The future of thermal power generation in New Zealand - implications for a greenhouse policy

Janice Wright
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TE WHARE TAOKA MO KA KAIWHAKAHAERE
CENTRE FOR RESOURCE MANAGEMENT

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1 Introduction

1.1 Background

This study focuses on a potential conflict between economic policy and environmental policy in New Zealand. On the one hand, New Zealand has an economic policy of deregulation; on the other, an environmental policy aimed at limiting greenhouse gas emissions is being developed. The first has been a hallmark of Labour's economic reform since 1984; the second reflects the tremendous concern that has arisen over the threat of global climate change.

It is likely that a greenhouse policy will soon be formulated. In a number of other countries, limits on greenhouse gas emissions have been targeted. For instance, the Norwegian Government has set a target of 50% reduction in 1980 carbon dioxide emission levels by 1993 (Bye, *et al.*, 1989, p.32). Is such a target achievable in a deregulated economy?

One of the aims of deregulation is the opening up of electricity generation to competition. Electricity supply authorities may soon own power stations. One competitor, the giant multinational, Consolidated Zinc Rio Tinto Australia (CRA) showed signs recently of wanting to break Electricorp's monopoly. The CRA proposal was for a 1000 MW coal-burning power plant at Bream Bay in Northland. A simple back-of-the-envelope calculation on the carbon dioxide that would be emitted by this proposed plant triggered off this study. This single power plant would increase energy-related carbon dioxide emissions in New Zealand by about 30% and it seemed to us that this would more than negate any strategies aimed at reducing carbon dioxide emissions.

While this report was still in a draft form and undergoing review, the immediate issue was defused by an announcement from CRA that the Bream Bay plant was to be deferred indefinitely. Shortly afterward, Electricorp announced that the mothballed Marsden B power station is to be commissioned. In the light of these announcements, we have made some minor changes to the report but believe the analysis will still prove useful, even if rather hypothetical.

The advertisement in the Northern Advocate (30/3/90) announcing the deferral of the Bream Bay power station is interesting because of the mixed message. On the one hand, it is implied that opponents of the plant are to blame.

"As with most large industrial developments, there appears to be a group of committed opponents. In the end the community and the nation have to make the decision. They will have to decide on the balance between no development and development with a high standard of environmental protection bringing associated benefits of investment, economic growth and jobs."

However, the statement ends by saying that the power plant has been deferred because there will probably be no market for the power for some time.

"There has been a strong view that no new electricity generating capacity is needed in New Zealand until after the year 2000, which may be correct. It was only the long lead times with power station projects that led to the recent activity on the project. Therefore, having completed the latest round of studies, there is unlikely to be further substantial work on the project for some time to come, probably several years."

This paper focuses on the specific case of the Bream Bay plant. But underlying this case study is the broader question of whether the current institutional environment is likely to produce outcomes consistent with the widespread concern over climate change.

1.2 Objectives

The study began with the following four objectives.

(a) To examine the impact of the proposed coal-fired power station at Bream Bay on emissions of greenhouse gases.

(b) To look at the system of electricity supply, demand and transmission in New Zealand - both present and planned - in order to understand the rationale for building the Bream Bay plant.

(c) To examine whether economic policy is in conflict with a greenhouse (environmental) policy.

(d) To examine whether such conflict, if it exists, is inevitable.

The first two objectives are covered by Sections 2, 3, and 4. The last objective is the subject of Section 5 and the third objective runs as a theme through the whole report.

2 Thermal generation and carbon dioxide emissions in New Zealand

This section provides a brief summary of technical matters concerning carbon dioxide emissions from fossil fuel combustion. This is followed by a look at the history of thermal generation in New Zealand and an overview of current thermal generation.

2.1 Carbon dioxide from power plants

Most thermal power stations derive their primary energy from carbon-containing fuels. The quantity of carbon dioxide released to the atmosphere per unit of useful (end use) energy is not simply a matter of the chemical composition of the fuel. It depends on a number of factors, the main ones of which are listed below.

a) The chemical composition of the fuel.
b) The heat (enthalpy) of combustion of the fuel.
c) The efficiency of conversion of the heat of combustion to electricity.
d) The efficiency of use of the electricity in its final application relative to the efficiency with which the primary fuel (or alternative energy sources) can be used to achieve the same final end.
e) The post-combustion treatment of the flue gases in the power station.

For most purposes, the chemical composition and the heat of combustion can be combined to produce an indication of the basic amounts of carbon dioxide produced per unit heat of combustion of a carbon fuel. This has the advantage that it gives a more readily used measure in doing energy/pollution calculations. It is notable that for any given fuel type, the variation in carbon dioxide/energy ratio is significantly less than the individual variations in the carbon content and the energy/mass ratio.

Carbon dioxide emissions are expressed either as tonnes of carbon or as tonnes of carbon dioxide. One tonne of carbon is equivalent to 3.7 tonnes of carbon dioxide. We shall express all emissions in terms of **carbon dioxide.** Table 1 shows carbon dioxide/energy ratios for different fuels.

The figures in Table 1 are consistent with those quoted by Grant (1989) and by Whitney and Hennessy (1989) who give a very consistent 92 +/- 3 kg CO_2/GJ over a wide range of types and calorific values of New Zealand coals.

From Table 1 it can be seen that coal-burning power stations are roughly twice as bad as gas-burning power stations from a greenhouse perspective.

Table 1. Carbon dioxide produced by various fuels.

Fuel	Carbon content %w/w	Heat of combustion MJ/kg	CO_2 production kg CO_2/GJ
Methane	75	55.6	49.5
Coal	55 - 87	22 - 34	86 - 101
Petroleum	85	45	70
Wood	44	12 -14	117 - 130

2.2 The historical shift toward thermal generation

Between the 1920s and 1970s, the electricity generating system in New Zealand developed around the use of hydro and geothermal resources to provide base and intermediate load with thermal stations providing peaking capacity. This pattern changed in the mid-1970s with the expectation of using large quantities of natural gas from the Maui field to fire base-load thermal power stations in the North Island (Stratford, New Plymouth, Otahuhu and Huntly). Increasing use of coal for electricity (Meremere and Huntly) to serve the growing demand of the Auckland region also occurred during the last decade.

Thus, in the space of two decades, there has been a marked shift in the mix of resources used for electricity as shown in Table 2 below. During this period, the amount of electricity generated from carbon sources increased 12-fold. Carbon dioxide emissions will have increased by a similar order of magnitude.

Table 2. Trends in the use of fossil fuels for electricity, 1965-85.

Year	Installed capacity		Electricity generated	
	Hydro/geo. %	Thermal %	Hydro/geo. %	Thermal %
1965	90	10	95	5
1975	79	21	86	14
1985	65	35	80	20

2.3 Current thermal generation and carbon dioxide emissions

There are eight thermal power stations in New Zealand, all owned by Electricorp and all in the North Island. Data on these power stations are set out in Table 3. Marsden B has never been commissioned.

Table 3. Existing thermal power stations.

Station	MW	No.Units	Type	Fuel
Huntly	960	4	single cycle steam	gas/coal
Marsden A	230	2	single cycle steam	H/F oil
Marsden B	240	1	single cycle steam	H/F oil
Meremere	144	5	single cycle steam	coal
New Plymouth	600	5	single cycle steam	gas/oil
Otahuhu	270	6	single cycle gas	gas/oil
Whirinaki	220	4	single cycle gas	oil
Stratford	220	4	single cycle gas	gas

The installed capacity of the country's electricity generation system and the relative use of fossil and non-fossil generating capacity in 1988 is summarised in Table 4. The figures refer to capacity owned by Electricorp and the Electricity Supply Authorities, but not other privately owned plant.

Table 4. Current installed electricity capacity and production in 1988.

Type	MW	%	GWh	%
Hydro/geothermal	4798	65	23250	81
Thermal	2591	35	5436	19
Total	7389	100	28686	100

Various estimates exist for the total carbon dioxide emitted into the atmosphere in New Zealand. Whitney and Hennessy's estimates converted to carbon dioxide are shown in Table 5. Figures supplied by the Ministry of Energy to the Ministry for the Environment (MfE, 1989b) are in substantial agreement with those in Table 5.

Table 5. Carbon dioxide emissions in New Zealand.

Fuel	Millions of tonnes/yr of CO_2
Oil and LPG	12.8
Gas	7.3
Coal	4.4
Wood	1.8
Total	26.3

The Ministry of Energy estimates that of this New Zealand total of 26 million tonnes per year, 3.9 million tonnes per year of carbon dioxide are discharged by thermal power stations. Thus, thermal generation is currently responsible for 15% of carbon dioxide emissions.

3 Prospects for thermal generation in a deregulated environment

Likely developments in the mix of hydro and thermal generation are now explored, for these will indicate some probable future trends in carbon dioxide emissions. The following is what we would expect to happen **in the absence of any large new thermal power stations such as that proposed for Bream Bay.**

We have considered a range of factors, some of which are resource-related and technical in nature and some that are institutional. There are also a number of uncertainties that must be taken into account.

3.1 Resource-related and technical factors

Potential sites for further hydro development in the North Island are very limited. Even if there are sites considered appropriate on engineering and environmental grounds, which is questionable, the relative economics for new hydro and thermal power stations could well favour the thermal option. Hydro stations have higher capital costs (MoE, 1984, p.58) and usually longer planning and construction times, which places them at a disadvantage when assessed on short-term financial criteria.

The existing HVDC link imposes a severe constraint on transferring electricity from the South Island for at least the next two years. Transpower has decided to proceed with an expansion from the current 600 MW capacity to 1200 MW with completion expected in 1992. Expansion will allow for an additional 5000 GWh per year from South Island hydro to meet North Island demand, although there will not be sufficient South Island hydro-electricity in dry years to take up all this expanded capacity immediately, even with Clyde commissioned. In the meantime, growth in North Island demand must be met from North Island generating capacity.

The Ohaaki geothermal power station in the North Island came on line during 1989. Assuming a 90% annual load factor (Wairakei's average during the 1980s), Ohaaki will contribute 850 GWh per year. Electricorp recently announced a six-month growth in sales of 567 GWh (4.1%). Although this growth is not sustainable, one further year of such growth would absorb Ohaaki's contribution.

In a dry year, less electricity is available from South Island hydro stations. In September 1989, South Island storage lakes were at their lowest level in 13 years (Electricorp, 1990), registering only 11% full. This resulted in an unusually large southward transfer of electricity across the HVDC link of 66 GWh during the December quarter (Electricorp, 1989).

The entire system has become increasingly energy constrained in recent years. There is plenty of installed capacity to meet peak demands, if all the available thermal generating stations are included. Thus, growth in overall demand is likely to be met by operating existing stations more of the time. Table 6 summarises average load factors for categories of generating station in the year to 31 March 1988. It indicates clearly that the greatest opportunity for increasing electricity generation from existing plant is in North Island thermal power stations.

Table 6. Average load factors in 1988.

Location & type	Average load factor (%)
NI hydro/geothermal	46
NI thermal	24
SI hydro	61

Note: These load factors have been averaged over each class of power station.

3.2 Institutional factors

Electricorp came into existence as a State Owned Enterprise on 1 April 1987. It owns 96% of all installed generating capacity in the country at the present time; thus its approach to managing electricity supply is a central consideration.

With the assets that Electricorp was required to purchase from the Government, the Corporation was faced with a clear surplus of thermal generating capacity in the North Island (Cox, 1989, p.3). This situation is not altogether disadvantageous. While surplus capacity makes it necessary to rationalise existing plant, it also gives the Corporation the ability to keep tariffs low, and falling in real terms, with the additional benefit of having incremental capacity that can be brought back on stream at a cost that is competitive with any new thermal power station (*op.cit.*, p.4).

Electricorp has adopted a pricing strategy of reducing tariffs in real terms (Electricorp, 1990, p.4), which will not only promote growth in electricity demand but also put the corporation in a strong position vis-a-vis competitors. The "success" of this strategy is reflected in the recent increased sales volumes mentioned earlier in this report. The growth in demand due to such a pricing strategy will lead to the production of more carbon dioxide, particularly while increased access to hydro generation for the North Island is constrained.

Electricorp is, in fact, planning (i) to rationalise plant utilisation, that is, mothball almost 500 MW of existing capacity and consider refabricating Whirinaki and Meremere power stations into a single combined-cycle station, and (ii) to promote greater use of the remaining thermal power stations as demand grows. The stations involved in temporary mothballing of generating units are scarcely used at present. The clear implication is that greater use can be expected to be made of the other thermal stations in future, giving a better return on existing assets, reducing the unit costs of thermal generation, and producing more carbon dioxide.

Competition among suppliers of fuels for electricity generation has resulted in lower prices for both coal and natural gas. For example, short-term coal contracts have been competitive enough to make coal-fired electricity from Meremere cheaper than gas-fired electricity from New Plymouth (Electricorp, 1990, p.5). Such a trend imposes less and less of a cost penalty on thermal generation compared with hydro.

3.3 Some uncertainties

Several factors add uncertainty to this assessment.

There remains uncertainty over commissioning the Clyde Dam. This is currently expected to take about a year, beginning in late 1990. If, because of problems with land stability, the filling of Lake Dunstan is substantially delayed or it is not filled at all, then significant increases in the use of North Island thermal stations will occur to meet growing demand. (This restricted view reflects entrenched attitudes of suppliers to the use of centralised generating plant but not the broader view offered by the technical alternatives that are not commonly acknowledged.) Even if Clyde is fully commissioned, its mean-year capability is equivalent to only three year's forecast growth.

Electricorp has to reapply for all its water rights by 2003 (Electricorp, 1990, p.2). These cover rights to water for electricity generation in all its hydro stations as well as the rights to use cooling water in thermal power stations. As well as granting an entitlement to use the water, the rights usually also stipulate upper and lower bounds on lake levels. The specific water right hearing currently in progress for the Western Diversion of the Wanganui headwaters involves an entitlement to about 10% of the North Island hydro generating resource. It is quite possible that the review process will result in reduced access to water for hydro-electricity generation. While Electricorp presently pays no resource rental for the water it uses, as a result of an agreement with the Government, this may change in the future.

Demand forecasting is an uncertain and risky business, partly because of the rudimentary nature of the simple econometric methods traditionally used. There is a large difference between the 4.1% demand growth in the last six months and the 2.1 % per annum growth predicted using econometric models. The recent rapid growth in electricity demand creates problems for system planners. No matter how desirable it may be from a commercial standpoint, such growth is not sustainable; it translates into a doubling of total demand in about nine years! It implies large increases in carbon dioxide emissions as well as enormous demands for capital funds and the consequent economic impacts.

3.4 Conclusions

On balance, increased use of thermal power stations can be expected to meet the growth in demand anticipated in the short to medium term.

The pricing and marketing strategy adopted by Electricorp already indicates rapid growth in demand in the next few years, most of which will be in the North Island. When combined with the constraints and uncertainties discussed above, there seems little doubt that thermal power stations in the North Island will be used increasingly to meet this demand.

It is not difficult to speculate on the quantitative increases in thermal generation, but any speculation is founded on a host of uncertain assumptions. We would tentatively expect an increase in the use of thermal power stations over the next decade of the order of 30-50%.

What is certain is that increasing the use of thermal power stations is associated with increasing greenhouse gas emissions. We estimate that total energy-related carbon dioxide emissions in New Zealand would rise by 4-7% as a result of this greater use of thermal stations.

The rate at which this occurs will depend directly upon the growth in demand that eventuates and this, of course, depends on the sorts of signals electricity consumers receive. We should stress that our conclusions in no way suggest that Electricorp's pricing strategy is unusual for a commercially-oriented corporation functioning to best advantage.

4 The Bream Bay proposal

The focus of this report now expands from an emphasis on the corporatisation aspects of deregulation to explore the implications of opening up the electricity supply market to competition.

The question addressed in this section concerns the likely impacts on existing trends in thermal power generation from the entry of an independent supplier into the market.

There have been at least two competitors waiting in the wings - CRA with its proposal for a coal-burning plant at Bream Bay, and the Auckland Electric Power Board with its proposal for a combined-cycle gas-burning plant south of the Auckland isthmus. This report is particularly concerned with CRA's proposal.

In the interval between preparation of this report and publication, (as explained in Section 1), CRA announced that further work on the Bream Bay project is unlikely for several years. The proposed plant does remain a possibility and a "greenhouse analysis" of a large baseload coal-burning power plant still seems a useful exercise.

4.1 Background

We first examine factors that support or explain the choice of Bream Bay as a site suitable for a competitor in the electricity supply market.

The Auckland isthmus is a constraint to the existing centralised supply system in several ways. Firstly, past resistance to new transmission corridors through the isthmus means that there is a technical limit to the amount of electricity that can be carried northward. This constraint is most likely to affect peak power before it affects total GWh. However, there are ways of upgrading the existing link that would involve little change to its visual impact. Secondly, it is considered by some that the passage of all transmission lines through the narrow isthmus makes electricity supply to the whole Northland area vulnerable to disruption should the lines be damaged in any way. Thirdly, the isthmus constrains some of the other alternatives as well (see below).

Alternative opportunities for centralised generation north of the Auckland isthmus are limited. There is no substantial hydro potential and the Ngawha geothermal field is considered uneconomic at present. Marsden A is a functioning power station, currently used only for voltage stability reasons. The main limitation on its greater use is the cost and availability of suitable fuel; current estimates put electricity from Marsden A at 18c/kWh (Bertram, 1989). Marsden B has been mothballed since construction. Electricorp announced in May 1990 that Marsden B is finally to be commissioned although the fuel has not yet been chosen. Transport of coal or natural gas through Auckland is likely to be controversial.

Northland is one of the highest cost regions that Electricorp supplies, being furthest from its power plants. It is, therefore, probably seen as a region where Electricorp is most vulnerable to competition from an independent supplier.

Demand has been growing north of the isthmus at a much higher rate in recent years than for the country as a whole. Over the past six years, growth in demand has averaged 6.7% per year compared with 3.5% for the North Island as a whole and 3.8% for the South Island.

CRA proposes to use coal from its own mines in Indonesia or Australia, which is expected to be considerably cheaper than New Zealand coal. Another possible advantage of using imported coal might be that it would not be subject to any mineral royalties that might be considered in New Zealand.

The proposed Resource Management Act changes the rules for the granting of consents. The new role of regional councils and their primarily local focus of interest may well be seen as more favourable to a new regional development such as that proposed by CRA.

When CRA originally launched its proposal, it was probably influenced by issues concerning South Island hydro power availability and HVDC link expansions that had not been resolved at the time.

4.2 Carbon dioxide from the proposed Bream Bay plant

The proposal is described in an information paper from Electric Power Generation Limited (EPG), a subsidiary of CRA set up to pursue the concept of a privately owned generating facility in the Northland area. Specifically, the company has investigated the establishment of a 1000 MW coal-fired generating plant at Bream Bay between the Marsden Point refinery and the existing Marsden A and B power stations.

In the proposal there is an assertion that there is an existing overcapacity in the New Zealand generation system that will cease about 1995 and the company planned to have stage one, the first 500 MW of their proposal, operational by then. (This timetable is now changed as explained in section 1.) It is claimed that the proposal will only be implemented if it is confirmed as the lowest cost new source of base-load electricity.

The actual source of the coal is not stated although the EPG information paper asserts that "*coal with high calorific value, low ash and low sulphur content will ensure compliance with New Zealand environmental standards*", and "*the coal sources of primary interest for the study will be those already supplying the well developed international market from Australia and Indonesia*". The estimated coal consumption given in the information paper is 1.5 million tonnes per year for the first stage rising to three million tonnes per year when the second stage is built "*when required to meet load growth*".

In the absence of an exact analysis of the coal that would be burned at the proposed plant, precise predictions of the carbon dioxide emissions cannot be made. They can, however, be estimated in several ways.

Our first approach was to assume a reasonable estimate of the composition of the coal at between 63 and 84% carbon. For the stated coal consumption of the Bream Bay plant this leads to the first column of figures given in Table 7.

An alternative approach is to assume an efficiency for the generating station and to estimate the emissions from the kg CO_2/GJ column of Table 1. It appears from the figures quoted by EPG that the proposed station for Bream Bay is intended to be a single cycle pulverised fuel unit and this would have an expected efficiency of about 35 -37%. For a good single cycle base-load station we would expect an availability of 85-90% or perhaps even better. Using this efficiency, a figure of 92 kg CO_2/GJ for the emissions from coal, and the assumption that the station is base-load with an availability of 90%, the second column of figures given in Table 7 can be derived.

Table 7. Carbon dioxide emissions from Bream Bay plant.

	Millions of tonnes per year	
	Based on coal consumption	Based on power output
Stage 1 (500MW)	3.5 - 4.6	3.8
Stage 2 (1000MW)	7.0 - 9.2	7.6

Our next concern is to put these figures into the context of current New Zealand energy use and carbon dioxide emissions. Currently, thermal generation is responsible for the release of about 3.9 million tonnes of carbon dioxide per year.

The operation of only the first stage of the Bream Bay plant would double the annual carbon dioxide emissions from thermal generation.

In terms of the total emissions for the entire country, carbon dioxide from the proposed Bream Bay plant would represent about a 15% increase in the first stage and a 30% increase in the second stage.

It is perhaps worth noting that the Ministry for the Environment (MfE, 1989) has made rough estimates of the carbon dioxide emissions that could be averted by an intensive energy management and conservation programme. These add up to approximately 16% of current emissions. These reductions would be totally negated by the first stage of the CRA plant.

4.3 Would the Bream Bay plant retire less efficient plant?

One of the arguments for the Bream Bay plant is the possibility that it can replace older less efficient (and hence more polluting) power plants. This possibility can be examined in detail for a particular case only if one has access to details of all the existing plant, all the load data, and all the alternatives for the future. Of particular interest are the figures for the installed capacity, efficiency and current production of existing large thermal generating plants as listed in Table 8. An availability of 85% has been assumed.

Table 8. Performance of existing thermal generating plant in 1988.

Plant	Efficiency (%)	Capacity (MW)	Output Max (GWh)	Output Actual (GWh)	CO_2 (1000 tonnes)
Meremere	21	144	1072	100	165
Marsden A	31	230	1712	import	-
New Plymouth	32	600	4467	1002	532
Huntly	35	960	7148	3877	2300
Stratford	25	220	1638	76	53
Whirinaki	25	220	1638	1	1
Otahuhu	25	270	2010	1	1
Total		2644	19685	5057	3,052

Note: The discrepancy between the two estimates of carbon dioxide emissions - the 3.9 million tonnes/yr in Section 4.2 and the 3.0 million tonnes/yr in this table is attributable to three causes:
(i) differences in the estimates of carbon dioxide/energy ratios;
(ii) the fuel used in spinning reserve;
(iii) the fuel used in stations such as Marsden A where there is a nett import of electricity.

These figures illustrate two things. Firstly, all but Marsden A have been used as peaking stations at some time and, secondly, none has been used as a base-load station. Indeed apart from New Plymouth in 1983 and Huntly in 1986 and 1988, no stations have been significantly over a 50% annual load factor in the last six years.

At first sight, the only station that could be retired would appear to be Meremere. Transfer of Meremere's load to a station of 35% efficiency using coal would reduce the carbon dioxide emission by a tiny 60 thousand tonnes per year.

It is clear from these figures that the introduction of a new 1000 MW thermal generation base-load station burning coal would have a major impact on the carbon dioxide emissions of New Zealand that could not be mitigated to any extent by retiring existing plant. There is practically no lower efficiency plant that can be retired and the effect of the new plant would be to add a minimum of about seven to eight million tonnes per year to the present load of 26 million tonnes per year of carbon dioxide.

5 Greenhouse friendly alternatives

5.1 Introduction

In this section technical alternatives to additional coal-fired generation at Bream Bay that will produce less carbon dioxide are examined. It should be made clear that the choice of an alternative is not simply a choice between the large centralised electricity generating alternatives - hydro, gas, oil, coal and nuclear. These major electricity supply options provide generating capacity in large units generally of 250 MW or more. Many of the other options described below provide supply or substitute for electricity consumption in very small units and thus offer **the opportunity to cope with demand growth in an incremental way.**

There are five main classes of alternative - energy management/conservation, increased transmission capacity, direct use of fuels, increased efficiency in burning fuels and substitution with "renewable" energy. Each of these is discussed in turn.

It must be noted that the Bream Bay proposal is for power station development in two stages each of 500 MW, each stage consisting of two 250 MW alternators. The alternatives are, therefore, discussed, where possible, in terms of blocks of energy corresponding to baseload generation at 250 MW. In other words, alternatives that involve blocks of energy of about 1850 GWh (corresponding to 250 MW at 100% load and 85% availability) are sought.

5.2 Energy management and conservation

The history of electricity in this country has so far revolved around the development of centralised generation. The pattern of development reflects the natural resource opportunities - hydro, geothermal, coal, natural gas, and imported oil. What, so far, decision makers have failed to recognise is the potential for "generating" electricity by improvements in end-use technology - sometimes referred to as the "fifth fuel". The scale of this potential is commensurate with the total level of electricity supply.

Examples of the "fifth fuel" are computer control of heating and ventilation in commercial buildings, and more efficient lights that produce the same light intensity from less power. There are a multitude of such systems that operate at the microscopic end of the energy chain.

There is enormous potential for economic electricity "generation" from energy management. However, the "resource" is complex and diffuse and a detailed analysis is beyond the scope of this report. The Ministry for the Environment's preliminary and very approximate estimate of the potential for reductions from energy management are about 77 PJ per year in energy and about 3.8 million tonnes per year of carbon dioxide.

5.3 Increased transmission capacity

The HVDC link is to be upgraded by 1992 - an action that will help prevent the absurdity of burning coal in the North Island while water is spilled in the South Island. This cable is believed to be of 1200 MW capacity, which will allow for another 600 MW to be sent north assuming that the power is available. The installed capacity of the Clyde station is 432 MW which will about match the new cable's extra capacity.

In the long run, however, it is not simply the installed capacity of the generating stations and the cable that matter but rather the relation between the river flows, the storage capacities of the hydro lakes and the load patterns that determine how much electricity can be sent from south to north (and vice versa). This is a matter for detailed modelling of the whole generation and transmission system which is outside the scope of this study (and is, presumably, being carried out on a continuing basis by Electricorp). The maximum possible assuming that Clyde comes on stream is about an extra 500 MW peak load and perhaps 250 MW average. This corresponds to an annual reduction of about two million tonnes of carbon dioxide from future North Island generation.

5.4 Direct use of fuels

Burning fossil fuels to generate electricity incurs a high energy penalty; two thirds goes up the stack. Gas can be burned directly for heating at an efficiency of 60-90%, whereas if the gas is first converted to electricity, the overall efficiency of heating is only about 32% (including transmission losses).

If we assume that half of the electricity generated in thermal stations is used for heating and that this is replaced by direct use of the fuel at an efficiency of 66%, then a 25% reduction in fuel consumption (and in carbon dioxide production) would be achieved.

5.5 Increased efficiency in burning fuels

There are a number of ways in which fuels can be burned more efficiently to generate electricity than in the proposed Bream Bay plant.

Firstly, the design of the Bream Bay plant could be modified to a combined cycle system. Until recently, combined cycle generation was confined almost exclusively to gas- and oil-fired systems because of the difficulties in firing gas turbines from coal. However, there has been a move to integrated coal gasification combined cycle (IGCC) systems in which the coal is first gasified. Demonstration plants using this technology are currently under construction. Construction of the Bream Bay plant as an IGCC system would reduce the carbon dioxide emissions from about 8.4 million tonnes per year to about 7.0 million tonnes per year.

Secondly, existing power plants could be converted to combined cycle operation. Conversion of both New Plymouth and Huntly to gas turbine boosted combined cycle offers the possibility of an extra 400 MW or more of total capacity for a carbon dioxide emission of about 650,000 tonnes per year. In other words, these two stations could generate 40% of the output of the Bream Bay plant but it would be accompanied by 80% less carbon dioxide per GWh.

A third possibility is the use of natural gas to upgrade the use of geothermal fluid for power production. This possibility arises because New Zealand's geothermal generating systems are based on a supply of superheated water from which steam is flashed to feed the turbines. The possibilities here range from gas-fired superheating of the flashed steam to the use of the geothermal fluid as the preheating source for the boiler water to a very large gas-fired system. The marginal efficiency of the use of the gas varies depending on the manner in which it is used and the scale on which one wishes to generate from a particular geothermal source, but it can always be arranged to be significantly higher than that of a simple Rankine cycle or of a combined cycle. The carbon dioxide emissions would be correspondingly lower. A range of possibilities has been discussed in some detail by Dobbie (1979 and 1985) and it seems unfortunate that these possibilities have apparently been overlooked in recent geothermal developments.

A fourth way of raising the efficiency of fuel use is cogeneration. Cogeneration is the generation of electric power in conjunction with the production of low temperature process heat from the combustion of high temperature fuels or by using waste heat from industrial processes. This has been discussed in detail in the past (Wallace & Williamson, 1984, Dobbie, 1979 and 1985). The most recent survey by Zoellner (1990) lists 43 existing installations with cogenerating capability totalling 157 MW.

Because cogeneration uses the excess temperature of the fuel combustion above that required for the process, it generates electricity at a very high marginal efficiency (85-100%) and therefore produces 50-60% less carbon dioxide per kWh even than new combined cycle installations.

The potential for further cogeneration plant depends on the price of electricity that the cogenerator can avoid or can realise by selling back to the grid (these are not necessarily the same). In many cases the economics have been muddied because of the difference between the price charged for bulk supply from the grid to the supply authorities and the cost of cogenerated electricity and the long run marginal cost of new generation. Depending on how these are related, one can arrive at economic cogeneration capacity of from 150 to 500 MW and from 600 to 1200 GWh per year. This corresponds to from one sixth to one half of the installed capacity and from one twelth to one sixth of the energy of the Bream Bay plant.

Because of the structure of the electricity generating and distribution industries in New Zealand it has not in the past been easy for the two parties most concerned with cogeneration, namely the generating group (Electricorp) and the cogenerating group (industry), to come to suitable commercial arrangements of benefit to both. In fact, potential cogenerators in New Zealand have been actively discouraged by pricing structures and other means. It is noticeable that in countries where there is only one commercial boundary between the main electricity generating company and the consumer (potential cogenerator), much more progress has been made in the implementation of cogeneration.

5.6 Substitution by renewables

There are many "renewable" technologies for electricity generation or substitution. For example, Electricorp has been carrying out investigations for wind turbine sites and also considering wave generation for the Chatham Islands.

We have selected one "renewable" technology with which we are very familiar - domestic solar water heating - for assessment. In what follows, a comparison of this "soft" dispersed energy source and a thermal power station is made.

The technology for solar water heating is well developed and a range of types of equipment suitable for various applications is available. It is clearly not convenient to try to provide all of a household's hot water energy from the sun since this would require an inordinately large installation. Experience has shown that for New Zealand conditions it is appropriate to design for the provision of about two thirds of the annual hot water energy to be supplied from the solar system. This means that a typical solar installation should aim to provide around 2500 kWh per year.

We estimate that at least 50% of New Zealand's one million houses would be suitable candidates for solar water heating. The potential for substitution is thus about 1250 GWh per year.

This translates to one third of the output of the first stage of the Bream Bay plant, about one third of the present output of Huntly or 12 times the present output of Meremere. In terms of carbon emissions, this would eliminate the need for a thermal station that would burn about 500,000 tonnes of coal per year and emit 1.4 million tonnes of carbon dioxide per year.

One analysis showed that solar water heating using a system available at that time could produce hot water at an equivalent cost of around six cents (1985) per kWh (Wright & Baines, 1986). This analysis has been updated to give nine cents (1990) per kWh. The cost would be lower with large scale production of solar systems.

The cost of electricity "supplied" from a domestic solar water heater should be compared with the marginal cost of power **delivered** from centralised power plants. Estimates of marginal cost are very dependent on the characteristics of the particular power plant under consideration. We estimate the **delivered** cost of electricity from new thermal plant such as that proposed by CRA to be from nine to twelve cents (1990) per kWh if the fuel can be obtained cheaply; that is, the coal would need to be purchased at about $80 per tonne.

However, the domestic solar hot water option barely competes with the average cost of electricity as it is presently sold to consumers. In particular, the option cannot compete with off peak domestic rates. This problem again can be traced to the fact that electricity is generated and transmitted by one agency (Electricorp) that sells it to a second agency (the Electricity Supply Authority) at some kind of average price. The second agency distributes the power locally and sells it to the consumer. These two commercial boundaries act like "crossed" polarisers so that the generating agency that could benefit from solar water heating and, the consumer, who under the current arrangements would pay the capital cost of the installation, never "see" each other. As a result there is a classic non-market situation where the costs and the benefits accrue to different parties.

One of the advantages of solar water heating is that the substitution releases energy in the area in which the increase in demand occurs, and there is therefore less need for new transmission lines from remote generating stations. Solar water heating also has the advantage that it can be implemented at a number of rates since the quantum of installation is small. This is also a disadvantage. At the moment the scale of the industry is very small, so that overheads are large and costly labour-intensive methods are used.

Another advantage of an industry of this kind is that it is sufficiently flexible to respond to changing conditions. For example, if it turned out that for some unanticipated reason solar water heating were not a good thing, one would not be faced with the question of whether or not to abandon a programme into which tens or even hundreds of millions of dollars had been sunk and out of which nothing had come. Abandoning a solar water heating programme, for whatever reason, would leave one with the advantages of the equipment already installed up to the point of cessation and the only real loss would be the few million dollars in manufacturing plant.

Solar water heating is not the only substitution industry that should be considered; however, it is an outstanding example of a neglected opportunity.

It is worth noting that in the very long run it may prove possible to incorporate solar electricity generation into the system. Present technology is capable of producing electricity from solar energy either by direct (photovoltaic) methods or by indirect (solar thermal) methods. The largest solar thermal installation at present is in California and has a capacity of 300 MW with a further 300 MW to be installed by 1992. The cost of the electricity is claimed to be eight cents (U.S.) per kWh, which is competitive with nuclear excluding the costs of decommissioning and fuel reprocessing (Luz Engineering, 1990). The scale is certainly appropriate for consideration in terms of plants like Bream Bay.

The cost of solar electricity is still significantly higher than that of conventional thermal generation. However, if the emission of carbon dioxide into the atmosphere is controlled or taxed then solar thermal generation will become a much more viable option.

6 Conclusions

This section is presented in two parts. The first is a list of statements that summarises the content of this report. In the second part the implications of this report for government policy are examined.

6.1 Summary

1. In the last two decades the amount of electricity generated from fossil fuels has risen 12-fold.

2. Currently, 15% of New Zealand's total carbon dioxide emissions are from thermal power stations.

3. Electricorp is planning to run its thermal stations more. Thus the trend toward more thermal generation (and the emission of more carbon dioxide) is continuing.

4. Electricorp's recent 4.1% growth in electricity sales, which occurred in just six months, is alarming from a greenhouse perspective (and out of step with the rest of the developed world).

5. It is not all bad news; the upgrading of the Cook Strait cable is positive from a greenhouse perspective.

6. In the new deregulated environment Electricorp's monopoly is challenged by potential competitors. By far the most damaging, from a greenhouse perspective, is the CRA proposal for a coal-burning station at Bream Bay.

7. It was proposed that the Bream Bay power plant be built in two stages - 500 MW and 1000 MW. With 1000 MW commissioned, total carbon dioxide emissions in New Zealand would increase by about 30%.

8. Some criticisms of the decision to build the Clyde dam focused on the surplus of generating capacity in New Zealand. Clyde was to be commissioned in 1985; it is still not operational and to date there has been no shortage of electricity. However, the concept of surplus takes on a new meaning in a deregulated economy.

9. There are alternatives to the Bream Bay plant that are less threatening to the environment. They include energy management, upgraded transmission, direct use of fuels, increased efficiency in burning fuels and substitution with "renewables".

10. No **single** alternative completely replaces the Bream Bay proposal. However, its replacement is well within the capabilities of a **package** of much more environmentally benign alternatives.

11. The impediments to more environmentally benign electricity supply options are institutional rather than technical. One impediment is Electricorp's strategy of decreasing real prices in order to increase demand. Another is the scrambling of price signals due to the double commercial barrier between generator and consumer discussed below. A third impediment is the tendency of technologists and politicians to look for the single solution to a problem.

6.2 Some implications for environmental and energy policies

In considering a greenhouse policy, the Ministry for the Environment must pay special attention to the thermal generation of electricity. Although thermal generation currently accounts for only 15% of total carbon dioxide emissions, it is entirely likely that the trend toward more thermal generation will continue. In particular, the achievement of any targeted reduction in carbon dioxide would be seriously threatened were a large coal-fired base-load power plant, such as that proposed by CRA, to become a reality.

We have the impression that most thinking on the energy aspects of a greenhouse policy has centred on the potential for carbon dioxide reduction through encouraging the more efficient use of energy, that is, energy management. Ministry for the Environment staff have made a preliminary estimate of a 16% reduction in carbon dioxide through energy management. Such a reduction would be negated by just the first stage of the Bream Bay plant. Energy management plus the Bream Bay plant would amount to one step forward and two steps backward.

Alternatives to large centralised generation do exist. There is enormous potential for increasing the efficiency with which energy is used and there are many benefits beside carbon dioxide reduction associated with this. The potential is much greater than 16%; the real limits can be found in the laws of thermodynamics. But energy management and other small-scale options like cogeneration and solar heating face a common institutional difficulty derived from the structure of the electricity industry.

The present structure of the electricity industry consists of three groups separated by two commercial boundaries.

Generation (& transmission) // Distribution // Consumption

This structure ensures that except for five major consumers who deal directly with Electricorp, the consumer and the generator have no direct commercial contact. As a result there is a serious barrier to the implementation of any activity by the consumer that produces or saves electricity at a cost that lies between the long run marginal cost to the generator and the selling price of the supply authority to the consumer. Elimination of this barrier would not, of itself, solve the problem; it is a necessary though not a sufficient change.

Alternatives involving consumer action are further handicapped in that the consumer must find capital for an investment whose long term benefit is partly to the generator (and indeed to other consumers of electricity).

The proposed alterations to the structure of the electricity industry (Report of Electricity Task Force, 1989) do practically nothing to alleviate this situation. The opportunity for vertical integration gives the supply authorities the opportunity to become generators but it does very little to promote this and nothing to encourage consumers to become generators.

Thus it is difficult to see how more greenhouse-friendly electricity generation can be more than just token in the current institutional environment.

It seems timely to finish this report with a look at the proposed Resource Management Act with the aim of seeing how the Bream Bay plant and a greenhouse policy would fare under it.

One of the major "green" objections to the proposed Act is the new powers it gives to regional councils. It is likely that the Northland Regional Council would favour the Bream Bay plant since the benefits are primarily local (cheaper electricity, employment) and the costs primarily global.

The proposed Act allows for the Minister for the Environment to make a national policy statement on greenhouse emissions (cl.40-44). The question is whether such a national policy statement has "teeth" or not. The Northland Regional Council would be required to consider the national policy statement, but may choose not to initiate any changes locally (cl.45). If a disparity between the national and regional policy statements remained, it is not clear whether the Minister could challenge this in the courts.

However, CRA would require a number of consents to build the Bream Bay plant. They would not require a mineral permit since the fuel is to be imported but would require land and water use consents and permits for discharging cooling water into the sea and combustion products into the atmosphere (cl.74). Applications for these consents would be considered by the Regional Council but the Minister has the power to call in "*applications of national significance*" (cl.121).

Thus, it appears that a clear national policy statement on greenhouse emissions from the Minister would be an essential first step to bring the issue of carbon dioxide emissions from the Bream Bay plant into the decision-making process. Further, we would expect the Minister would need to call in a project of this nature and magnitude, given that it would be likely to arouse "*widespread public concern or interest regarding its actual or likely effect on the environment (including the global environment)*" (cl.121).

We should like to conclude by quoting from Dr Dan Bromley, the institutional economist who spent some time observing and commenting on the reforms underway in this country.

> "*As an outsider I do not come with any preconceived views about the ultimate wisdom or wrong-headedness of corporatisation. I come, rather, with an interest in helping you to avoid the mischievous and incorrect application of economic concepts to matters of collective choice. That mischief is caused by an analytical approach that will find contrasting "objective truth rules" - that is, pronouncements about efficiency - depending upon the status quo institutional arrangements. If the status quo is permissive of pollution then pollution is "efficient" unless it can be proved otherwise. If the status quo is restrictive as regards pollution then clean water (or air) is "efficient" unless it can be proven otherwise. An objective truth rule that is this fickle would seem to have little to recommend it*" (Bromley, 1988, p.31).

Epilogue

On the prospects of a technological cure for the carbon dioxide problem

The production of energy from fossil fuels without the production of gaseous carbon dioxide has been considered in a number of studies. Almost all the schemes proposed have involved the collection of carbon dioxide from combustion gases by scrubbing and its subsequent conversion into a storable form.

Dry ice (solid carbon dioxide) at -78^{o}C has been considered, as has the absorption of the carbon dioxide into sea water and its discharge into the ocean at sufficient depth to keep the carbon dioxide in solution. Neither of these proposals is a permanent disposal in that the carbon dioxide will slowly be re-released to the atmosphere. To scrub the carbon dioxide from the Bream Bay flue gas would require about two million cubic metres of water per hour at 10^{o}C or about eight times as much water as will be needed for cooling. While this is not a great deal in terms of ocean sizes it would take a considerable amount of pumping. The scrubbing water would have to be discharged at a sufficient depth that the carbon dioxide would not diffuse back to the surface for some considerable time.

One of us has begun preliminary studies of the conversion of carbon dioxide to a chemically stable storable form. This requires a workable chemical cycle in which the raw materials are available in natural form in sufficiently large quantities, the chemistry is feasible, and the final product is capable of being stored for extremely long periods. At present the most technically promising approach is to scrub the flue gases by one of the conventional methods and to convert the concentrated carbon dioxide to ferrous carbonate. This compound can be prepared via appropriate chemistry from the oxide ores of iron that occur naturally in great abundance and the carbonate ($FeCO_3$) is sufficiently stable to be stored in bulk under atmospheric conditions, though ready access to moisture and oxygen will lead to its decomposition to ferric oxide and carbon dioxide. Such a process would be enormously expensive to run and would require the mining of about 1.6 tonnes of iron ore (as Fe_2O_3) for every tonne of carbon dioxide collected. In terms of the Bream Bay plant this would require almost seven million tonnes of iron ore per year for the first stage and 13.5 million tonnes per year in the second stage. About 42 million tonnes of iron ore per year would be required to deal with the carbon dioxide emitted into the atmosphere in New Zealand.

Another possible solution is afforestation which is capable of taking up about 29 tonnes of carbon dioxide per hectare per year and producing about 20 tonnes of wood per hectare per year. Afforestation on the scale appropriate to the Bream Bay plant would require about 150,000 hectares of forest for the first stage and 300,000 hectares for the second stage. (The wood could, of course, be used as a substitute fuel.)

These figures are introduced not to indicate that a technological fix exists, but rather to emphasise the enormity of the problem we are creating by undoing in a few hundred years what nature put together in a few hundred million years.

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