GAS IN ELECTRICITY GENERATION

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Abstract

Gas is New Zealand's major thermal fuel for electricity generation. This paper describes what influences the volumes of gas burnt by ECNZ, and forecasts future gas demands for electricity generation. It also reviews the uncertainties associated with these forecasts and likely competition in building new electricity generating stations and outlines the strategy now being formulated to accommodate them. Because ECNZ's generation system is hydro-based, relatively small rapid changes in hydrological conditions can significantly affect the amount of gas used. This situation will change over time with major increases in thermal generation likely to be needed over the next 20 years. However, there are considerable uncertainties on gas supply and electricity demand levels in the long run, which will complicate investment and fuel decisions.

Introduction

Electricity generation constitutes a major market for natural gas in New Zealand with 55 PJ being used for this purpose in 1993. So far, only the Electricity Corporation, or ECNZ for short, burns gas in large thermal power stations.

Electricity generation is obviously an attractive market for natural gas. Thermal power stations burn large volumes of gas at a few points of delivery over long periods of time. These stations can also accommodate a wide range of gases of differing quality, without the need for expensive treatment to meet tight quality specifications. The potential to act as a "sink" for large volumes of gas is particularly important in New Zealand with its reticulated gas market too small to justify the development of a gas find of any significant size.

On the other hand, I must acknowledge that natural gas is an ideal fuel for thermal electricity generation. It is clean, flexible and convenient and with new technology can produce electricity at conversion efficiencies 50% greater than coal fired thermal stations.

It is not surprising therefore that the discovery of natural gas in New Zealand has aroused the interest of both your industry and mine about the possible use of your product in our stations.

Some Facts on Gas and Electricity

Indeed, when the Kapuni field was first discovered back in 1959, there was much debate whether the gas should be used in a power station on the site. It was probably for the best, although it pains me somewhat to admit this, that the gas was used to revitalise what was then a manufactured gas industry in terminal decline.

It is also worth mentioning that the Maui field was originally developed on the basis that 90 percent of its gas output would be used to fuel three, possibly four, power stations with a total capacity of just over 4000 MW. The petrochemical plants, built as a part of "Think Big", now use gas which was first earmarked for two large thermal plants which were to be located near Auckland.

Some people have rather unkindly remarked that electricity generation is a wasteful use of a valuable and scarce resource and that natural gas should be conserved by restricting its use to the most efficient and highest value end use. That is, for sale into the reticulated gas market some time in the distant future. I am concerned that such loose thinking may gain some credibility amongst the public and the nation's decision-makers during these times of concern about our long term gas supplies.

I would like offer the following points in rebuttal of this argument.

First, as noted in the Maui White Paper "...the (Maui) field's economic development was primarily dependent on there being available a user of the gas who would be both able and willing to commit itself to the purchase of very substantial quantities of gas under a long-term contract." As noted later in the White Paper "... power generation provided the only use for the gas at a realistic price in sufficient quantities."

The situation is still essentially the same, except that the petrochemical industry could also provide a market for large quantities of gas in the future. Talk about the national good and the needs of future generations is all well and good, but unless markets exist, resources are not going to be developed for either this or future generations.

Second, I would dispute that electricity generation is necessarily a wasteful use of gas. With the new combined cycle station technologies leading to conversion efficiencies of over 50% and recent advances in electrotechnologies the position is not nearly so clearcut for many applications. For example if electricity is used to provide precisely controlled drying via an induction process, not only does the energy advantage lie with electricity, but the product quality can be enhanced. When a mechanical process can be used instead of a thermal one a comparison of thermal efficiencies becomes meaningless. The advantage of using electricity can be as high as ten to one.

There are also a range of intermediate technologies, such as heat pumps, which enable electricity to be used with an effective end use efficiency of 300 to 500%.

In summary, electro-technology, including heat recovery, already provides a wide range of processes to use electricity at much higher efficiencies. This range is expected to expand quickly with the current international research focus on efficiency.

ECNZ recently received the inaugural "Green Tick" award from the Royal Forest and Bird Protection Society because of the steps it is taking to introduce these technologies to New Zealand.

New Zealand's Electricity System

In a year of normal hydrological inflows about 75 percent of ECNZ generation is hydro, 7 percent from the geothermal stations and the remainder of about 18 percent from the thermal 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 hydro generation depends on highly 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 figure 1.

New Zealand river flows are highly variable and in terms of potential generation from existing stations, figure 2 shows the wide deviation possible from the mean system capability with annual variations in inflows ranging from plus 34 percent to minus 20 percent of mean.

These variations are even more dramatic on an individual catchment basis where changes of plus 42% to minus 85% have occurred on an annual basis. Short term inflow fluctuations can be up to 400% during a period of flood conditions.

It is important to note that North Island peak electricity demand and inflows occur at the same time in winter while for the South Island demand and inflows are out of phase. This gives ECNZ the opportunity to transfer electricity from the South Island to the North Island. However, 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 nine South Island storage 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 is equivalent to about 12% of annual demand. In contrast, some overseas systems can hold several years' inflows.

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.

Life is made even more difficult because 66% of our total storage is in Lakes Tekapo and Pukaki which are contained in one catchment. The water shortage period of 1992 showed what impact low levels in these two lakes could have on the whole generation system.

ECNZ's daily, weekly, and annual generation patterns influence how the electricity system is operated. The annual planning cycle is implemented 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

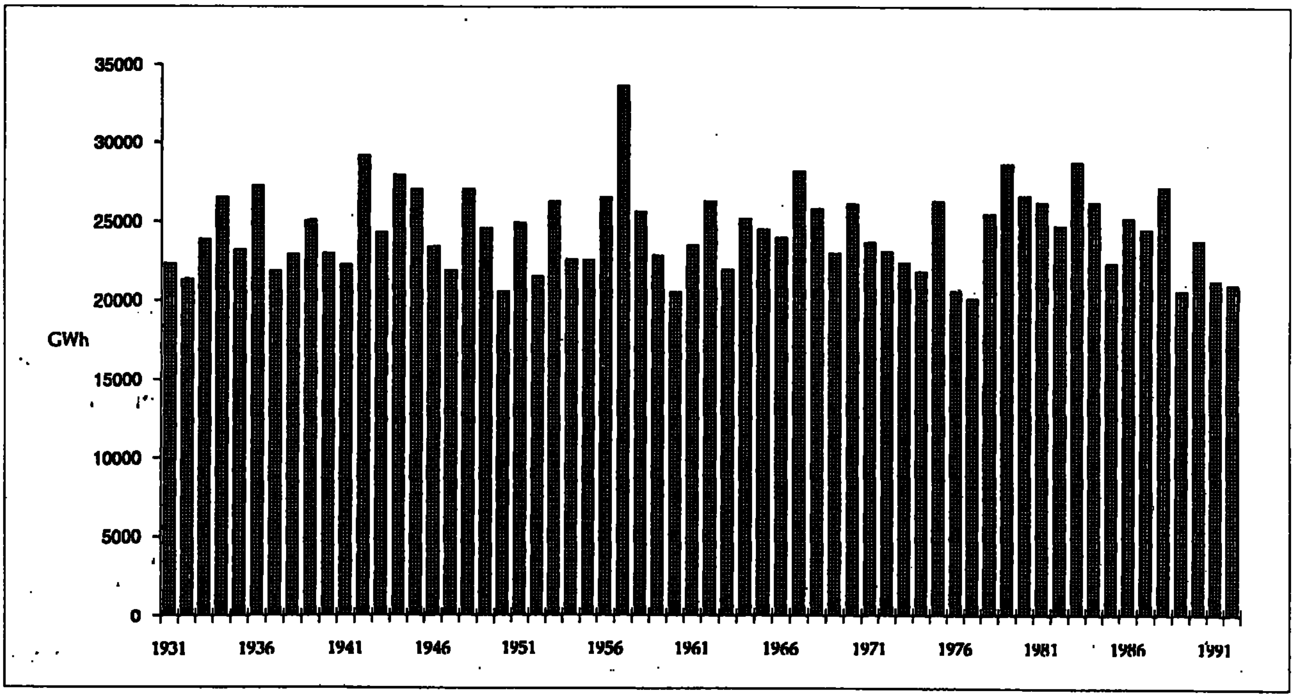

Fig. 1. New Zealand inflow potential generation.

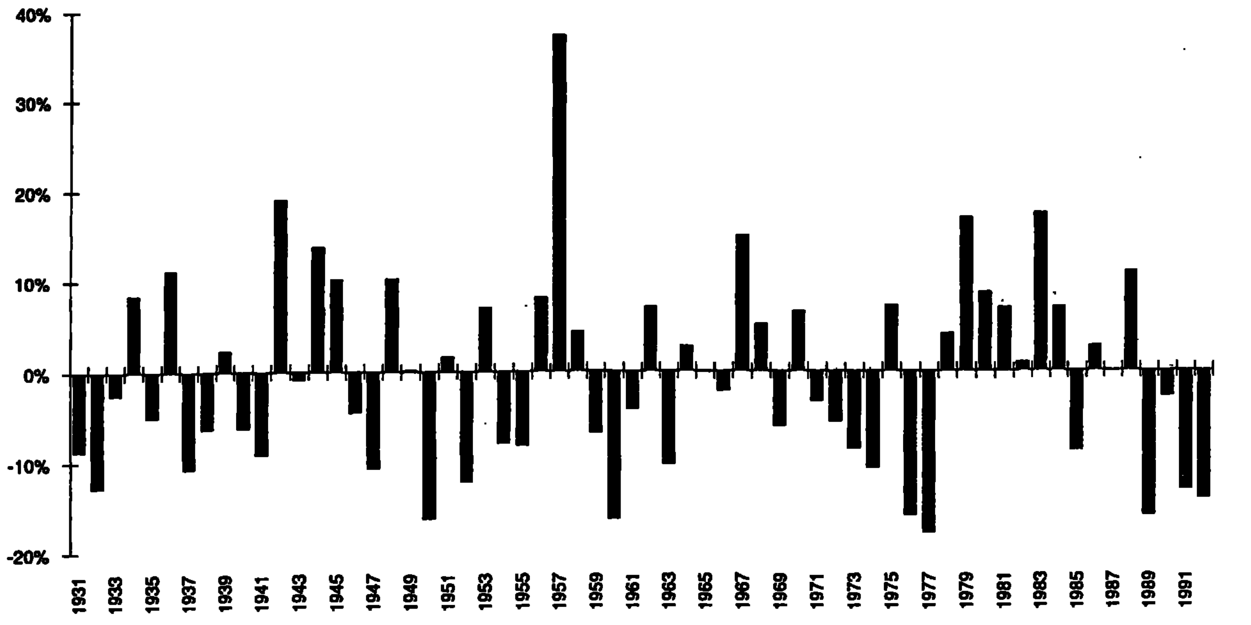

Fig. 2. New Zealand inflows: deviation from mean.

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.

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 storage is 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 illustrated in table 1.

Power stations 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 cheapest to the most expensive to minimise cost. 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.

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

Table 1. Sample merit orders for the operation of power stations.

Merit Order 1	Merit Order 2
High SI storage	Low SI storage
Low NI storage	Very Low NI storage
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

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, henceforward 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.

Because hydro-electric generation meets between 68 to 83 percent of New Zealand's demand and there is only limited water storage, relatively small changes in hydrological conditions or expectations can have a disproportionately high effect on our consumption for thermal fuels. This makes it impossible for us to forecast what our gas burn will be even in the relatively near future. This is illustrated in figure 3 which compares the forecasts for Maui gas made at the end of April 1993 for the following three months against the actual burns.

This lack of certainty and the wide variations between forecasts and gas takes have caused some concern amongst those folks at Shell Todd Oil Services responsible for shipping LPG and condensate.

In short, the thermal stations simplify the operation of the system and give ECNZ the ability to make better use of our water resources.

Of ECNZ's six thermal power stations, three (Whirinaki, Marsden and Otahuhu) are restricted to emergency generation at present. The other three (Huntly, New Plymouth and Stratford) predominately use gas. It is important to note, though, that the Corporation places a considerable premium on flexibility for both operational and strategic reasons. Accordingly, Huntly is fully dual fired with coal, Otahuhu can also burn diesel while the New Plymouth station can be converted back to oil. Incidently, at the current time, coal is cheaper to ECNZ than Maui gas.

None of these stations, apart from Stratford, have contracted fuel available to them over their expected economic lives. Maui gas is expected to provide only 20 percent of ECNZ's fossil fuel requirements in the year 2009. The remainder will have to come from coal, more natural gas, and liquid fuels. This gap offers both a challenge and an opportunity to your industry.

Future Investment

As you know, the electricity generation industry is characterised by large investments with long economic lives. The demand for our product is linked to a number of macro-economic and socio-economic factors beyond our control. Because of our size and monopoly status we are subject to intense public and political scrutiny. Our experience with the Marsden B power station is an illustration of what can happen if one or two major assumptions are significantly astray.

It will not surprise you to be told that ECNZ dedicates considerable resources and effort to forecasting future demand and investigating and progressing a wide array of development options. To minimise its commercial risks, ECNZ has already implemented a large number of efficiency improvements to our existing facilities which have increased our baseload generation capacity by 120 MW since 1986. This is in addition to over 1000 MW of extra capacity gained from the improved availability of existing plant by better maintenance and operational management practices. These have proved extremely financially beneficial to the Corporation. There is still the potential to add about another 150 MW of baseload generation and 80 MW of peaking capacity through system improvements.

Cogeneration and increased energy efficiency also have the potential to significantly defer the need for more generation capacity. However, this potential will not be realised to any degree until and unless electricity prices are set on economically rational grounds. I am surprised that this irrefutable fact has not yet been grasped by those who castigate the Corporation for not doing more to dampen down electricity demand and to encourage more energy efficiency.

Whatever effects these types of activities will have on electricity demand, it is clear that sooner or later additional generation capacity will still be needed. It should be remembered that during the recent period of low or negative growth in gross domestic product, electricity demand still increased by about two percent annually.

I think it would be useful at this point to explain in some detail how we plan for additions in future generation capacity. As a first step we review future generation requirements on a regular annual basis. This is a very sophisticated process which begins with a number of scenarios involving differing growth rates, the impacts of environmental constraints,

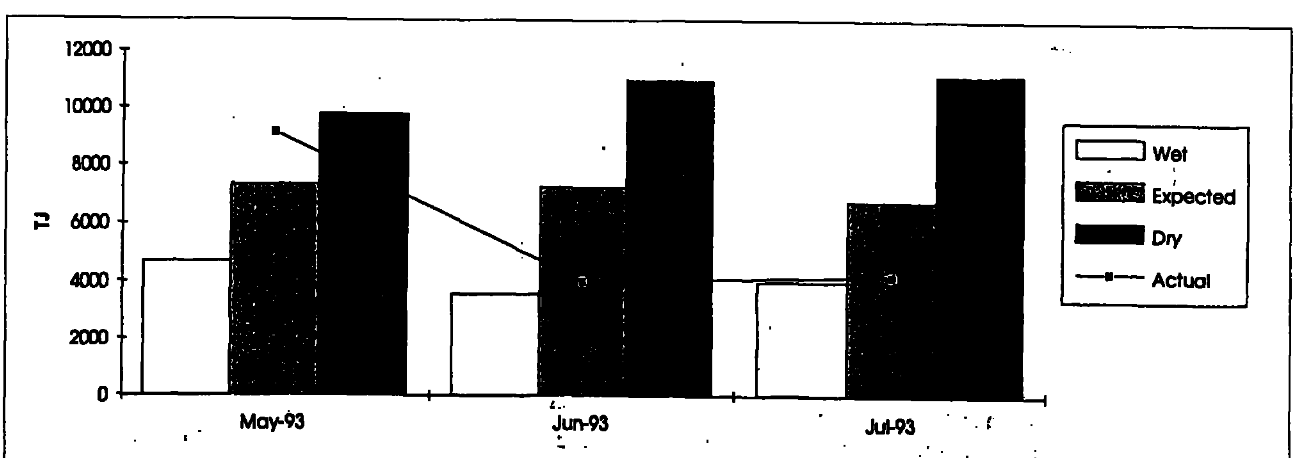

Fig. 3. Forecasts for Maui gas burns made against actual burns.

possible changes in Government policy and assumptions about fuel supplies, such as gas availability and coal prices. ECNZ then forecasts electricity loads 30 years ahead for each scenario. These incorporate assumptions about electricity prices, GDP, major industrial developments and population profiles.

This data, together with relevant engineering, financial and cost data and over 60 years of water inflow statistics, is processed by our simulation model to determine the total cost of operating the generation system for the next 30 years. The reports generated through this process are used to assess the least cost means of meeting the selected demand profile. In effect, this determines what should be built and by when.

Steps are then taken, through our investigatory and development programme, to ensure that projects are available for commissioning by the earliest date required by any of the high probability scenarios.

There are more than 60 development options which have been assessed as part of this process. Most of these are at various stages of investigation by ECNZ.

While I can't talk about the detail of these options and the outcomes of the planning exercise because of their commercial sensitivity, I would make the following points:

- There is obviously a great deal of redundancy amongst the development options under study. This gives us the flexibility to add or delete specific projects from consideration because of improvements in technology, changes in circumstances, or changes in fundamental assumptions and costs. For example, there are a range of options under consideration to meet ECNZ's thermal needs requirements in the future. These include burning Orimulson at Marsden, coal at Huntly and oil in combined cycle stations.
- While gas is an important fuel to ECNZ, the price we can afford to pay for it will be set by the cost of the cheapest alternative form of generation.
- The role of thermal fuels will shift from that of hydro-firming" to more that of meeting "base-load" demand. This shift in emphasis will have to be reconsidered if the Government introduces a Carbon Tax. This will favour other ways of adding to generation capacity.
- ECNZ is now seriously considering renewables such as wind generation because of recent improvements in both performance and cost-effectiveness. Wind generation may be economic from the year 2000 onwards.
- ECNZ has no legal obligation or commercial incentive to add the next increment of generation capacity. Indeed, there are strong strategic advantages for the next plant to be built by a third party. Indeed there have been a plethora of announcements by electricity retailers and others about their intentions in this regard. For our own planning purposes we have included what we have regarded as the most likely of these in our exercise.

As I mentioned earlier, a key variable in planning for this additional capacity is what will actually happen to demand. Figure 4 sets out the forecast demand for fossil fuels, ignoring hydrological variations, and shows what will happen over our planning horizon under two of ECNZ's many demand scenarios. The Status Quo case assumes that electricity demand will continue to grow at 2 percent while the Export Led Growth scenario presupposes electricity demand growth of 4 percent.

The Future for Gas and Electricity

While we have a few years' grace, it is obvious that additional capacity will be needed from about 1997 onwards, unless there are major gains through energy efficiency and

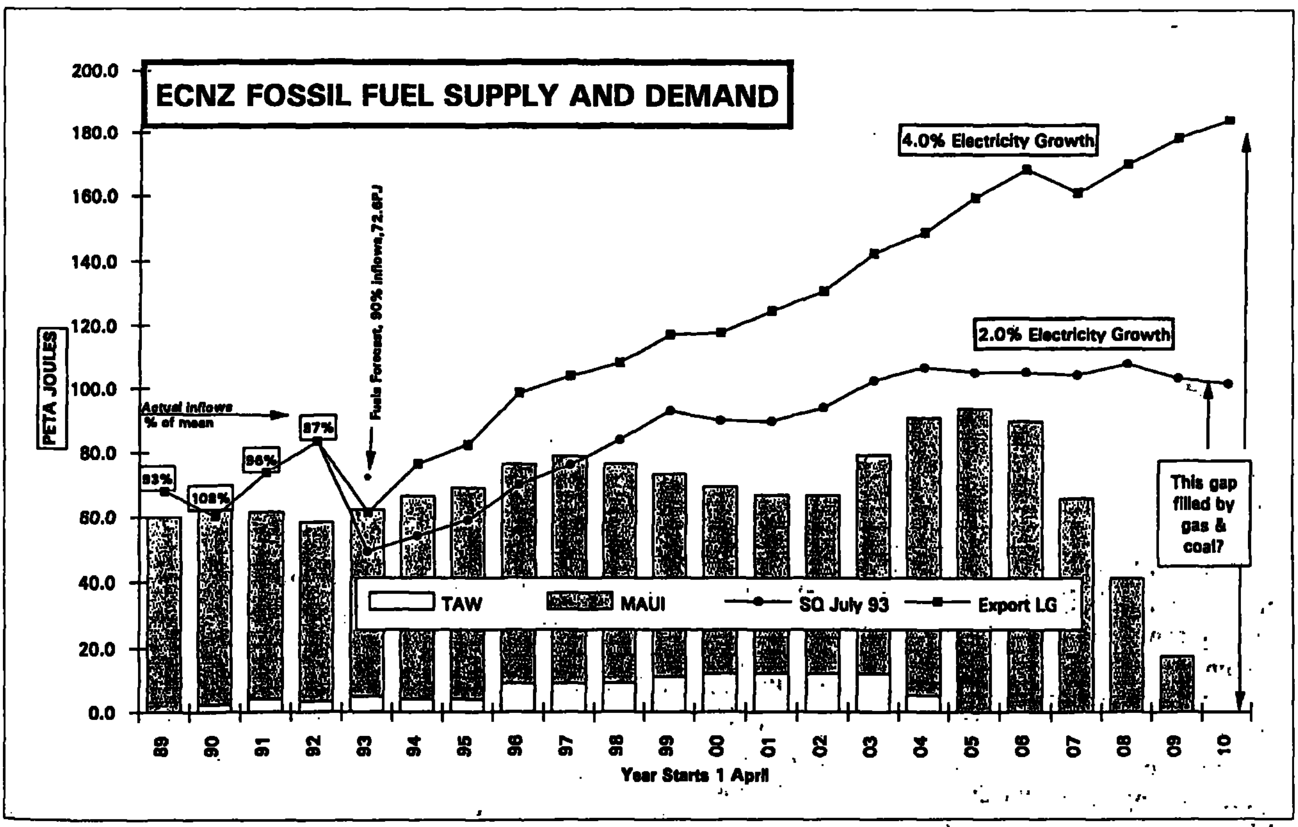

Fig. 4. Forecast demand for fossil fuels.

cogeneration. Our analysis indicates that, providing gas is available, a combined cycle station in Taranaki is the preferred option. However, there is a range of other possible projects whose economics are close enough to make them viable contenders if any of the basic assumptions underlying the decision to progress the combined cycle plant are wrong.

The key to a combined cycle power station is a long term source of gas. This will require further exploration and subsequent discovery. Therefore, ECNZ are currently considering encouraging further exploration for gas by standing in the market with a "take option" with a predetermined price and volume up to some agreed maximum. The intention is to encourage gas field explorers with a guaranteed market for the gas, before exploration begins, because of the perception that the small New Zealand gas market can be glutted by the discovery of a modest gas field.

The construction of new generating capacity would need to be undertaken on a commercial basis, whether it was done by ECNZ or another party. This means that the price of electricity would need to rise from present levels towards the long run marginal cost of the electricity generated by the new plant, to ensure a commercial return on the investment involved.

I have presented this paper in the expectation that the fortunes of our two industries will become more intertwined over time. The more we know about each others' intentions, drives and challenges, the more likely we are to achieve our respective objectives.

This dialogue has already started. ECNZ has recently had some very constructive interactions with some of the local petroleum explorers and we are hopeful that we can work together in the future for the benefits of both our industries and New Zealand as a whole.

Author

KIERAN DEVINE trained as an electrical engineer gaining Bachelor of Engineering (BE) Honours in 1975 and a Master of Engineering (ME), Electrical, from the University of Canterbury, New Zealand, in 1976. Research concentrated on the development of a battery-powered town car. He undertook additional business training, gaining a Master of Business Administration (MBA) awarded with Distinction, from Victoria University of Wellington, New Zealand, in 1989. He researched management control in the largest 200 New Zealand commercial companies.

Currently, Kieran is a Registered Engineer in New Zealand, and a member of: Institution of Electrical Engineers, London; Institution of Professional Engineers, New Zealand; and Institute of Electrical and Electronic Engineers, USA. He is presently employed with the Electricity Corporation of New Zealand Limited as Fuel Resource Manager, based in Wellington. He is responsible for the operation and control of ECNZ's 38 power stations, including the provision of all fuel resources, 80% of which is water.