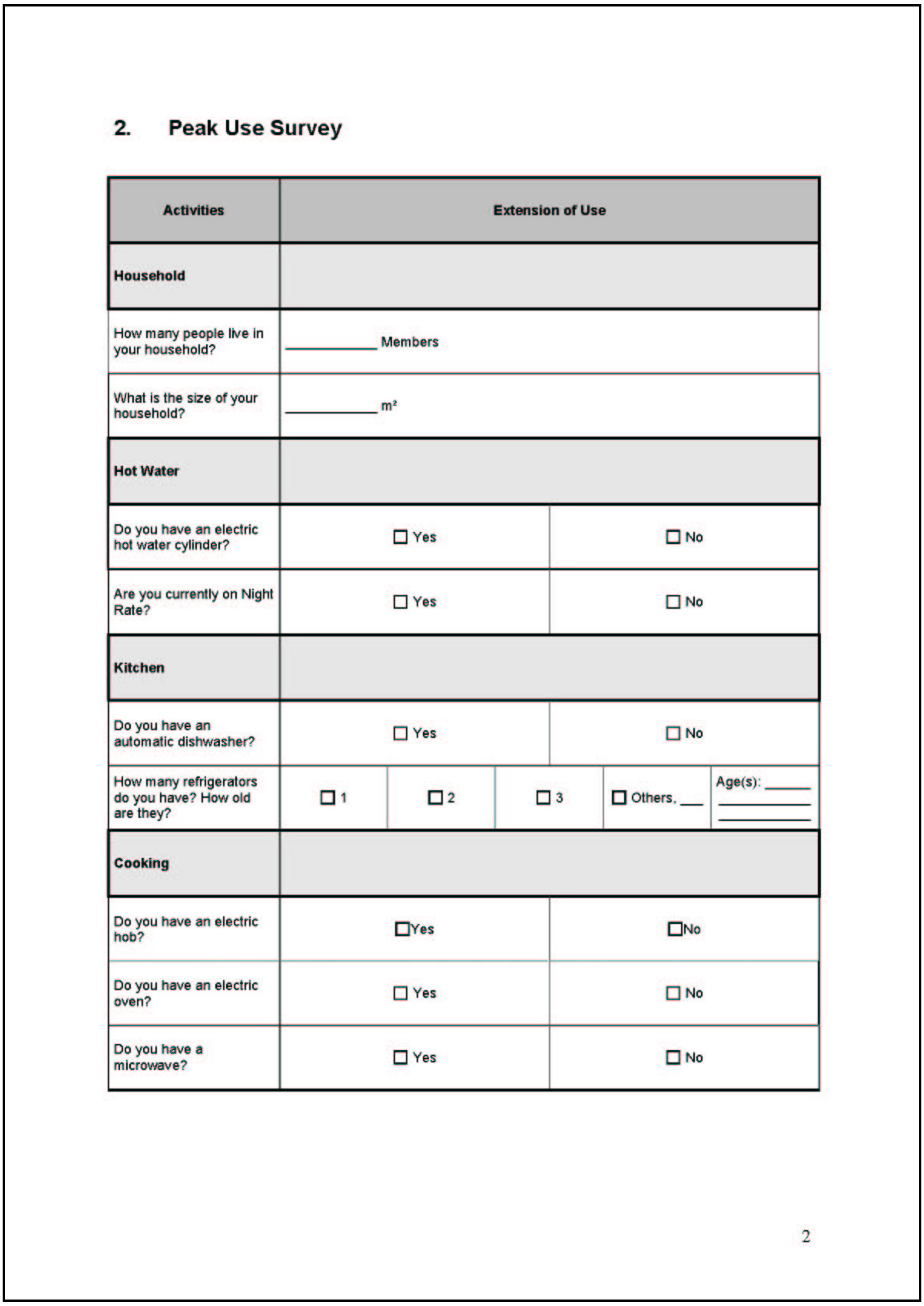
Address: ______________________________
____
____

Contact details:

Phone: ______________________________

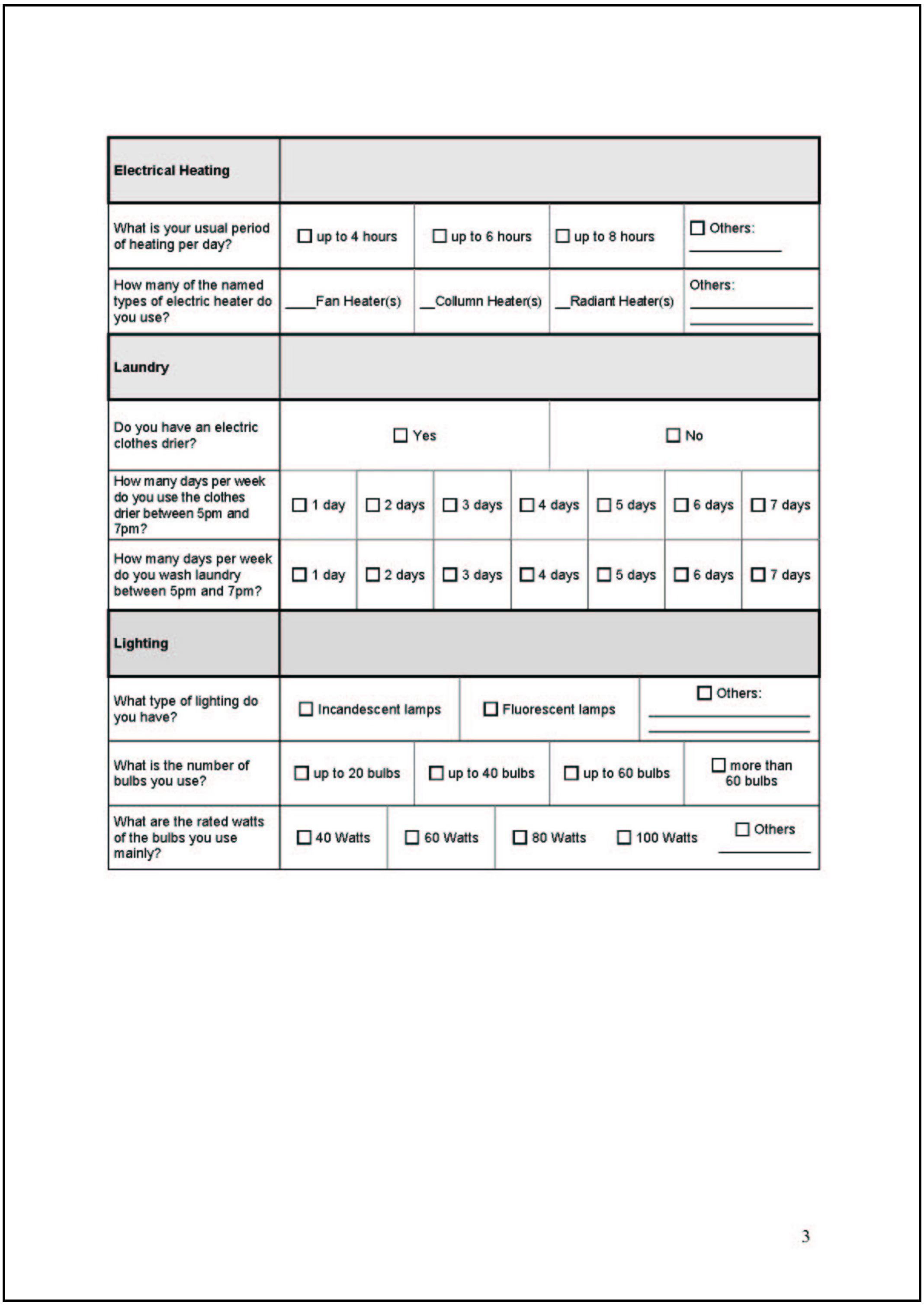
E-Mail: ______________________________

1

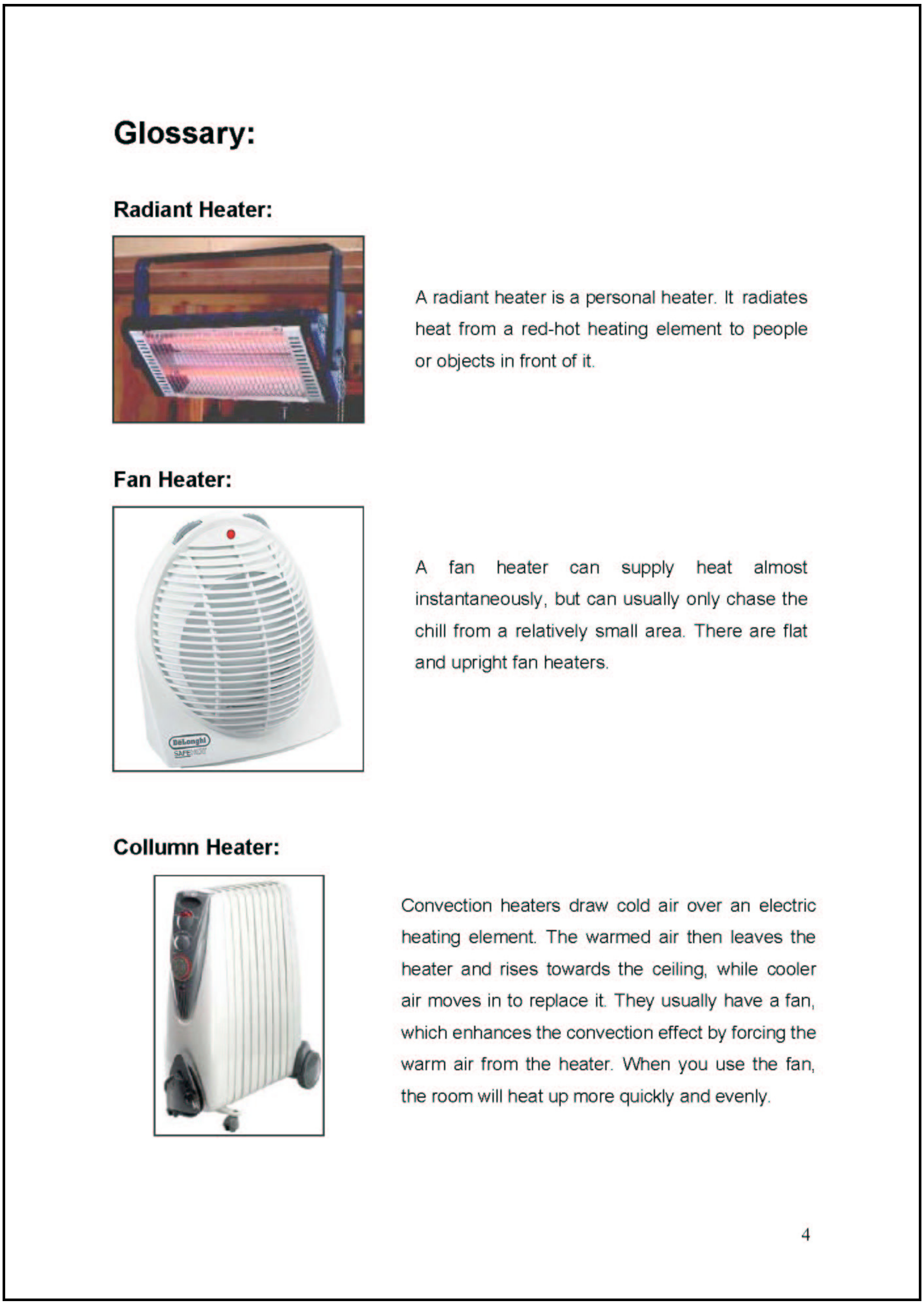


2. Peak Use Survey

Activities	Extension of Use				
Household					
How many people live in your household?	___________ Members				
What is the size of your household?	___________ m²				
Hot Water					
Do you have an electric hot water cylinder?	☐ Yes		☐ No		
Are you currently on Night Rate?	☐ Yes		☐ No		
Kitchen					
Do you have an automatic dishwasher?	☐ Yes		☐ No		
How many refrigerators do you have? How old are they?	☐ 1	☐ 2	☐ 3	☐ Others, ___	Age(s): ______ ___________ ___________
Cooking					
Do you have an electric hob?	☐Yes		☐No		
Do you have an electric oven?	☐ Yes		☐ No		
Do you have a microwave?	☐ Yes		☐ No		



Electrical Heating							
What is your usual period of heating per day?	☐ up to 4 hours	☐ up to 6 hours	☐ up to 8 hours	☐ Others: ____			
How many of the named types of electric heater do you use?	____Fan Heater(s)	__Collumn Heater(s)	__Radiant Heater(s)	Others: ____ ____			
Laundry							
Do you have an electric clothes drier?	☐ Yes	☐ No					
How many days per week do you use the clothes drier between 5pm and 7pm?	☐ 1 day	☐ 2 days	☐ 3 days	☐ 4 days	☐ 5 days	☐ 6 days	☐ 7 days
How many days per week do you wash laundry between 5pm and 7pm?	☐ 1 day	☐ 2 days	☐ 3 days	☐ 4 days	☐ 5 days	☐ 6 days	☐ 7 days
Lighting							
What type of lighting do you have?	☐ Incandescent lamps	☐ Fluorescent lamps	☐ Others: ____ ____				
What is the number of bulbs you use?	☐ up to 20 bulbs	☐ up to 40 bulbs	☐ up to 60 bulbs	☐ more than 60 bulbs			
What are the rated watts of the bulbs you use mainly?	☐ 40 Watts	☐ 60 Watts	☐ 80 Watts	☐ 100 Watts	☐ Others ____		



Glossary:

Radiant Heater:

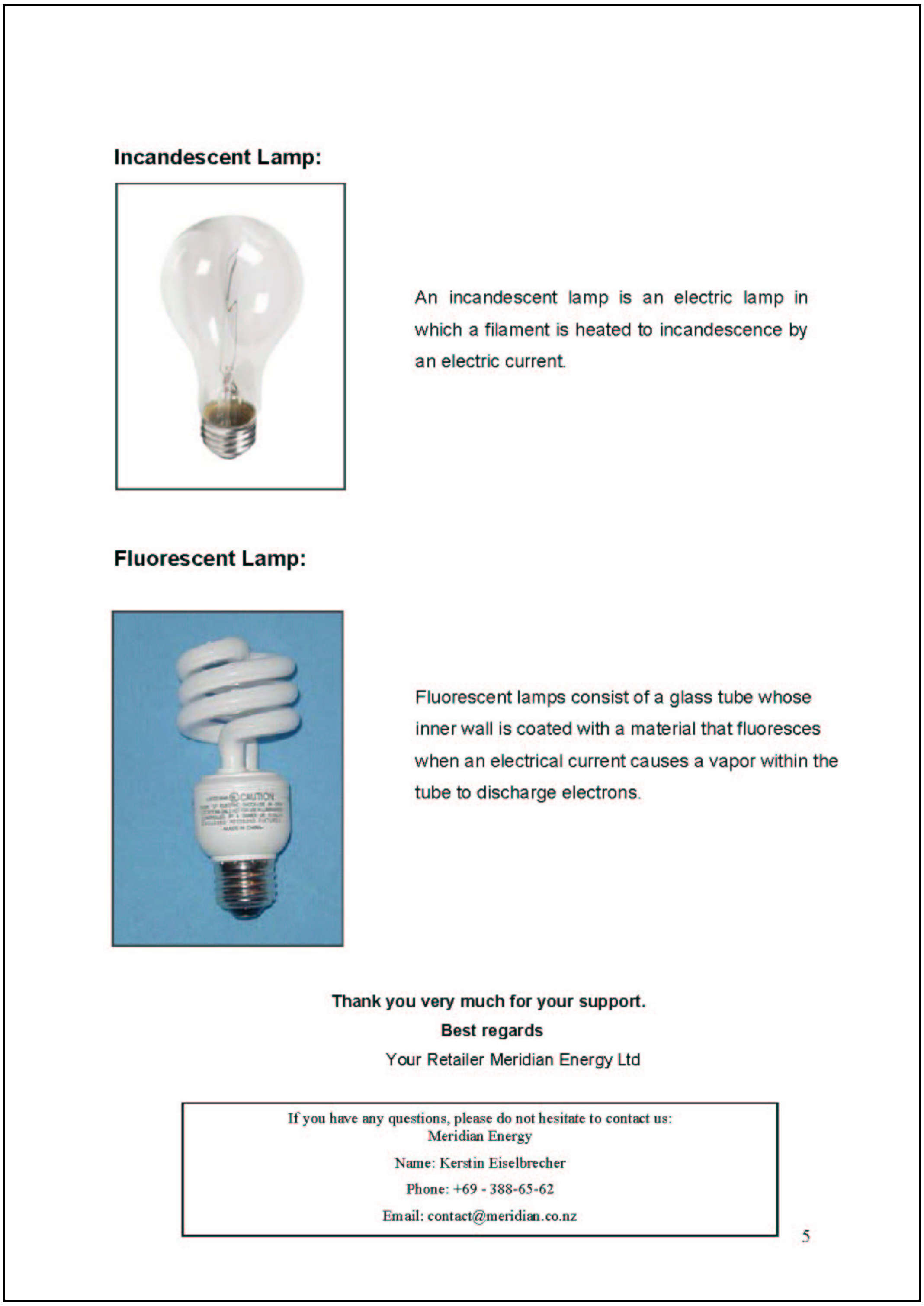
A radiant heater is a personal heater. It radiates heat from a red-hot heating element to people or objects in front of it.

Fan Heater:

A fan heater can supply heat almost instantaneously, but can usually only chase the chill from a relatively small area. There are flat and upright fan heaters.

Collumn Heater:

Convection heaters draw cold air over an electric heating element. The warmed air then leaves the heater and rises towards the ceiling, while cooler air moves in to replace it. They usually have a fan, which enhances the convection effect by forcing the warm air from the heater. When you use the fan, the room will heat up more quickly and evenly.



Incandescent Lamp:

An incandescent lamp is an electric lamp in which a filament is heated to incandescence by an electric current.

Fluorescent Lamp:

Fluorescent lamps consist of a glass tube whose inner wall is coated with a material that fluoresces when an electrical current causes a vapor within the tube to discharge electrons.

Thank you very much for your support.
Best regards
Your Retailer Meridian Energy Ltd

If you have any questions, please do not hesitate to contact us:
Meridian Energy
Name: Kerstin Eiselbrecher
Phone: +69 - 388-65-62
Email: contact@meridian.co.nz

5

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DECLARATION BY CANDIDATE

I hereby declare that this thesis is my own work and effort and that it has not been submitted anywhere for any award. Where other sources of information have been used, they have been acknowledged

Canterbury, 13.12.2005

Signature: ……………………………………….