ECNZ

The Role of Manapouri Within the ECNZ Generation System: A Report Prepared for the National Issues Taskgroup of the Waiau River Working Party

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1 Introduction

1.1 Background

This report has been prepared for the National Issues Taskgroup of the Waiau Working Party. The Waiau Working Party is a consultative group, co-ordinated by the Southland Regional Council, whose task is to ensure that all major environmental issues associated with the operation of the Manapouri power station have been identified. This process attempts to identify how adverse effects on local communities and interest groups can be addressed before an application is made to the Southland Regional Council to renew the consents needed to operate the station, as required under the Resource Management Act (1991). The National Issues Taskgroup is one of several set up by the working party to investigate specific issues in more detail.

The authors of this report are part of the Fuel Resource Group of ECNZ, which has the responsibility for obtaining and renewing major resource consents and the optimal scheduling of generation plant. Most of the material included in this report originated from a diversity of ECNZ publications. Special thanks are due to the following ECNZ personnel:

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1.2 Scope of this Report

The objective of this report is to ensure that the National Issues Taskgroup is informed on the integrated nature of the ECNZ generation network, the unique characteristics of the operation of Manapouri power station, its importance in the national electricity network and links to broader issues like; future supply, energy efficiency and electricity pricing. Having considered the issues contained in this report the taskgroup is expected to report to the working party.

1.3 Contents

The first section of the report includes a discussion of the characteristics of the ECNZ generation system. This begins with a description of the daily, weekly and annual demand cycles which greatly influence how the generation network is operated. The variable nature of

hydro inflows are described and the crucial role of New Zealand's limited hydro storage capability in meeting demand. Management of energy resources via the operating plan, merit order and dispatch of individual plant are also described. The implications of Manapouri's high position on the merit order, because of the likelihood of periodic high inflows, are also explained. This essentially means that the effect of reduced demand is to limit the use of stations further down the merit order and that any reduction in generation from Manapouri increases generation from stations lower in the merit order. This increases costs and environmental effects at stations other than Manapouri, and possibly brings forward the date that additional power stations are required to maintain security of supply.

The second section of the report outlines the important characteristics of the generation from Manapouri and its importance to electricity supply in New Zealand. Periodic high inflows into the catchment means that careful management of the Manapouri -Te Anau storage is needed to ensure the resource is used to best effect by minimising the spill of valuable water.

Next follows brief sections on factors which affect the demand for electricity, in addition to the cyclic nature of demand mentioned earlier. One factor which influences demand for electricity is its price and the prices of other forms of energy. Some broader pricing issues like the requirement to produce a return on assets, separation of energy and transmission charges and the South Island differential are also considered. Another factor which may influence the rate of growth of demand for electricity is the rate of uptake of end-use energy and electricity efficiency improvements. ECNZ recently carried out an extensive examination of this issue and the main points from the analysis are included. The key finding is that attempts to encourage increased efficiency of energy use must focus on consumer values and be undertaken for commercial reasons, rather than attempting to constrain energy use by regulating its supply.

The distinction between plant capacity or power (MW), and generation or energy (GWh), is briefly described, as is the role of the Cook Strait cable (HVDC Link). While New Zealand may have some surplus capacity during times of normal hydrological inflows, there is no surplus of generation. Any generation lost from Manapouri will have to be substituted for by generation from stations lower in the merit order at greater cost.

This leads into a discussion of the emerging generation technologies that may contribute to meeting future demand for electricity. An example of initiatives that ECNZ has been involved in have been the trial wind turbine located near Brooklyn in Wellington and wave power measurements carried out by university researchers in Te Wae Wae Bay.

The final section examines the sorts of trade-offs involved in a resource allocation decision like issuing consents for the Manapouri scheme. These range from changes in the local catchment versus higher cost electricity nationally or additional CO_2 and other atmospheric emissions. Local decisions have effects in other regions and nationally and essentially involve balancing different environmental effects.

2 System Operation

2.1 Characteristics of the ECNZ Generation System

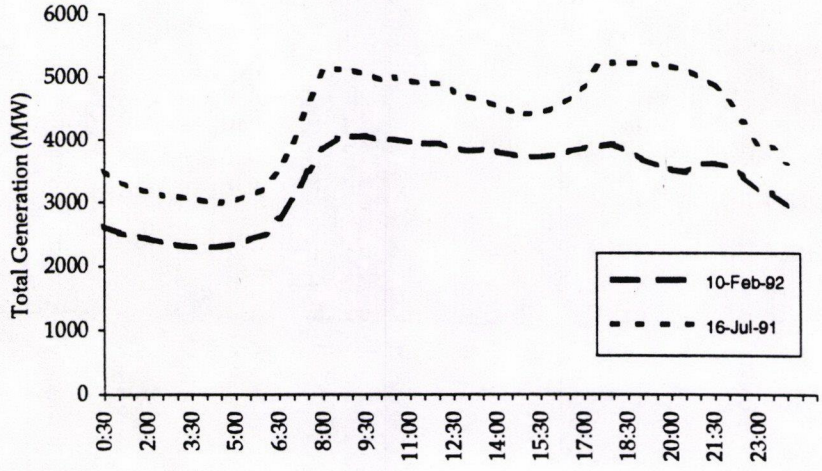
The ECNZ generation system produces about 96 percent of New Zealand's electricity needs. The remainder is produced by supply authority stations and co-generation plant. During normal hydrological inflows, about three quarters of ECNZ generation is hydro, seven percent from Wairakei and Ohaaki geothermal stations and the remainder is from fossil fuel stations.

Hence the ECNZ generation system has a mixed hydro-thermal character, with the hydro component dominant. Although expensive to construct, hydro stations once they are built have negligible generation costs, hence the high value of their generation. The amount of generation depends on highly variable hydrological inflows. Fossil fuel stations are generally cheaper to construct than hydro stations, the cost of fuel making them more expensive to run. Geothermal stations presently have no charge for the input energy (geothermal fluid) but incur drilling and maintenance costs for the wells that supply the input energy. Both Wairakei and Ohaaki operate to the maximum possible output when available, i.e. in a base load role.

2.2 Demand

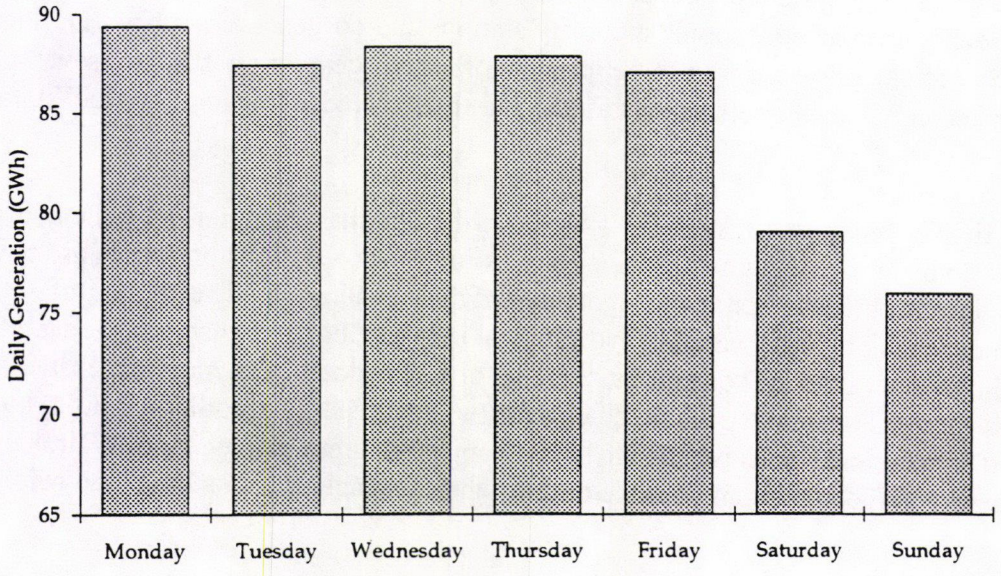
The demand for electricity, which ECNZ currently uses best endeavours to meet, exhibits a number of cycles which are illustrated in *Chart 2.2.i.* During a normal day, demand falls to a minimum in the early hours of the morning before rising to a peak at about 8.00 am. Demand then falls to a trough during the day before rising to the evening peak at about 6.00 p.m. and then returning to the overnight low.

Chart 2.2.i **ECNZ Generation - Daily Patterns**



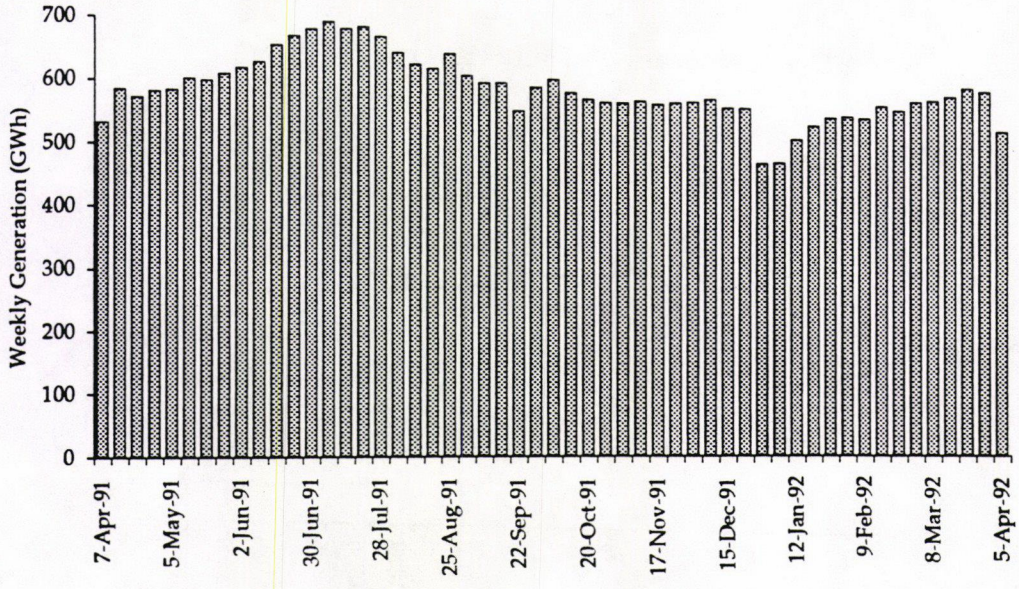
The weekly cycle, as shown in *Chart 2.2.ii,* is characterised by high demand from Monday to Thursday before a small reduction on Friday and low demand during Saturday and Sunday.

Chart 2.2.ii **ECNZ Generation - Weekly Pattern**



The annual electricity demand cycle exhibits minimum demand during the summer months, with a pronounced dip during the Christmas-New Year period, and maximum demand in winter.

Chart 2.2.iii **ECNZ Generation - Annual Pattern**



2.3 Supply

As indicated earlier, the ability of ECNZ's 30 hydro stations to produce electricity is dependant upon inherently variable hydrological inflows. Average inflows into the present ECNZ hydro station network would produce about 24,500 GWh/yr, however over a 60 year hydrological record, generation would have varied from as low as 20,000 GWh/yr to as much as 33,000 GWh/yr as illustrated in *Chart 2.3.i.* The analysis behind *Chart 2.3.i* assumes that all present stations are available, with the only variable being the hydrological inflows.

Chart 2.3.i **New Zealand Inflow Potential Generation**

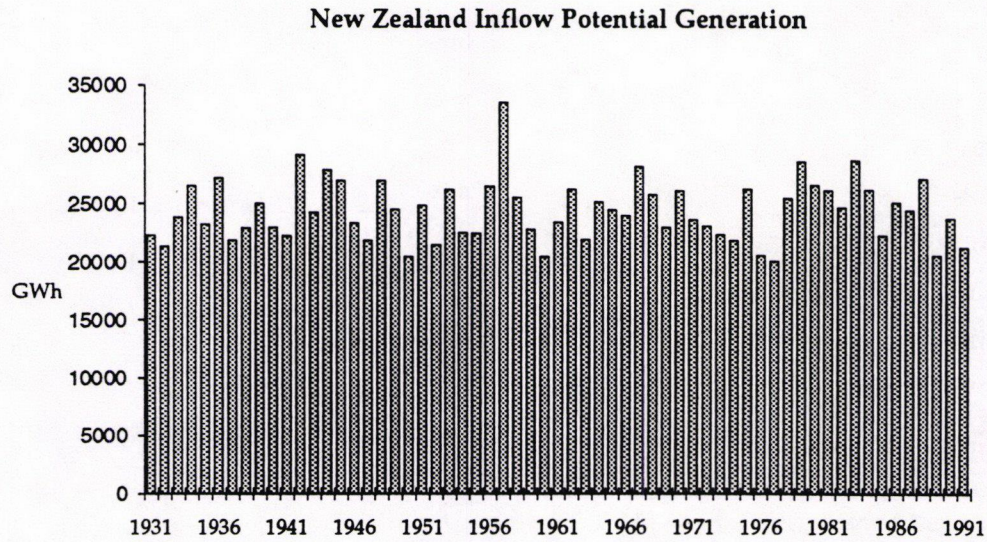
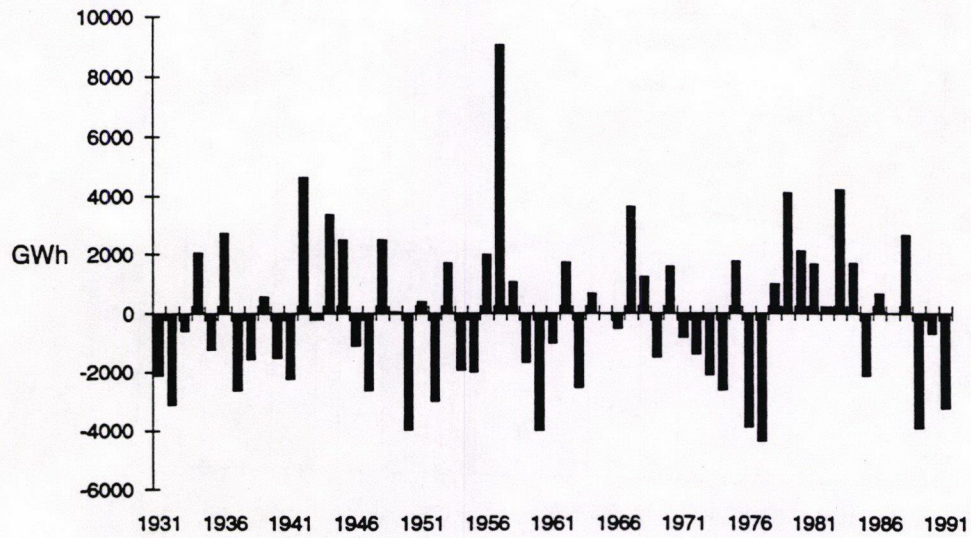


Chart 2.3.ii **New Zealand Inflows - Deviation from Mean**



New Zealand river flows are highly variable and in terms of potential generation from existing stations, *Chart 2.3.ii* on the previous page shows the wide deviation possible from the mean system capability. The high variability of New Zealand river flows, expressed as potential generation from existing stations, are demonstrated in *Chart 2.3.ii*.

The relationship between mean hydrological inflows and demand are illustrated in *Charts 2.3.iii* and *Chart 2.3.iv*. Note that North Island peak demand and inflows coincide while for the South Island they are out of phase.

Chart 2.3.iii **Inflows vs. Demand - North Island**

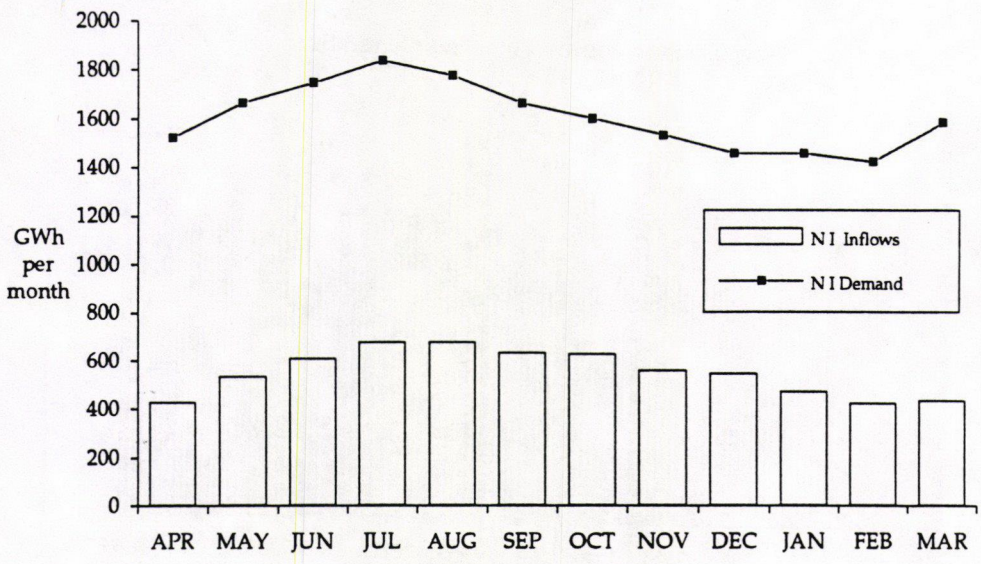
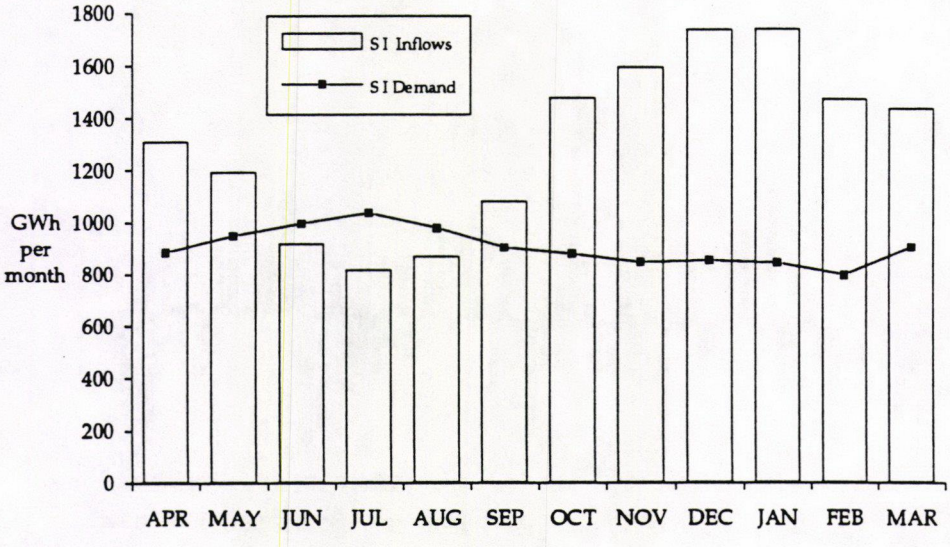


Chart 2.3.iv **Inflows vs. Demand - South Island**



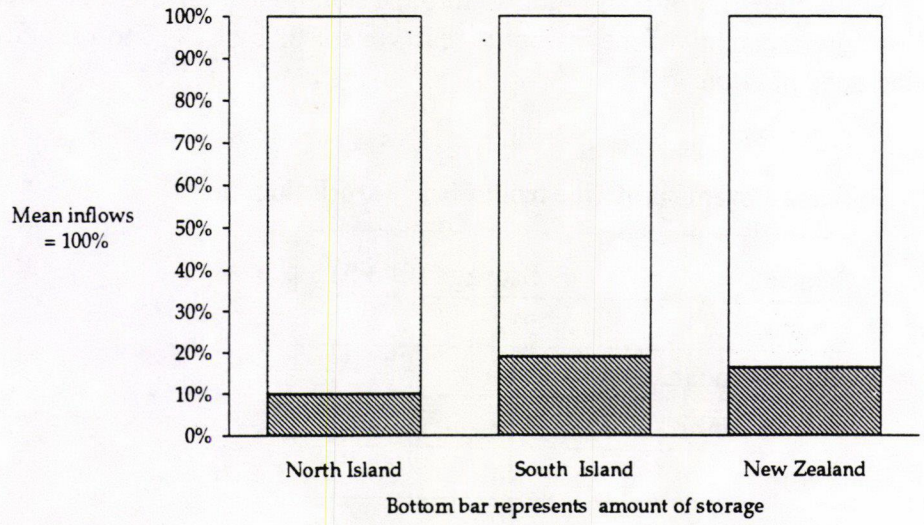
If all the inflows not required to meet demand in the South Island were transformed into electricity and transferred to the North Island, there still exists a shortfall to be met from thermal generation. To utilise the out of phase inflows into the South Island hydro lakes water must be stored. The storage capability of the 9 storage reservoirs used by ECNZ to provide seasonal storage are included in *Table 2.3.i*.

Table 2.3.i **Storage Potential of Controllable Hydro Lakes**

Name	Storage (GWh)
Taupo	512
Waikaremoana	144
North Island	**656**
Tekapo	774
Pukaki	1599
Hawea	292
Te Anau	240
Manapouri	141
Coleridge	39
Cobb	29
South Island	**3114**
New Zealand	**3770**

The identified reservoirs store water from periods of high inflow for use when demand is high, and also minimise the flood risk to downstream communities. Individual stations' head ponds also provide storage to assist meeting the generation demand during the day. Total hydro storage, tabulated in *Table 2.3.i* and illustrated in *Chart 2.3.vi*, is about 15 percent of total annual hydro generation. The characteristics of the ECNZ generation system, described here, governs how the New Zealand electricity system is operated. The limited hydro storage means that if hydro inflows remain high for a period, water may be spilled after lakes have filled, and hence not be available for generation in the future.

Chart 2.3.vi **Hydro Storage as a Percentage of Total Hydro Inflows**



2.4 Scheduling Generation

The daily, weekly, and annual generation patterns identified earlier, influence how the electricity system is operated. The annual planning cycle is incorporated via the operating plan, daily scheduling of plant occurs via the issuing of the merit order and minute by minute dispatch of plant is by control centres in accordance with the merit order and any constraints that apply.

Firstly, the operating plan sets out how the available energy resources will be managed to meet demand at least cost and to a given security of supply standard, currently a 1 in 60 year standard. That is, generation is managed so that full supply of electricity will be maintained even when water inflows fall to a 1 in 60 year low. Factors taken into account when developing the operating plan include; catchment inflows, forecast demand, release of plant for maintenance, availability of plant, storage and deliverability of fuel (especially water), fuel costs and environmental restrictions.

The operating plan provides a set of water values for each week of the year based on historical hydrological information. They are calculated in a computer optimisation model called SPECTRA that simulates the operation of the power system. The water value is the cost of fossil fuel thermal generation that is avoided because sufficient water is available. Sequentially for each week of the year, actual reservoir levels and expected hydrological inflows are used to calculate the value of water for that week.

Table 2.4.i **Sample Merit Orders for the Operation of Power Stations**

Merit Order 1	Merit Order 2
Uncontrolled Inflows (SI)	Ohaaki
Uncontrolled Inflows (NI)	Wairakei
Coleridge	Uncontrolled Inflows (SI)
Manapouri - Te Anau	Stratford (Waihapa)
Tekapo	Uncontrolled Inflows (NI)
Pukaki (in the SI)	Huntly (gas)
Ohaaki	Coleridge
Wairakei	**Manapouri - Te Anau**
Stratford (Waihapa)	Tekapo
Pukaki (in the NI)	Pukaki (in the SI)
Huntly (gas)	Cobb
Taupo	New Plymouth
Waikaremoana	Pukaki (in the NI)
New Plymouth	Huntly (coal)
Huntly (coal)	Stratford
Stratford	Taupo
Cobb	Waikaremoana
Otahuhu (gas)	Otahuhu (gas)
Otahuhu (oil)	Otahuhu (oil)
Whirinaki	Whirinaki

Secondly, the mechanism that is used to put the operating plan into effect is the merit order determined following an analysis of water values for a particular week as described above. If the value of water storage is below the cost of thermal generation then use of hydro generation would be maximised. Conversely if the water value is greater than the cost of generation at a thermal station then water would be conserved for later use to displace even more expensive thermal generation. Hence when the reservoirs are full extra water has a low value, and when they are low extra water has a high value. The value of water varies according to the storage level, and the time of the year.

Two sample merit orders are tabulated above in *Table 2.4.i*. Merit order 1 is for a situation when no water conservation is required in the South Island (because of high inflows and reservoir levels). Because of moderate inflows into the North Island, Huntly on gas is being used to provide some conservation of North Island water storage. Merit order 2 illustrates conservation of reservoir water in all catchments up to the cost of Huntly generation with additional conservation of North Island water storage being provided by New Plymouth and Stratford gas fired stations.

Thirdly, the decision about what station is operated on a minute by minute basis is made by Trans Power at control centres located at Hamilton and Islington under contract to ECNZ. The process begins with receipt of the merit order and detailed planning takes into account short term factors like expected tributary (uncontrollable) inflows into head ponds, plant availability and spinning reserve requirements. Large thermal power stations take up to 12 hours from start up to full load operation, hence forward planning occurs even in the short term. Scheduling hydro plant can be more complex since not only must the appropriate output be requested, but also the control centre must ensure that sufficient water is available. This is more difficult where several stations are located on a single river.

Power stations in *Table 2.4.i.* are ranked from cheapest to most expensive to operate from top to bottom for each merit order, which reflects a particular combination of plant availability, storage, and inflows. Hence plant is scheduled to meet demand in order from the top to the bottom. As indicated earlier, demand exhibits daily, weekly and annual cycles and this determines at any particular time how far down the merit order plant is required to generate. For example using merit order 1 above, early in the morning during a summer weekend demand may only reach as far as Stratford power station (on Waihapa gas), while early during a cold winter evening, expensive plant like Otahuhu power station (on gas) may be required.

A very important aspect to note is that storage from Manapouri -Te Anau ranks highly in both merit orders, often above other hydro storage. This occurs to minimise the risk of spilling water. Utilising the inflows in this catchment is particularly difficult due to their flashy nature and the lake level restrictions. Consider a situation during the cold winter evening mentioned above, where supply authorities instituted conservation measures by turning off hot water cylinders to reduce demand. It is likely that as demand was reduced, the marginal station from merit order 1 would shift from Otahuhu on gas to Cobb or Stratford. The conservation strategy (or in the longer term an energy efficiency strategy) is highly unlikely to in any way affect the demand for generation from Manapouri. That is, a conservation or an efficiency drive is only likely to affect the demand for generation from stations at the bottom of the merit order.

If generation from Manapouri becomes more constrained because of plant or additional environmental limitations, then more generation will be required to from stations below Manapouri in the merit order. For example, if the marginal station at a particular time is release of water from Waikaremoana storage in merit order 1, then additional restrictions on Manapouri could make New Plymouth the marginal station. This increases the average cost of electricity in the short term and in the longer term, brings forward the date when additional capacity like Taranaki combined cycle, or Tuapeka hydro projects would be required to maintain security of supply.

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1. Reliability of Electricity Supply Project, Generation. Centre for Advanced Engineering, University of Canterbury, 21 April 1993

2. Tom Halliburton, Investigations Engineer, Fuel Resources Group

3 Role of Manapouri

3.1 Description of the Manapouri/Te Anau System

The Manapouri/Te Anau system consists of a 585 MW hydro power station located at West Arm on Lake Manapouri. Generation from the station is achieved using water from the Manapouri/Te Anau catchment, with Lakes Te Anau and Manapouri being used as a buffer to store water between high inflow events. Water from Lake Te Anau is released via the Te Anau control structure and travels down the Upper Waiau river into Lake Manapouri. Water from the Mararoa River is also diverted into the system at the weir structure located where the Mararoa River meets the Lower Waiau River.

Manapouri provides a mean annual generation of about 4300 GWh, or 17 percent of total hydro generation, to the national electricity system. The total water stored within Lakes Te Anau and Manapouri, has a generation potential of less than 10% of Manapouri's total annual generation.

3.2 Manapouri Operation

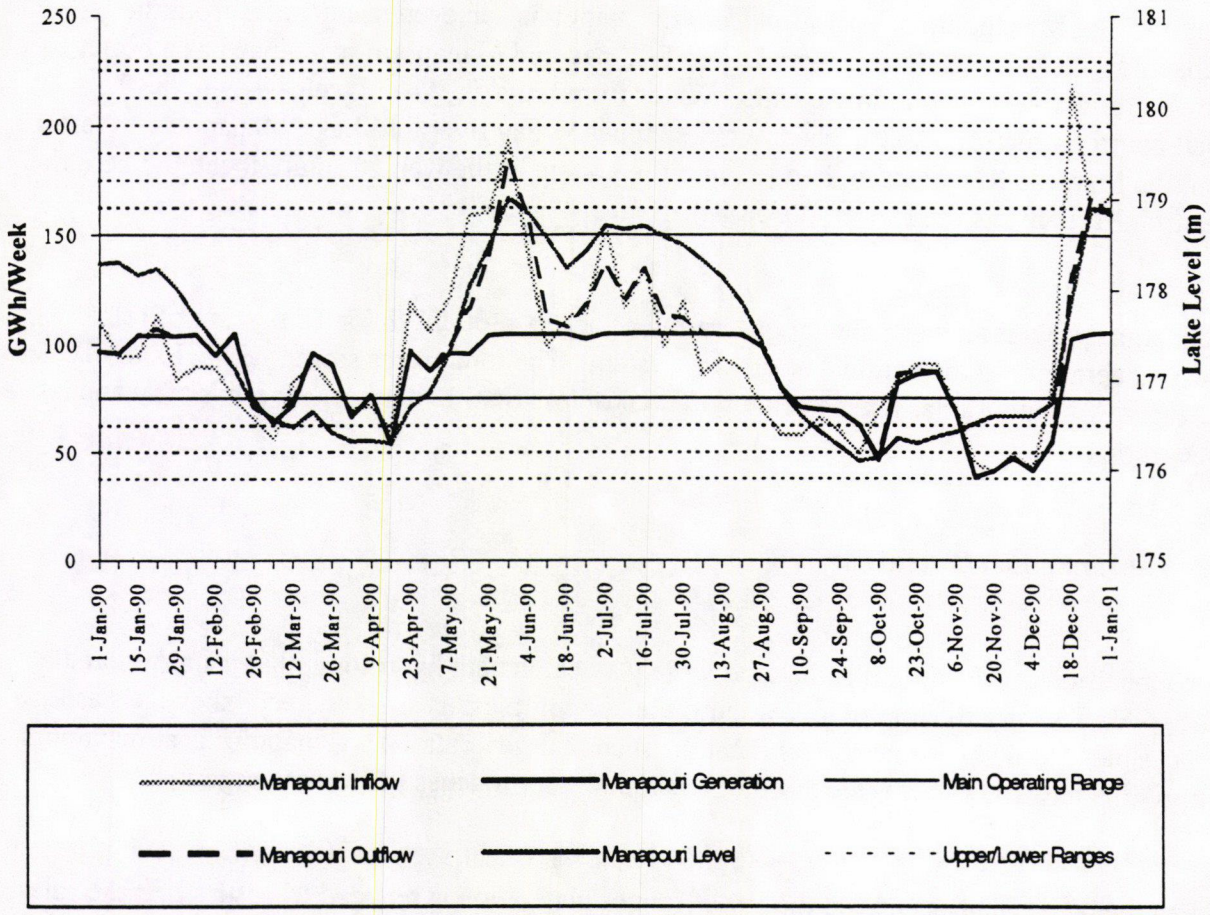
The Operation of Manapouri is dictated largely by catchment hydrology, that is inflows and lake level. In order to capture inflows into the system it is necessary to keep lake levels as low as possible. Looking at *Chart 3.2.i* it can be seen that generation at Manapouri is at maximum (approximately 100 GWh/Week) until the lake level approaches the lower ranges.

When the lake level has entered the lower ranges generation is reduced to ensure that the rules set out in the Manapouri/Te Anau Guidelines are adhered to. These rules dictate that the lake level can only be in certain ranges for a specific number of days for any one continuous period and a maximum number of days in any 12 month period. There is also a "draw down" rate constraint, designed to reflect natural conditions, that dictates the maximum rate at which the lake level can be drawn down. This constraint directly impacts on the amount of generation available from the station.

Both Manapouri and Te Anau have highly variable and volatile inflows arising from weather driven events which yield high inflows over short periods of time. These inflows are captured using the lakes' storage as a buffer. In some events not all of the inflows are able to be captured because the lake level rises rapidly and enters the high operating ranges. The Manapouri/Te Anau guidelines dictate that at various lake levels (within the high ranges) water is "spilled" from the lake and released down the Lower Waiau River, by-passing the station and so are not used for generation.

The guidelines also have rules regarding the duration of time that the lake level can remain in each of the high ranges, and the minimum time that the lake level is below each of the high ranges before they can be re-entered.

Chart 3.2.i **Manapouri Operation**



There are occasions when the water in the Mararoa River becomes discoloured. During these times this water is not diverted into Lake Manapouri, but is released down the Lower Waiau River. These releases are termed "Dirty Water Spill", and they tend to occur when flows on the Mararoa River are high. Consequently "Dirty Water Spill" contributes a large amount to the total uncaptured water in the system. "Dirty Water Spill" is caused by weather events that occur on a few occasions a year in the Mararoa catchment.

Occurrences of spill can be seen on *Chart 3.2.i* where "Manapouri Outflow" is greater than "Manapouri Generation". A large proportion of this spill occurred when the lake was in the "Main Operating Range", that is "Dirty Water Spill" as opposed to "Mandatory Spill" due to high lake level. The nature of the hydrology and the complexity of the operating guidelines requires that Manapouri operation is closely considered; *Chart 3.2.i* incorporates the above concepts and presents them in chart form.

The rules for operating the Manapouri power station are the most detailed of any power station in New Zealand. They significantly restrict the flexibility of the station, however they are of course designed to protect important environmental attributes.

References

1. Ari Sargent, Southern Generation Controller, Fuel Resource Group

4 Forecasting Electricity Demand

4.1 Introduction

One of the areas of uncertainty facing the Electricity Industry as a whole, is the future demand for electricity. Currently ECNZ supplies about 96% of New Zealand's electricity demands, and unless split up into multiple competing companies, will continue to be the dominant generator in the foreseeable future. The people of New Zealand, as the owners of ECNZ, demand a reliable supply of electricity at a "reasonable" price and expect ECNZ to use its "best endeavours" to meet all electricity demands all the time.

The demand for electricity in New Zealand is a subset of New Zealand's total energy demand. Electricity competes in the non-transport energy market against fuel alternative's like natural gas, LPG, wood, and coal. Energy users allocate resources to give the lowest *apparent* end cost product, be it heat, light, cooling, a process, service, or an end product. The amount of energy used in any situation depends on the costs of continuing with the status quo versus replacing with, or upgrading to, a more efficient technology with potential savings from reducing energy use. Because of electricity's instantaneous availability, and flexibility, its use normally increases at the expense of other energy forms, as over time users reinvest in more efficient energy technologies.

Consumers buy inputs, like electricity, to be processed into the outputs they desire. For a long time New Zealander's have concentrated on the "cost" of electricity, rather than its value to them. Forecast electricity demands reflect the value that users place on electricity relative to other fuels, efficiency improvements, or conservation, and hence their expected demand for it as a product.

4.2 Preparation of Electricity Demand Forecasts

Electricity demand forecasts are prepared using a method generically known as scenario forecasting. It involves generating a range of possible futures for the wider environment in which ECNZ operates.

Three scenarios have been developed for 1993 Strategic planning, each describing a different socio-economic future with the associated electricity demands. These scenarios have two main uses: they are used to assess the effects of major, long term changes; and they provide a range of contexts in which to explore specific issues, such as a major loss of plant or restrictions on access to water or other fuels.

While there are endless possibilities of focus for scenario development, the national socio-economy provides the most appropriate basis for business planning for ECNZ, given its national operation and the way that demand for energy services arise. Scenarios based on alternative paths for the national economy on a sectoral basis provide the only way to quantitatively represent changes in end-uses in some detail. Without this level of information, scenarios can provoke consideration of different uncertainties but cannot calibrate the nature and scale of potential change with which ECNZ may be faced.

Three scenarios have been developed to help predict future electricity demands. They are the *Status Quo Scenario*, the *High Economic Growth Scenario*, and the *Commodity Trap Scenario*.

4.3 Outline of the Status Quo Scenario

This scenario opens with a resumption of economic growth, driven largely by higher export prices and an increase in investment. Domestic fiscal constraint, however, restrains the pace of economic growth to an average of 1.7% a year between 1990 and 1995. Economic growth accelerates modestly to 2.1% between 1995 and 2000, before slipping back a little to 2.0%, from 2000 to 2005. The downward trend continues to 2010 with growth at 1.8% before stabilising between 2010 and 2020 at 1.6%.

Export growth is matched by growth in imports for much of the period and the country does not achieve a balance of trade surplus (excluding capital servicing costs which would be large) until after 2010. As the scenario progresses, the economy is increasingly burdened by the cumulative debt.

Over time there is a progressive shift in the export mix with the share of forest based products and manufacturing growing, largely at the expense of processed food exports. The forest based industries are a significant driver of growth in the scenario, fuelled by a 170% increase in the value of output from the forests by 2020. There is significant growth in local processing and the export of wood products and pulp and paper (up 195%), but this is accompanied by a nearly eight fold increase in log exports.

Other sectors tend to show steady but unspectacular growth consistent with the scenario theme of reflecting long-run trends of slowly changing economic structure, modest population growth and mixed fortunes in overseas markets. The Glenbrook steel mill increases production with the upgrade of the mill in the early 1990s and then has a modest growth in returns as it shifts slowly to higher value products. Output from the general manufacturing sector doubles over the 30 year period. In contrast, the Synfuels plant, and the ammonia-urea and methanol plants close down in 2003 as gas resource depletion becomes more imminent.

Over the 30 years there is a 70% increase in GDP which is accompanied by a 20% increase in consumer energy reflecting, in part, the energy efficiency improvements which occur. Lights and Motors is the largest end use of electricity rising from 45% in 1990 to 55% by 2020. Electricity's share of the consumer energy market (including transport) rises from 30% to 50% over the 30 years.

4.4 Outline of the High Economic Growth Scenario

The assumption underlying this scenario is that the current economic revival is part of a longer term trend with the country experiencing sustained export led growth. Overall growth in the economy is 2.4% per annum between 1990 and 1995 rising to 3.7% between 1995 and 2000, and 4.2% per annum for 2000 to 2005. Growth is checked between 2005 and 2010 as the economy suffers a mild recession. After a modest 1.2% growth a year between 2005 and 2010, the economy then recovers to grow at 2.2% and 3.0% between 2010 and 2020.

In this scenario, New Zealand benefits from increased trade with countries in South East Asia, where incomes are rising. The dairy industry successfully continues the transfer of production into value added products. The meat industry progressively restructures, and later in the scenario, the wool industry turns around. Forest planting expands rapidly to high levels, encouraged by world wood supply shortages. Local processing expands with a major shift into paper production based on mechanical pulp. There is also a significant expansion in the production and export of sawn timber and board products.

The aluminium smelter is assumed to continue in production until 2013 with a progressive upgrading of the plant between 1994 and 2003. This enables the quantity of aluminium produced to increase while electricity consumption remains unchanged. It is assumed that international environmental constraints deter the aluminium smelter from relocating overseas.

The current reinvestment in the NZ Steel mill, results in its conversion into a successful producer for niche markets. Other manufacturing, including textiles, is restructured and rapidly expands exports and hence total output.

In the services sector, tourism grows steadily, fulfilling the ambition of 2.5 million visitors by 2005. After that growth is largely in yield per visitor rather than increased numbers of visitors. Personal services expand with rising incomes, while Government administrative services contract overall, but with some growth in health and education. Government finances and the balance of payments improve rapidly as economic growth returns, unemployment slowly contracts, and indebtedness slowly falls.

The continued operation of the Synfuels and Methanol plants until 2018 restricts the availability of gas to the electricity industry in spite of substantial gas finds. Growing environmental concerns are reflected in the scenario in an increase in recycling, and the uptake of energy efficiency measures.

4.5 Outline of the Commodity Trap Scenario

This scenario begins with the same mild upswing in the economy as in the *High Economic Growth Scenario*. The good prices for commodities diverts attention away from the structural problems in the economy to reducing the high levels of unemployment and to income maintenance. The diversification of the economy and increase in local value added seen in the *High Economic Growth Scenario* does not happen as producers pin their hopes on log exports and other basic commodities. In traditional fashion, good export prices are also accompanied by rising imports.

When the squeeze goes on commodity prices in the late 1990s and early 2000s the economy is ill-prepared. The country continues to run balance of payments deficits and suffers from spiralling overseas and internal debt. Lack of capital for investment is a major contributor to the low levels of investment and slow turnover of capital equipment which prevails through the scenario. This exacerbates the position of the country's manufacturing industries which become increasingly uncompetitive. The lack of investment is also a significant factor in restraining efficiency improvements in the use of energy and other inputs.

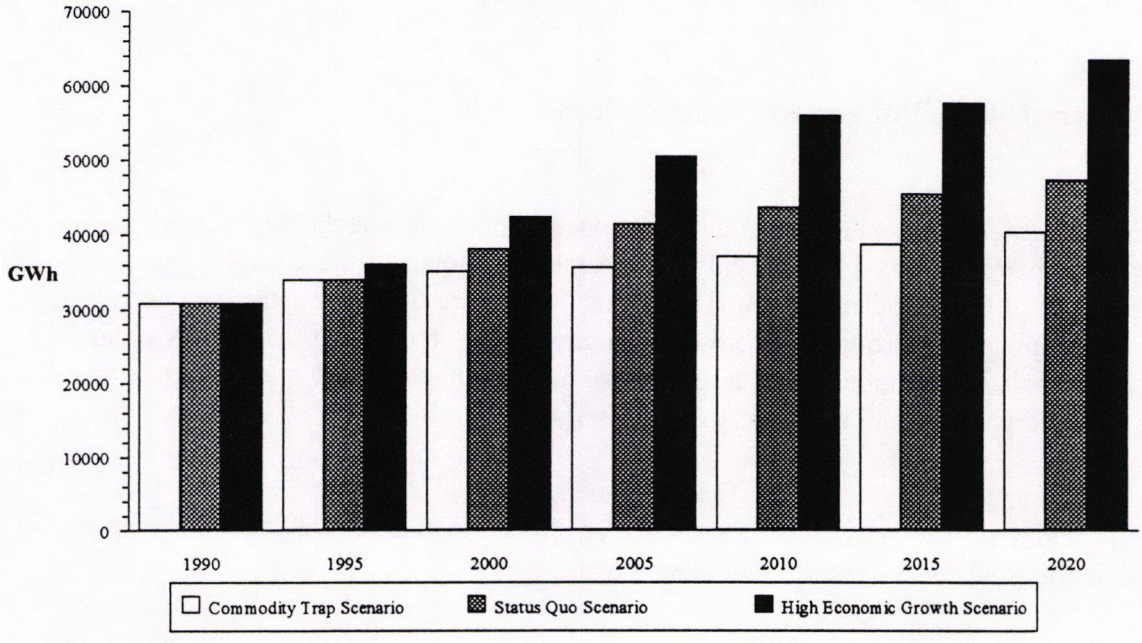
The increase in volumes of forestry production in the first two decades of the scenarios results in significant increases in log exports. Investment in forestry continues although at lower levels than in the *High Economic Growth Scenario*. In contrast, the upturn in dairy, meat and other food industries in the 1990's are not sustained and growth in manufacturing is slow. The Bluff smelter continues right through the scenario while NZ Steel expands but never produces at full capacity. The Synfuels plant closes down by 2005 through the lack of major new gas finds, and the methanol plant closes by 2015.

Growth in tourism is modest, reflecting the unsettled social conditions caused by high levels of unemployment and increasing crime rates. The growth that occurs tends to be at the backpacker rather than the high value end of the tourist market. Environmental quality also suffers from the depressed state of the economy, further depressing the country's attractiveness as a tourism destination.

Overall growth in the economy over the 30 years is very modest and in per capita terms, living standards are actually lower in 2020 than they were in 1990.

Chart 4.5.i compares the expected future electricity demand forecasts that are derived from the scenarios described here.

Chart 4.5.i **Forecast Electricity Demands for the Three Scenarios**



4.6 Important Factors Effecting Electricity Demand

The electricity demand forecasts are synthesised from variables contained within the scenarios described in this chapter. Scenario inputs include economic growth, demographic trends, government regulation and industrial development patterns. The effects of two key variables, electricity pricing and energy efficiency, are described briefly below. Electricity pricing is fully covered in Chapter five, and energy efficiency in Chapter six.

4.7 Effect of Electricity Pricing on Electricity Demand

Historically, the price of electricity for most users consisted of a cents per kilowatt hour energy charge. An electricity user whose pattern of electricity use varied widely, and without warning, faced no higher per unit electricity cost than a user who required a constant supply, and was able to accurately predict future electricity demand. Also over time, supplying electricity to users who require a constant, or predictable supply is less expensive than supplying erratic demand.

Now electricity charges have recently been separated into fixed transmission costs and variable energy costs. Transmission charges recover the fixed costs of providing electricity transmission services to an electricity user. The cost of the energy then reflects the true cost of providing it as a product. This allows users to make informed decisions on the costs and benefits of using electricity versus other energy forms including any capital costs.

Although controversial, separating out fixed electricity transmission costs and energy costs is an important step in maximising the efficient use of energy. Efficiency is maximised when the overall use of energy and capital expenditure is minimised. The pricing of electricity has an important effect on the efficient use of all forms of energy.

4.8 Electricity and Increased Energy Efficiency

Electricity is an efficient energy form when matched with modern technologies, and when its use is properly optimised. The efficient use of electricity enhances the lifestyles and economic well-being of all New Zealanders. Businesses and homes are finding minimising energy costs while maintaining or improving performance an imperative, in order to survive. A significant trend is that existing technologies that used fossil fuels as their primary energy sources are being replaced with technologies that use electricity.

It is expected that over time, electricity's share of the energy market will increase, even though growth in the total energy market will slow down.

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5 Electricity Pricing

5.1 Historical Background

Up until April 1987, when ECNZ was formed by the SOE Act, electricity pricing was a function of Government policy. The price in no way reflected a realistic rate of return on the costs of building the generation assets, and the tax payers cross-subsidised electricity users. At first glance this may appear to have been reasonably equitable, as tax payers are normally electricity users. However there were four serious deficiencies in this approach:

1. Electricity users did not see the true cost of the electricity they were using, including environmental, and resource depletion related costs. There was little incentive to use electricity more efficiently, as electricity was subsidised while efficient technologies were not.
2. Governments and Supply Authorities forced commercial users to cross subsidise domestic consumers, and local body services. By "levying" captive electricity users, some Supply Authorities were able to maintain "cost plus" structures, with tax payers topping up the costs of providing "cheap" electricity.
3. The public of New Zealand were led to believe that access to electricity was a right and that no matter how much electricity they wanted, somehow the government would provide it. The price of electricity, especially to domestic consumers, was considered a totally separate issue.
4. The result of (3) was that the electricity industry has not operated like other industries, on the basis of supply and demand, with the cost of supplying electricity being balanced against what consumers were willing to pay for it. Until now, many consumers have not analysed their demand requirements in similar commercial terms, but have reverted to the previous system of trying to influence prices by political means.

It has been argued that while ECNZ is 100% government owned, electricity prices are just another form of tax. Such a rationalisation considers politically motivated electricity price fixing as just another form of welfarism. However such an approach leads to the inefficient use of resources (mainly scarce government revenue), prevents competition and innovation in energy markets and in the technologies that use energy, and prevents supply and demand ever becoming balanced.

5.2 The Relationship between Wholesale and Retail Electricity Prices

Since 1987, ECNZ has operated on a commercial basis, allowing the wholesale price of electricity to fall by more than 14% in real terms, while still making an average real rate of return of 7.74% for the people of New Zealand. ECNZ is a wholesaler of electricity and apart

from a few large commercial customers that it supplies directly, it cannot set the final price for end users. By reforming and opening up to competition the generation and sale of energy, consumers should be able to see separated out, the transmission and electricity cost, including the retailers margin. Retailers who do not negotiate competitive wholesale electricity contracts with generators, or who charge high margins due to their inefficiency or to make excessive profits, will not survive for long in the now deregulated market for the supply of electricity.

Many of the benefits of lower prices that have been passed on to the Supply Authorities (who are the electricity retailers), have been absorbed by them or used to remove cross subsidies that they had built into their pricing structures. As competition in the retail sector of the electricity industry results in increased efficiency, the benefits that the industry has been absorbing over the years should be released to the consumers, either in the form of lower price increases, or as profits to individual or community owners.

For ECNZ and retailers, selling electricity is now only part of the picture. Providing consumers with the energy services they require will become increasingly important, be it heat, light, comfort, security, processes, etc. Individuals and firms have historically looked at short term input costs rather than longer term output costs. A move to longer term, one to ten year electricity contracts, will enable larger users to accurately compare the costs of using various forms of energy, including capital costs. The move away from viewing electricity as a "take it or leave it" commodity, to a resource that when used efficiently can give firms and individuals a significant competitive advantage, is important for efficient economic performance .

5.3 Costs ECNZ Must Recover to Meet its Commercial Objectives

ECNZ as an SOE, is required to act as a commercial organisation making a market rate of return on its assets. ECNZ is not obligated to supply electricity to an energy merchant, however in reality, ECNZ recognises that it is presently a monopoly supplier of an essential service, and by best endeavours seeks to constantly supply all electricity demand.

ECNZ's assets are generally characterised by low operating costs (or variable costs), but very high capital financing costs (or fixed costs). Before it can make a profit, ECNZ must earn enough revenue to pay for all its operating costs and financing costs. Variable costs are minimised by reducing staff numbers, optimising fuel use, lowering maintenance costs, maximising plant availability, etc. Variable costs are reduced to the level where safe and reliable electricity supply match the demand for electricity.

The fixed costs faced by ECNZ depend on how the financial markets perceive the riskiness of ECNZ relative to other similar industries. ECNZ can minimise the interest rate financiers require to lend money to ECNZ by two main methods. Firstly it can operate as a financially sensible company by not taking on too much debt, and risk overextending itself. Financiers demand higher interest rates when there is the slightest risk of default. Secondly it can

minimise interest rates by being better than similar organisations when it comes to efficiency, safety, reliability, and commercial ability. ECNZ has done this very successfully.

The share holders of ECNZ are ultimately the people of New Zealand, with the Minister of SOE's and the Minister of Finance acting on their behalf. ECNZ has a 51:49 debt to equity ratio, so the government owns shares worth 49% of the value of ECNZ. They currently require a 11% rate of return on equity. Unlike most companies, the shareholder negotiates the return it requires in advance.

A merit order dispatch mechanism, (*see Chapter 2.4 for a full description*) is used so that ECNZ operates its power stations efficiently, from the cheapest to the most expensive. A station will be used only when any cheaper to operate power stations are already generating, users are demanding more electricity, and will pay enough to cover that stations variable costs, (normally fuel costs).

5.4 Wholesale Electricity Pricing Since 1987

ECNZ has little leeway when it comes to electricity pricing. ECNZ has increased its profits by operating its assets more efficiently, by reducing its costs of generation and improving the performance of the plant. It has increased market share from other energy sources, and captured a larger share of the growth in energy demand. About 70% of its market is contestable, and for marginal sales the energy market is price sensitive. Although ECNZ has a monopoly in the electricity market, it competes against other energy forms. Experience has shown that price increases above the level of inflation, necessary to provide for capacity expansion to meet future electricity demand, are very difficult to get acceptance for. ECNZ seeks to avoid price regulation by being open about costs because that distorts the supply and demand balance.

The major change in energy pricing methodology has been to separate out transmission costs and electricity costs to the Electricity Supply Authorities. Overall costs to some consumers have readjusted as there is now no cross subsidisation between the cost of generation, and the cost of transmitting electricity, and between domestic and commercial users. ECNZ must compete with potential independent generators and it does not control access to the transmission system. If ECNZ wants to build a new power station, it will face the same costs that any competitor will for access to the same transmission lines.

The wholesale electricity price has reduced in real terms by more than 14% since 1987, as ECNZ strove for market share, especially against the natural gas sector. Electricity Supply Authorities now have one year wholesale electricity contracts. These encourage the Supply Authorities to forecast their annual demand for electricity and sign contracts with ECNZ where they receive 90% of their annual electricity demands at a negotiated price with ECNZ Marketing. ECNZ carries the risk that in a low rainfall year, it may cost more to produce the electricity than the negotiated price, as happened in 1992.

The Supply Authorities buy the remainder of their electricity requirements on the spot market. The spot market prices electricity at its marginal production cost at its time of use. Supply Authorities can buy, and sell back, electricity to the spot market, at the time of use price. The spot market price depends on rainfall, the time of year, and the time of day. Supply Authorities use these prices to set retail electricity prices, for example lower cost off peak electricity rates. The spot market prices also show potential competitors ECNZ's marginal cost of generation, and hence whether they could build a power station and compete economically.

5.5 Transmission Costs and the South Island Electricity Price Differential

At a wholesale level, the need to separate out electricity transmission costs to encourage competition has meant that most South Island Electricity Supply Authorities are better off. Supply Authorities transmission costs are based on the percentage of the existing transmission capacity they require, plus an allowance for the distance to the main source of generation that supplies them with electricity. Most of the South Island's transmission lines have a capacity well in excess of local requirements, as they were designed to carry excess electricity to the Cook Strait Cable. Since most South Island Supply Authorities do not face transmission constraints in the foreseeable future, the need to pay for transmission upgrades is unlikely.

At the retail level, South Island Supply Authorities are often faced with large, expensive infrastructures, and few users. Governments traditionally subsidised the construction of power lines in remote areas, and maintained wholesale electricity prices at about 20% lower in the South Island than those in the North Island. The final electricity cost to consumers was normally very similar in the North and South Islands.

With the deregulation of the electricity industry, the subsidising of power line construction ceased. The upgrading of the Cook Strait Cable removed the South Island's "electricity surplus" by unconstraining electricity transmission to the North Island. If the differential had been maintained on the South Island energy price, energy traders could have arbitraged, buying electricity in the South Island, and contracting with Trans Power to send it to the North Island. The South Island differential has been maintained as an explicit annual subsidy from ECNZ to Trans Power, who then subsidise South Island transmission costs.

5.6 Future Trends in Electricity Pricing

The electricity industry is rapidly changing from being supply driven to being demand or consumer driven. As the government is unlikely to finance new power stations, the timing of a new power station will depend on the expectations of investors. If insufficient investment in generation occurs, there would be electricity shortages from around the year 2000.

ECNZ would like to see a competitor enter the generation market by building the next major power station, and is working towards this end. The electricity industry recognises that long term electricity purchase and fuel supply contracts are required, so that financiers will fund power stations that normally require long pay back periods. A wholesale electricity market is being established that will allow buyers and sellers to match their requirements. Risk averse buyers and sellers will pay a premium to traders who specialise in managing risk, who in turn will guarantee them a supply of electricity, or monetary compensation.

The wholesale electricity market will be run by an organisation independent of ECNZ, and will provide the spot electricity prices that will underlie long term electricity contracts. Electricity contracts will be bought and sold by energy traders, (e.g. Supply Authorities), with Trans Power selling transmission rights for the use of its power lines. Supply Authorities will not be able to prevent traders using their power lines for tolling electricity to consumers, and will charge a commercial rate of return for providing the transmission service. As trading electricity will become a high volume, low margin industry, some Supply Authorities may be forced into partnerships or be bought out. Adding value to selling electricity by offering a range of services, levels of reliability, packages of electricity with appliances, etc. will become the norm.

The price of electricity will go up, reflecting the running out of the low cost electricity New Zealand has enjoyed, due mainly to its government subsidised hydro programme. How much electricity prices rise depends very much on Government policies, especially those related to environmental issues, the availability of natural gas, and future economic growth. Pricing is very much out of ECNZ's hands, as from now on consumers will be dictating how much they are willing to pay to maintain their reliable supply of electricity, without any subsidies from tax payers.

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6 Energy Efficiency

6.1 Background

Energy intensity, the average quantity of energy needed to produce each dollar of goods and services, increased significantly in New Zealand during the 1970's and early 1980's. Most industrialised nations had a long run trend of falling energy intensity which slowed during the 1950's and 1960's. The principal reasons for New Zealand moving against this trend for a period were the substitution of capital equipment for labour and major energy projects like; the Synfuels plant, the refinery expansion, the Glenbrook steel mill expansion and developments at the Tiwai Point aluminium smelter. New Zealand has the lowest price of electricity in the developed world and so gives electricity intensive industries a real advantage.

This divergence from the global energy intensity trend plus the energy sector reforms of the last decade, heightened awareness of the issue of energy efficiency in New Zealand. The level of uptake of end use efficiency improvements can influence the long term rate of growth in demand for a particular form of energy like electricity. One outcome of this increased interest was a major study on end use energy efficiency funded by ECNZ, which resulted in the publication of a discussion paper entitled *"The Developing Market for Energy Efficiency in New Zealand"* in November 1992. The key conclusions from this study form the basis of the following comments.

6.2 Description of the ECNZ Study

The study was undertaken by Dialogue Consultants Ltd in association with staff from several overseas organisations and from within ECNZ. Research undertaken as part of the study included:

- an analysis of overseas experience of end-use energy efficiency and how relevant this is to the deregulated energy market likely to apply in New Zealand;
- an analysis of international data on energy and electricity intensity for IEA countries;
- an estimate of the potential for end-use efficiency in New Zealand and the potential impacts on different sectors of the economy;
- definition of commercial opportunities for the promotion of end-use efficiency within the electricity industry.

The core of the study involved the preparation of 3 scenarios of the New Zealand economy up until 2005. These scenarios were used in an input-output modelling framework to model

economic changes, their interactions with energy supply and the use of energy services, to asses the implications of different rates of uptake of end-use efficiency improvements. The three scenarios developed were as follows:

- a **standard** scenario where existing rates of equipment and building stock turnover were assumed, based on a continuation of past attitudes towards energy efficiency and energy use;
- an **efficiency** scenario with accelerated rates of equipment turnover, as anticipated from a deregulated energy market with appropriate political action; and
- a **frozen** efficiency scenario where 1990 energy output ratios are assumed except for a few sectors where major structural change is considered likely.

Note than none of the scenarios developed were presented as forecasts of what is likely to happen, rather they were designed to draw out the implications of different assumptions about changes in the economy and the energy sector.

6.3 Definition of Energy Efficiency

Initially the concept of energy efficiency was equated with fuel or electricity conservation. That is, people make do with less to reduce the absolute quantity of energy used. Some measures like switching off lights in empty rooms imply modest effects on individuals, while others like carless days have major effects.

During the 1980's the concept of energy management evolved, often referred to in the electricity industry as demand side management. Demand side management was designed to manipulate load to more closely match the limitations of supply. Energy management can be viewed as providing a given level of service with less energy. Many studies exist where claims are made concerning potential reductions following technological or behavioural change. Such studies, while broader than energy conservation, unduly focus on a single energy source (usually electricity) and ignore the broader dynamics of social and economic changes, especially attitudes to changing technologies.

The supply side focus of the energy conservation and energy management approaches arises naturally from concerns about the availability of resources and the adequacy of energy supplies. This in turn results in a technical view of the problem and prescribing solutions without taking into account the people who use the energy. A broader definition of energy efficiency was applied in the ECNZ study where supply and demand factors and consumer behaviour were considered.

The definition of energy efficiency used by the authors was **"...the systematic use of technology and services to maximise consumer values from energy use."** It could also be viewed as part of behaviour by a consumer to minimise total cost for a given level of output or service. The advantages of this definition were given as follows:

- it directs attention to the services energy provides and the value derived from its use, from a focus on the energy itself as in an energy management approach;
- it recognises that efficiency improvements arise from the gradual replacement of expensive and long-lived assets over time, the principal reason for the long term decline in energy intensity;
- it refocuses attention away from theoretical potential savings from a given technology (which takes no account of existing investment, industry structure, patterns of energy use, or consumer preferences and tastes) onto the structure of the marketplace and consumer values.

6.4 Overseas Experience

The key features of the overseas experience of energy efficiency for New Zealand are as follows:

- no other country has a regulatory regime like that to be introduced by the Energy Sector Reform Bill. It is generally recognised that proper commercial incentives must exist for energy efficiency to be actively promoted by utilities and energy service companies (ESCO's). The proposed New Zealand regime should allow this to occur without requiring a costly bureaucratic support structure.
- New Zealand should aim to avoid any arbitrary impediments to the promotion of energy efficiency which would be imposed by price control;
- many overseas utilities are still supply driven in their energy efficiency programmes, i.e. focusing on demand side management rather than viewing energy efficiency as a new business opportunity.

The energy sector reforms in New Zealand provide an opportunity for the development of energy service companies without such initiatives being hampered by price controls or complex bureaucratic processes, which overseas have often had a net overall cost to consumers and taxpayers.

6.5 Highlights

Some of the key outputs from the ECNZ efficiency study are shown in *Table 6.5.0.i* for the "standard" and "efficiency" scenarios.

Table 6.5.i **Changes in Energy Usage from Scenario Analysis: 1990 to 2005**

	Std. Scenario	Effic. Scenario
GDP Growth	45%	47%
Consumer Energy	+13%	-8%
Consumer Energy Intensity	-22%	-37%
Non-Elect. Consumer Energy Intensity	-31%	-42%
Consumer Electricity Energy Intensity	+19%	-24%
CO_2 Emissions	+36%	-4%
CO_2 Emissions / Unit of GDP	-6%	-35%

Points to note from *Table 6.5.i* the following:

- GDP growth over the 15 year period is similar for both the standard ("business as usual") and efficiency scenarios;
- changes in consumer energy intensity illustrate significant improvements in energy efficiency even under the standard scenario;
- the differences between non-electricity and electricity consumer intensity imply that the long run trend of increasing market share and (possibly) increasing absolute electricity demand should continue;
- under a standard scenario type future, total CO_2 emissions should rise, even though the comparative intensity measure falls (recall GDP has increased by 45%) and an efficiency scenario type future offers the prospect of stabilising CO_2 emissions.

6.6 Conclusions from the ECNZ Study

The way energy efficiency has been viewed has changed over time, currently emphasising a focus on customer values. This requires a change in the roles and responsibilities for governments and energy industries, with a shift away from regulation and intervention to an increasing emphasis on inherent commercial incentives. Internationally many regulators still follow the supply-side paradigm emphasising energy savings, but as the limitations of a regulated approach become apparent there is a trend towards policies that shift market behaviour towards increased distribution of efficiency products and services.

The framework provided by the Energy Sector Reform Bill should encourage the selling of energy services and the emergence of energy service companies during the next few years. Within the electricity industry, some power companies are already promoting energy efficient technologies to a greater extent than before. Hence it is likely that the electricity industry will make a significant contribution to reducing New Zealand's energy intensity via uptake of efficient electro-technologies.

6.7 ECNZ Initiatives

ECNZ has expanded its role in promoting energy efficiency and this trend is likely to continue in the future. Initiatives currently being undertaken include:

- establishment of an energy services group to pursue investments in efficient electricity use;
- development of a comprehensive domestic energy efficiency service, HERO;
- promotion of energy efficient features in new housing (Medallion Homes);
- support for innovative energy auditing and assisting with technology transfer via an ECNZ subsidiary company (Design Power)

6.8 Generating System Availability and Capacity Improvements Since 1987

Maximising the efficient use of ECNZ's power stations and Trans Power's transmission lines has been an important goal since 1987. For ECNZ, efficiency is about improving electricity services to users while reducing the costs of production and distribution. Fuel is the major variable cost facing ECNZ. Minimising its cost to ECNZ is difficult as 75% of fuel is water, which is highly variable in its annual supply. ECNZ has improved overall efficiency by increasing availability at hydro and key thermal power stations, and where economic, by increasing station capacities. *Table 6.3.i* outlines the improvements that have been made to thermal power stations.

Table 6.8.i **Thermal Station Availability & Capacity Increases Since 1987**

Thermal Stations	Availability		Capacity (MW)	
	1987	1993	1987	1993
Huntly	65%	90%	960	1000
New Plymouth	70%	85%	575	575
Stratford	80%	95%	575	575
Total			2110	2150

The increased availability of Huntly has meant that older inefficient power stations are not required, saving fuel, and reducing unwanted thermal emissions. Improvements to hydro power stations have had an effect equivalent to building a new 120 MW hydro power station. Improvements are ongoing as they become economic. The improvements at the hydro stations minimise water spill and allow better utilisation of stored water. The upgrading of the Cook Strait cable has resulted in reduced electricity losses from the transmission system, and reduced South Island hydro spill.

From 1987 until now, the system improvements have been the equivalent of adding a 120 MW baseload power station. Over the next 10 years the potential is to add about another 150 MW of baseload generation and 80 MW of peaking capacity through electricity generation efficiency improvements. The energy improvements have the potential to defer the next major power station by one year.

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7 The Difference Between Energy and Capacity (Technical Issues)

7.1 Introduction

When the Electricity Department was corporatised in 1987, ECNZ identified that there was an electricity generation capacity surplus. The generation system had 50% more capacity than was required to meet the maximum demand for electricity. ECNZ has decommissioned or rationalised expensive to operate power stations, like Meremere and Marsden A, while at the same time meeting increased electricity demand by using the remaining power stations more efficiently. In 1992, the generation system that normally easily supplies New Zealand's electricity needs, was nearly stretched to its limit. The existing power stations were still available, yet total electricity output was lower due to a shortage of water.

The capacity of a power station is measured in megawatts (MW), which gives the potential for the station to produce electricity. A station requires fuel to produce electricity and in New Zealand the range of fuels used are, water, geothermal steam, gas, coal, oil, and wind. When a station is producing electricity, it is converting a primary energy source into the desired energy product, electricity. In the case of hydro stations a sufficient flow of water is required. Some hydro stations are designed to provide a high output for a short period, e.g. Waipouri, while others maintain a steady output like Benmore. Stations operate at their peak capacity in either short bursts or in a continuous mode. The peak output is a station's capacity, while the accumulation of generation over a period is known as energy. There has never been a surplus of energy output, or a wastage of water.

7.2 The Effect of Supply and Demand for Electricity

From 1 April 1992 to 31 March 1993, ECNZ's power stations generated 29569 gigawatt hours (GWh) of electricity from an installed capacity of 7359 MW (obtained by adding up all the stations' MW). This results in the power stations having utilisation's on average of only 46%, i.e. on average a hydro would run at full capacity for just 46% of the time. The need for the apparent "surplus" capacity is due to the nature of New Zealand's generation system being mainly hydro, and the variable demand for electricity. Note that 1 hour of generation at the 1000 MW Huntly power station will produce 1 GWh of electricity, enough for about 120 houses for one year.

7.3 Generation and the Supply of Electricity

New Zealand's electricity generating system comprises a mix of hydro electric power stations, geothermal power stations, thermal power stations, and a wind generator. New Zealand is unusual in that about 75% of its electricity is normally generated by hydro power stations. Electricity demand is largely independent of variations in annual precipitation, unless severe

water shortages result in electricity users having to reduce their demand. Such a high dependence on the weather to provide fuel, in the form of water (average annual water inflows vary between +34% to -20%, see *Chart 2.3.i*), means that the entire generation system must have a significant capacity margin.

Under normal weather conditions North and South Island precipitation patterns are different, with North Island lake inflows being at their maximum in early winter, (due mainly to rain), and the South Island in early summer, (due to snow melt), see *Chart 2.3.iii*, and *Chart 2.3.iv* on page 6. *Chart 2.3.vi* on page 7 shows that the major storage lakes, Pukaki, Tekapo, Hawea, Manapouri, Te Anau, and Taupo can store about 15% of the average annual inflows to ECNZ's hydro power stations. Due to minimum river flow requirements, seasonal precipitation patterns, lake level constraints, and the limited water storage capacity, water can only be stored between seasons, not from year to year.

In an average hydrological year, the South Island hydro power stations can generate more electricity than can be consumed in the South Island see *Chart 2.3.iv* on page 6. Without the Cook Strait cable, water would be spilt, while the North Island would have to use expensive thermal fuel to meet its electricity demand. In a dry year, the South Island's power stations cannot produce enough electricity to meet local demand, and without the Cook Strait cable, the South Island would be faced with shortages, and the need to build more power stations. The Cook Strait cable maximises the flexibility of ECNZ's hydro resources, reduces the risk of electricity shortages, and minimises the use of expensive fossil fuels.

Electricity generating stations must be regularly maintained, and are never 100% reliable. As electricity demand is continuous, the generating system has enough spare capacity so that it can continue to supply electricity when stations are "out" due to regular maintenance or due to failure. Maintenance is planned well in advance, and costs relatively little as the system is designed to accommodate a certain level of plant outage. Unexpected failures can be very expensive due to their randomness, and due to the fact that the risk of one happening is much higher when all power stations are required, like during a drought.

Unexpected failures are normally fixed very quickly and power stations are maintained so that the chance of them occurring at all are minimal. ECNZ has four main ways of dealing with unexpected failures. Firstly ECNZ will try to increase the output of stations already generating, and then by starting up hydro stations that can release water rapidly without causing down-river flooding. Most hydro stations will be able to operate on full output for a short period before their "emergency supply" of water runs out. If necessary, ECNZ starts its high fuel cost "peaking" thermal power stations, like Otahuhu and Whirinaki. Finally, if the failure cannot be compensated for by extra generation, electricity users are cut-off according to a predetermined plan.

In summary, the electricity generating system is required to have a MW capacity margin because:

1. In an average precipitation year, hydro generation provides about 75% of New Zealand's electricity. Extra capacity is required to provide electricity in dry years, with stations like New Plymouth and Marsden A filling this role.
2. The physical separation of the North and South Island is partially overcome by the Cook Strait cable. However, to provide sufficient security, both islands have surplus generation capacity.
3. The generating system requires outages for regular maintenance and occasionally unplanned outages occur. A margin of "spare" capacity is maintained to allow for outages

The level of capacity required by the generating system is a trade-off between risk, required security levels, and cost. Until recently ECNZ has always determined the level of capacity internally, and charged users for providing it. With the deregulation of the electricity industry, it is hoped that by making the costs of spare capacity transparent, users of electricity will determine what they are willing to pay for.

7.4 Electricity Demand and the Requirement for Energy and Capacity

The demand for electricity is not constant. To allow for variations in demand, the generation system has a capacity margin, above that required for variations in electricity supply. There are four time periods that influence the aggregate demand for electricity:

1. Diurnal (daily) electricity demand
2. Weekly electricity demand
3. Seasonal (summer versus winter) electricity demand
4. Long term (five to ten years) electricity demand

Diurnal and seasonal electricity demand variations are the main reasons the electricity system needs more generation capacity than that simply required to meet the average annual electricity demand. *Chart 2.2.i* shows typical daily load variations for a winter and summer day. Note the two peaks created by domestic electricity demand at breakfast time and in the early evening. Demand fluctuations occur rapidly over short periods, and ECNZ's mix of power stations are operated accordingly. *Chart 2.2.ii* on page 4 shows annual variations in electricity demand for a typical year. The winter period of maximum electricity demand coincides with the period of low precipitation in the South Island, so lake storage levels are very important heading into winter. *Chart 2.2.ii* on page 4 shows the variation in electricity demand over a week.

7.5 Conclusion

ECNZ does not have a surplus of capacity or energy. From a generation point of view, the combined capacities of the power stations are carefully optimised to maximise the benefits, and reduce the risks, from ECNZ's predominantly hydro based generating system, while allowing for planned and unexpected power station outages. A capacity margin is also required to meet expected, and unexpected variations in the demand for electricity. The generation system is operated in a cost minimisation mode, and the loss of valuable hydro generation simply means more expensive thermal generation must be used.

The capacity margins require some power stations, like Whirinaki, to be available all the time, although they may only generate for a few hours a year. Providing a capacity margin is a form of insurance that the power users pay for. There are currently enough especially designed power stations in service, to provide that insurance role. As electricity demand increases, the potential for variations in supply and demand will increase, resulting in the need to install more capacity than is presently required to meet the average electricity demand. Electricity users are now determining the levels of security they require, as they are being exposed to the costs of both energy and the capacity.

References

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2. Reliability of Electricity Supply Project, Generation. Centre for Advanced Engineering, University of Canterbury, 21 April 1993

3. Capital Investment Strategic Directions Report, Generation Analysis Section, Technical and Development Group, SD BA 38, 31 July 1992

8 Emerging Generation Options

8.1 Introduction

There are new or improved electricity generation technologies being developed around the world. It is expected that some of them will eventually become economic in New Zealand. The impetus for their development comes mainly from environmental concerns over inputs, outputs, and development impact as outlined below:

- As fossil fuels, and access to hydro and geothermal resources becomes more expensive, due to scarcity, increased handling costs, and environmentally based taxes, the push is on to produce more electricity from less fuel, and to use alternative sources of energy as inputs.
- Using fossil fuels, mainly gas, oil, or coal, to generate electricity also results in unwanted outputs. Five potential pollutants are carbon dioxide, sulphur oxides, nitrogen oxides, hot water from cooling systems, and solid wastes.
- People are becoming increasingly concerned about environmental impacts of large power station developments. Hydro developments irreversibly alter large parts of the landscape, while thermal power stations have the associated issues of noise, fuel supply, and the disposal of wastes. Electricity transmission lines also have environmental impacts.

New Zealand is fortunate in that most of its electricity comes from renewable hydro and geothermal generation. New Zealand is currently spared many of the pollution problems other countries face, and will require new power stations about the time that some of the new "non-polluting" technologies described below become economic. Generally New Zealand is not large enough to match the level of research that is being undertaken in other countries. ECNZ continually monitors overseas development progress, and concentrates on assessing the suitability of each technology to New Zealand's future generation requirements.

8.2 Wind Energy

Wind energy is approaching commercial viability in New Zealand. Internationally the technology is improving. The unknown is how will wind generators perform in New Zealand's arduous wind conditions. ECNZ has built a 225 kW wind generator in Wellington primarily to gather New Zealand specific data. Wind generation may be economic in certain situations from around the year 2000. However wind generation can only partially replace thermal generation due to its intermittent nature, and the need to provide security of supply and peak MW capacity.

8.3 Wave Energy

Proven technology for large scale wave generation is not yet commercially available. New Zealand has a good potential for wave generation as it is an island nation, with no nearby land masses preventing the build up of good wave forms. An ongoing wave research programme is being undertaken by ECNZ, with one of the most promising areas around the Fiordland coast. Generating electricity from wave energy is expected to cost about twice that from a new hydro power station, and in New Zealand will probably not be economic until after 2020.

8.4 Solar Energy

Very small scale solar generation is currently used in New Zealand at sites like radio repeaters and navigation lights. Generation of electricity on a large scale from solar energy is unlikely until the costs drop significantly, and this will probably be well after 2010. New Zealand's solar energy levels are only average by world standards, and other technologies that utilise New Zealand's natural advantages, e.g. wind, will probably be favoured before solar.

8.5 Biomass Fuels

Two main sources of biomass have potential as fuel to provide both heat and electricity for industry. Waste from the timber industry is currently used to fire special boilers at pulp and paper mills to produce heat and electricity. Purpose grown biomass, like trees, crops, root crops, can be used in place of coal, oil and gas. However in New Zealand alternative non polluting, energy sources are expected to be available at a lower cost.

8.6 Fuel Cells

Fuel cells operate by reversing the process whereby an electric current can electrolyse water into hydrogen and oxygen. In a fuel cell, hydrogen fuel reacts with oxygen in a flameless electrochemical process to produce electricity, heat and water. Their advantages over conventional fossil fueled power stations include high efficiency, extremely low emissions, low noise, no moving parts, low maintenance, ease of control, fuel flexibility, and clean heat production.

Fuel cells could well be the energy break-through of the twenty first century. Where natural gas or LPG is available, they could be installed in buildings and houses, to provide hot water, heating, and electricity, totally negating the need for power lines. The technology is being rapidly improved, and fuel cells may be economic in certain situations within 15 years.

References

1. Shaun Cornelius, Research Manager, Technical and Development Group

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9 Trade-offs and Resource Allocation Decision Making

9.1 Resource Management Act (1991)

Section 5 of the Resource Management Act is fundamental to the interpretation of the Act and how resource allocation decisions may be made. The section states:

"5. Purpose-

1) The purpose of this Act is to promote the sustainable management of natural and physical resources.

2) In this Act, " sustainable management" means managing the use, development, and protection of natural and physical resources in a way, or at a rate, which enables people and communities to provide for their social, economic and cultural well-being and for their health and safety while-

(a) Sustaining the potential of natural and physical resources (excluding minerals) to meet the reasonably foreseeable needs of future generations; and

(b) Safeguarding the life-supporting capacity of air, water, soil, and ecosystems; and

(c) Avoiding, remedying or mitigating any adverse effects of activities on the environment."

The imperative of this objective is to manage resources for peoples' needs and at the same time providing for future generations the ecological and environmental aspects. The use of "while" implies some sort of balance between "use, development, and protection" and (a), (b) and (c) above. Clearly this balancing process allows for adverse environmental effects of resource use to be offset by other enhanced beneficial effects. Rather than focus on how the Act may be interpreted, some examples of trade-offs that may need to be considered when making resource allocation decisions are suggested.

9.2 Regional Versus National Interests

The regulatory agency which administers the resource consent renewal for Manapouri is the Southland Regional Council. If the decision made significantly reduced the average generation from the station then this would have national effects. Replacement generation from further down the merit order would increase the average cost of generation and hence the price of electricity to all New Zealanders. Since the marginal station is usually fossil fuel plant, then any reduction in hydro generation results in increased emissions of CO_2, which makes the Government's task of stabilising net CO_2 emissions at 1990 levels more difficult. Each GWh of generation that is lost from a hydro station if replaced by generation from

Huntly power station results in emissions to the atmosphere of 565 and 982 tonnes of CO_2 for gas and coal firing respectively.

Government does have mechanisms available to it in the Act to influence resource allocation decisions via use of National Policy Statements, National Standards and call-in procedures. However the intention was to have regional bodies implementing the Act and central government would only deal with an application in exceptional circumstances. Also sometimes the connection to national issues from an individual resource consent is indirect.

9.3 Inter-Regional Effects

The relationship between installed capacity (MW) and generation (GWh) has been described in Chapter 7. If the potential generation available from existing installed capacity is reduced by the imposition of additional restrictions upon use of water for hydro generation, then the security of supply from the existing network is reduced. Hence to maintain a particular security standard (currently a secure supply for at least a 1 in 60 dry year) additional installed capacity will be required earlier than anticipated. Hence loss of water for existing hydro stations would bring forward the construction of planned stations like Tuapeka hydro or Taranaki combined cycle.

This emphasises one key feature of the trade-off issue. Often it is claimed that say additional uptake of energy efficiency means that there exists "spare generation" so that other local uses of water can be better catered for. However, any loss of generation arising from changes in the merit order and longer term effects, results in a range of different environmental outcomes. That is, there exist more fundamental trade-offs between different types of environmental outcomes rather than just regional and national or inter-regional balancing. If energy end use efficiency did manage to reduce electricity demand, then it would mean simply burning less fossil fuels, not using less water.

9.4 Reconciling Trade-Offs

Clearly a resource allocation process which attempted only to mitigate local effects would impose economic and environmental costs on other regions and the nation. The intention of this report is to allow the regional interests, represented on the Waiau Working Party, to understand how Manapouri power station is linked to the integrated ECNZ electricity generation network. Further, the unique characteristics of the Manapouri - Te Anau catchment influence how the hydro resource is managed and the resulting effects on the local environment. Consideration of these broader issues will assist the working party and hence the regional council to perform the balancing required in a complex resource allocation decision.

In addition to the balancing of economic and environmental effects mentioned above, this report includes information about some longer term issues related to future electricity supply.

These longer term factors are relevant when the lifetime of a hydro power station is considered as reflected the period of a resource consent. The lessons learned from the recent ECNZ energy efficiency study are important because it provides New Zealand with the opportunity to minimise the impacts of future expansions of energy supply. Similarly, New Zealand will benefit when emerging new generation technologies become economic and reliable, expanding the range of options available to meet future demand. However, these broader and longer term options for future supply do not potentially substitute for generation from existing hydro stations where the local environment has already been modified. It is important when planning to achieve the sustainable management of natural and physical resources that maximum generation is obtained from existing modified environments while avoiding, remedying and mitigating any adverse effects as far as reasonably possible. It is hoped that the working party and the pending consent renewal process can achieve an appropriate balance, without imposing additional economic and environmental costs on the nation and other regions, which allows the important generation from Manapouri to be maintained while identifying how the locally adverse effects can be best minimised.