New Zealand After Nuclear War

THE BACKGROUND PAPERS

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460

CONTENTS

BACKGROUND PAPER 6

IMPACTS ON ENERGY SYSTEMS IN NEW ZEALAND

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This is one of a set of background papers prepared, in consultation with the Nuclear Impacts Study Team, from material provided by a wide range of contributors for a study of the impacts on New Zealand of a major nuclear war. Along with other sources, the papers comprised the basis of the report ***New Zealand After Nuclear War****, by Wren Green, Tony Cairns and Judith Wright, published by the New Zealand Planning Council, 1987. The assumptions that the study was based on are explained in Background Paper 1. Note particularly the assumption that New Zealand is not a target, and the variable assumption that New Zealand might, or might not, be affected by an electromagnetic pulse (EMP, see Background Paper 5).*

BACKGROUND INFORMATION

In a modern western society such as New Zealand, the fulfilment of every basic human need - food, urban water supply and sewage disposal, shelter, health care, and contact with family and friends - depends on a supply of concentrated energy such as electricity, gas, oil or coal. While these energy sectors will be discussed separately in terms of likely impacts and possible adjustments, their interrelationships cannot be emphasised too strongly. Likewise, the survival of all energy systems would depend heavily on New Zealand's post-nuclear war industrial capacity - which in turn would rely on a supply of energy.

This section summarises our present energy supply system and its inter-dependence, before examining the likely impacts of a nuclear war.

The electricity system

The national electricity grid connects power stations and consumers throughout both North and South Islands. A DC cable across Cook Strait makes possible the transfer of power in either direction. At present, about 75% of total electricity generation is from hydro stations, 4% from one geothermal station, and about 20% from thermal stations. The main fuel for thermal generation is gas. A substantial amount of coal is also used, though this may decrease sharply under management by the Electricity Corporation, as well as small amounts of fuel oil and distillate for peak power demand and in starting up other thermal stations.

All the thermal stations are in the North Island, and more than two-thirds of the hydro capacity is in the South Island. Even with present fuel availability for the thermal stations, there is an imbalance between power production and consumption in the two islands and a need to bring power north via the Cook Strait Cable.

Demand for electricity is highest in winter and during daytime, and peaks in the late afternoon.

The natural gas system

Natural gas comes mainly from the large Maui field, 34 km off the coast of Taranaki (90%), with a further 8% from the older and smaller Kapuni field (on-shore). The balance is from McKee, Kaimiro, and associated on-shore fields. The supply of gas depends on the continued functioning of the following facilities:

(a) The Maui platform which includes the drilling rig, power generation and primary separation facilities for gas and liquids.

(b) Two underwater pipelines which carry gas and condensate onshore to the Oaonui production station.

(c) The Maui production station at Oaonui which completes the separation of liquids and gas. This results in a condensate stream to the refinery, an LPG stream which is distributed by ship to regional storage facilities and a gas stream which is partly reticulated and partly further treated at the Kapuni treatment plant.

(d) The well-head facilities at the Kapuni field which carry out primary separation of gas and liquids.

(e) The Kapuni gas treatment plant where secondary gas/liquid separation and carbon dioxide removal occur.

(f) The oilfields production station which separates the small amount of gas from the McKee and associated fields.

(g) Compressor stations and pumping facilities which control gas flows through the reticulation systems.

Present uses for the gas are roughly one-quarter reticulated (domestic, industrial and CNG use); one-third to electricity generation; and the rest to the three major petro-chemical plants making synthetic petrol, methanol and ammonia-urea.

Liquid/transport fuels

Liquid fuels and transport fuels are overlapping categories which can lead to confusion.

Liquid fuels include petrol, two kinds of aviation fuel, diesel and various grades of fuel oil. Sometimes LPG is also put in this category. About 90% of this total is used in transport, including off-road vehicles (1985 Energy Plan, p. 56-57).

Transport fuels include the above mentioned 90% of liquid fuels, plus compressed natural gas, and a very small amount of electricity, principally for the Wellington suburban trains. Electricity will also power the North Island main trunk railway line if electrification is completed.

All liquid fuels at present proceed from the single refinery at Marsden Point. They originate from three sources:

(a) Imported crude oils, particularly heavy crudes which yield fuel oils and bitumen as well as the light transport fuels.

(b) Indigenous light oils and condensates from the Maui, Kapuni and Kaimiro gas fields, and crudes from the small on-shore oil fields such as McKee, all in Taranaki.

(c) Synthetic petrol from the Motunui synthetic petrol plant, which converts natural gas (80% from Maui, 20% from Kapuni) to 92-octane petrol. At present this is blended and has lead added at the refinery. If this were not possible, it could probably be distributed from Taranaki as a low-octane unleaded petrol suitable for low-compression engines (or with reduced performance and durability, for all petrol engines).

Fuels from the refinery are distributed to main ports by coastal tanker, and to Auckland by pipeline.

Self-sufficency in liquid fuels will peak in 1987/8 at about 55% (1985 Energy Plan, p. 60). Thereafter it will decline steadily as some fields are depleted and others progressively tap areas less rich in condensate. Barring further discoveries or policy changes, self-sufficiency will be only 27% by the year 2005. Thus the analysis in this paper must be taken as a "snap-shot" of the most favourable year. Its relevance is heavily dependent on the date of a nuclear war.

Coal

About two-thirds of New Zealand's coal is mined in the North Island, concentrated in the Waikato. About two-thirds of this production is open-cast. South Island coal comes from three main regions - in order of decreasing quality, Buller/Reefton, Southland/Otago, and Greymouth.

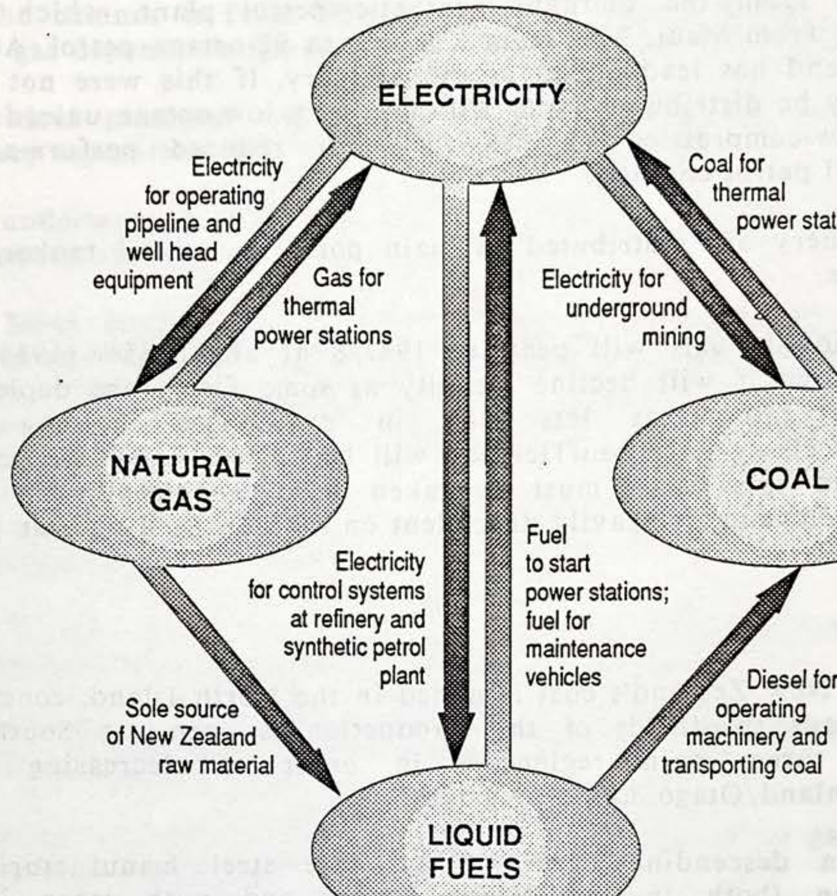
The main users (in descending order of use) are steel manufacturing and electricity generation (both in the North Island, and with large increases planned); dairy factories (mainly in the North Island); households for heating (mainly in the South Island); hospitals throughout the country; freezing works and cement works (mainly South Island); and paper making (mainly North Island). There is a gradual move away from coal and towards gas among North Island industries.

In addition, most of the production from the Buller/Reefton area is exported to Japan. Different types of coal are not necessarily interchangeable for some purposes. Most of the coal is produced by State Coal Mines.

Interrelationships in the energy sector

Figure 1 summarises the main ways in which different energy forms depend on each other. Electricity is essential to control systems everywhere, especially at the refinery and synthetic petrol plant. Transport fuel, mainly diesel, is essential to the inspection and maintenance of distribution networks such as the electricity grid or pipeline system. These are primary dependencies. Others shown in the diagram may be considered secondary - the lack of coal for electricity generation would reduce output by only a few percent, although it would disproportionately affect peak demand in the North Island.

FIGURE 1: INTERDEPENDENCE BETWEEN ENERGY SYSTEMS



Substitutability

Although several different energy forms may be used to perform the same task, the ability to change from one to the other is limited by the energy-using equipment that has been installed. Over the last decade there has been a steady move to substitute natural gas for other fuels, but this has involved capital investment in domestic stoves and water heaters, industrial boilers, and in CNG/LPG vehicle conversions to replace equipment designed for electricity, diesel, fuel oil, coal and petrol.

LIKELY IMPACTS WITHOUT AN ELECTROMAGNETIC PULSE (EMP)

In this scenario there would be no forseeable *physical* impacts on the energy supply systems in the first few weeks. They could however be very vulnerable to the attitudes and behaviour of the people who run them, which this paper does not attempt to predict. All forms of energy supply would suffer a sudden reduction in demand because of the cessation of export-related activities. This reduction can be roughly quantified at a primary level, for example, electricity used by pulp mills or the aluminium smelter. However, flow-on effects on demands for freight and personal transport fuels, and on the tertiary sector as it services exporting, are very difficult even to guess at.

All forms of energy production would begin to suffer within months, or in a few cases a year or two, from lack of imported spare parts. Over a longer time-scale, problems caused by corrosion would emerge. How rapidly the system would run down from there would depend on the capacity of our engineering workshops to refurbish, improvise and recycle, and to revert to earlier technologies and manual control systems.

Effects on the electricity system

Demand reductions

The aluminium smelter, which currently uses about 18% of New Zealand's electricity would be forced to close. In order to produce a stock of aluminium for New Zealand's use it might choose (or be directed) *either* to continue to run all potlines until existing stocks of bauxite were used, *or* to close all but one potline and continue to produce at a slower rate for a longer period. Wood, pulp and paper products use another third of the electricity supply. The big users in this sector are the pulp mills which produce mainly for export. To what extent the steel industry would reorganise to produce more products for New Zealand use has not been studied, but its electricity demand would undoubtedly drop. Freezing works and dairy factories would also have greatly reduced energy demand, but might divert present production of tallow and butter into diesel substitutes.

Demand increases

Domestic consumers use approximately 40% of electricity production. This demand might increase for two reasons. If many work places are closed, people may spend more time in their homes (using power for heating, even though they might not pay for it) where space, water-heating and lighting demands are greater per capita than in commercial or industrial buildings. Secondly, a 3^{o} drop in winter temperatures would lead to an increase in the demand for space heating. Wright and Baines (1986) quote Bassett and Trethowan (1977) that "the differential sensitivity of heating energy to indoor temperatures ranges from about 6% per degree C in the colder regions to about 10% per degree C in the north." Using Wright and Baines' figures for electricity used in domestic space heating in each of New Zealand's climatic zones gives a projected electricity increase of 400-500 Gwh/y. The effect would be disproportionately felt at peak hours in winter in the North Island.

Reduced hydro capacity

Lower rainfall or shifting distribution of rainfall associated with the climatic effects of a nuclear war would reduce inflows to hydro catchments and thus generating capacity, possibly by as much as a half.

Reduced thermal capacity

Thermal power stations, although providing only 20% of total electrical energy supply, provide 43% of the North Island's supply, and an even higher proportion of peak power in the North Island. The bulk of this is from natural gas. There are several reasons why fuel for thermal power stations may be reduced or unavailable after a nuclear war. Fuel oil will be especially scarce as it comes mainly from imported crude oil. Oil-fired stations provide only a tiny fraction of total generation, but coal-burning stations need oil to start up, and it may be necessary to run some oil stations - Marsden and Otahuhu - in order to maintain voltages in Auckland and Northland. What little fuel oil there is may be reserved for coastal shipping and the rail ferries. Once coal stockpiles are used at Huntly, the availability of coal for that station would depend on the availability of transport fuel (diesel) to bring coal from the mines. Coal for Meremere station is transported by electric cableway.

Without an EMP, there is no reason to expect short-term problems with gas supply, but as electricity generation converts gas at very low efficiency (up to 33%) it might be considered too valuable to burn. In the short term it would probably be supplied to power stations in considerable quantity in order to maximise the flow of condensate to the refinery. In the long term it would probably be reserved increasingly for CNG, methanol and direct, more efficient uses, some of which could substitute for electricity.

The Cook Strait cable (DC link)

The DC link consists of three cables. One is sufficient for half power transfer, two for full power transfer, and the third, a back-up, is no longer operational. Given the electricity surplus that would be created in the South Island by the closure of the aluminium smelter, and given the greater vulnerability of the North Island thermal stations, transfer of power across the strait would be important. There have been proposals in recent years to expand the capacity of this link and doubts have been expressed about its reliability. However, Electricity Division has stated that it could continue to transfer full power for a minimum of five years, and half power for a further ten.

Spares and technology at the terminals are sufficient for 20 years, according to the Electricity Division of the Ministery of Energy, but repairing the cable itself would probably be impossible without overseas equipment. New Zealand does have some spare cable sections and one contributor felt that, with a suitable flat deck ship, some repairs could be made, but it would seem wise not to rely on it.

Inter-island imbalance

At present the South Island produces more electricity than it can use, and the North Island uses more than it can produce. The system is balanced by the Cook Strait cable which sometimes has to work to maximum capacity (600 mw). The imbalance would be increased by closure of the aluminium smelter. It could also be increased by:

- higher domestic demand (because of population distribution)
- closure or decreased production from thermal stations because of lack

of fuel

- inoperability of the Cook Strait DC link for any reason.

The first of these effects is likely to be transient, and to occur mainly while thermal capacity is still available. In the longer term, much of the domestic heat load could be substituted by wood and solar.

The second two effects will occur in the longer term, but there will be time for adjustment.

Countering these effects would be the closure of export industries in the North Island. Electricity Division has estimated that, even taking this into account, and assuming full power transfer of the DC link, there would be an 800 mw *peak* power shortage in the North Island which would have to be supplied by burning gas. This is likely to be available in the short term.

Peak/energy ratio

A very large difference between peak and off-peak demand poses operational problems for any electricity system. In New Zealand the daily peaks caused by domestic consumers are balanced by industrial consumers who draw power continuously throughout day and night (e.g. the aluminium smelter) or which shut down completely during the late afternoon peak (e.g. parts of New Zealand Steel). Closure of export industries would greatly reduce off-peak demand without greatly reducing peak consumption. If thermal stations were forced to reduce their output, this would result in power cuts at the times most inconvenient to households.

Fuel for maintenance

Maintenance and repair of the grid and all its components throughout New Zealand is heavily dependent on fuels, especially diesel, both for patrolling vehicles and for heavy lifting machinery. Given no EMP even though diesel supply would be reduced by lack of imported crude, there should be enough available for priority users such as the electricity system. If the Maui platform or production station, or the refinery, was to suffer an accident which could not be repaired locally, maintenance of the electricity system would rapidly become difficult.

Spare parts and materials

Hydro-electric stations would be more easily repaired with New Zealand materials and technology than thermal stations. Electricity Division informed us that:

> "For the main pieces of machinery the most common serious fault, a stator failure, can be repaired once with spares held at the station. New Zealand should be capable of manufacturing further spares, although it may take 3-4 years to establish the expertise. The auxiliary and control equipment or a similar equivalent can also be manufactured in New Zealand oı eliminated. Equipment which can be eliminated is used for such functions as remote control, which would be replaced with increased manning at the stations.
>
> "Hydro stations also consume a small amount of lubricants and oil, but it

would be several years before this became a critical item. It is assumed that alternatives could be manufactured in New Zealand within this time.

"At the worst the output from hydro stations will decrease slightly as machine repair times increase. Given a healthy postwar society, New Zealand could even build new hydro-electric power stations.

"Thermal stations which burn a fossil fuel to produce steam will, if used during the postwar period, eventually break down over a time-span of decades. As a machine becomes damaged it can be used as a source of spares for other machines at the station, provided the damage on each machine is not identical. The boilers, turbines, valves and pipework are subject to high temperatures and pressures and require specialised materials to repair. These materials are imported and any stocks in the country would probably be diverted to industry.

"Gas turbine stations, if used during the postwar period, could be run until there was a blade failure, which would be an irreparable failure.

"Geothermal stations, which operate at lower temperatures and pressures than other thermal stations, would continue to operate indefinitely. Any repairs required should be within New Zealand's postwar capability, although repair times will be longer. Also, the output of most geothermal fields would taper off to some reduced, steady-state value, from present levels."

Transmission lines are robust and simple. Conductor wires for repairs could be made from aluminium ingots made before the closure of the smelter. Some lines would become redundant with reduced demand and could be cannibalised to repair others.

Substations have a one-year supply of circuit breakers and other spares, which would last longer postwar. New parts could be diverted from construction projects. Minor transformer faults could be repaired locally and in time, probably major ones as well.

In summary, if New Zealand was not affected by an EMP the electricity grid should continue to function well enough for the first year or two to maintain essential services and a reasonable degree of comfort. It would become progressively less reliable and more prone to unplanned blackouts. In the longer term both reliability and total output would decline. At what rate and to what level would depend on the engineering capacity New Zealand could establish postwar. A response from DSIR Industrial Processing Division has pointed out the complex interdependencies of New Zealand industry, so that even parts regarded as "wholly made in New Zealand" may be dependent, for example, on machine tools which cannot operate without imported bearings. We suspect that these interdependencies have not been fully realised by many contributors who are optimistic about New Zealand's postwar industrial capability. Often it can be quite small things which cause the problems, as Electricity Division has pointed out:

"The greatest problem area for spare parts is likely to be in the hundreds of small consumable items used in any workshop. These are items such as drills, hacksaw blades, cutting oil, solder. Essentially, the Electricity Division has a minimal stock of those small, general purpose items which have a short delivery time or can be bought off the shelf in New Zealand.

Large, specialised items have such a long delivery time that the Electricity Division is forced to carry significant spares in the country."

Effects on the Natural Gas System

Demand reductions

Even if full production remained possible from all gas fields, there would be major changes in the demand pattern. The methanol plant at Waitara (16 PJ/y) would have to close as its product is almost wholly exported. It would presumably do so once the 55,000 tonnes of port storage capacity was full (up to 45 working days at full production) and this storage would be enough for about three years of New Zealand's present internal consumption. This would allow time for a planned shut-down so that the plant could be restarted if and when conversion of vehicles to run on methanol was well underway.

The ammonia-urea plant (5 PJ/y) would probably also close as most of its output is exported, the balance used to a considerable extent on export crops, and it would be difficult or impossible to run it at very low throughput. Most of the 6 PJ/y used by the pulp and paper industry would be no longer required, as well as a substantial part of that used by freezing works, dairy factories and the steel industry. These closures would lead to about 20% reduction in demand.

Reduction of gas off-take would lead to an associated decrease in condensate production, further reducing the local supply of transport fuel. Two approaches to electricity generation are possible. At one extreme, power stations might be base-loaded on gas, and gas even flared to waste at the well-head, in order to maximise condensate production in the short-term. At the other extreme, gas might be considered too valuable a material to use at 30% efficiency in power stations, and both electricity and transport fuel production might be curtailed in order to improve survival in the long term. The application of these policies might depend on how close to depletion the gas fields were at the time the nuclear war occurred. There is recent evidence that recoverable gas reserves may be less than previously thought, and depletion, at least for major users, could even occur this century (Melhuish, 1987). If gas were to be denied to electricity generation for peaking, it would reduce demand by a further 25-30%.

The Maui platform and undersea pipelines

No corrosion-prevention work is needed on the platform for many years and the ship which was stationed there for that purpose has left. A smaller ship is kept in the port for routine inspections and that does not require any specialised spare parts. The platform and the facilities it supports would need the usual valves, pumps and compressors, whose turnover ranges from six months to a few years, but it generally does not require spares or maintenance, which are more import-dependent than the on-shore facilities. The major exception would be any failure which required diving. This would be extremely difficult without outside assistance and would need helium gas which is at present imported from the USA. The pipelines to shore should not need attention for years but, if they did, a lack of diving capacity would be critical (K. Wood, 1987). The platform produces its own power from gas turbine generators and stand-by diesel generators. Thus it is independent of the electricity grid, but dependent on gas turbines where a blade failure would not be repairable, and thereafter on diesel.

The Maui platform could be expected to operate normally until it required a spare part which could not be found in storage, borrowed from back-up facilities, adapted, or made here. That could be months or years, depending, as would everything else, on local engineering capability.

On-shore wells and productive facilities

Owing to long lead-times for overseas supplies, large stocks of equipment spares are held in New Zealand. Petrocorp and the Ministry of Energy agree that it should be possible to maintain surface production facilities at McKee, Kaimino and Kapuni on existing spare parts and technology for "some considerable time."

Effects of a loss of Maui platform

Although production of Maui gas appears reasonably robust, its location still makes it rather more vulnerable than the land-based fields. An accident could limit gas production to the on-shore fields. At present production levels, these supply only 20 PJ of gas, or about 11% of current demand. If this were allocated to the most efficient users (households and CNG - 9 PJ) the remaining 11 PJ would probably be sufficient for a reduced number of industrial users if the pulp and paper mills, freezing works and dairy factories, and part of New Zealand Steel were closed. There would be no gas for synthetic petrol or electricity, and refinery feedstocks would be reduced by over 40%. At present, however, Kapuni gas is being extracted at a faster rate than the treatment facility can handle, and about 50% is reinjected into the field, in order to maximise condensate production. Kapuni, as a gas-drive field, can be run at very high extraction rates and this might allow for a considerable increase in CNG to replace petrol. The limiting factor would be treatment facilities, as Kapuni gas is high in carbon dioxide, which must be removed for some uses, such as vehicle operation.

The reticulation system

The Ministry of Energy estimates that the gas reticulation system could be kept going for about five years without imports. The weak points would be compressors and pumps. Lack of parts would gradually lead to a decline in compressor efficiency and pressure drops at points of use. Electronic control systems would be difficult to repair or replace, but manual control would be possible with training. As with the electricity system, demand reduction would allow cannibalisation of parts from surplus equipment. The Wellington Gas Company sees no problem with parts and materials in the first six months but expects that there would be shortage after that, as most parts are presently imported from USA and UK.

Effects on liquid/transport fuels

Stocks

Some stocks of imported crude oil, and of refinery products, would be in the country at the time a nuclear war occurred. These can vary tremendously, but "normal" or "average" figures are given in Table 1. In addition, a tanker might be on its way, or other tankers at sea might seek a safe port here.

TABLE 1 - Oil Stocks post-nuclear-event

	Pumpable stocks in ports + Wiri	Refinery	Tankers	Unpumpable Depots etc (000 tonnes)	TOTAL STOCK
Premium gasoline	90	20	15	35	160
Regular gasoline	10	5	2	3	20
Gasoil (diesel)	80	20	10	25	135
Fuel oils	25	5	5	5	40
Bitumen	15	5	2	2	24
Jet fuel	35	15	4	5	59
Syngas	10 (NPly)	10	-	5	25

Source: Coastal Shipping Co-ordinating Committee.

This table shows a possible stock pattern. Actual stock could vary considerably from day to day, and can pass through periods of appreciably higher or lower stocks. Bitumen stocks are taken to be fairly low in line with a Southern Hemisphere mid-winter scenario.

Refinery feedstocks, both imported and indigenous, can be very variable, but a gross stock of 300,000 - 400,000 tonnes is quite normal.

In 1981, in response to the 1970s oil shortages, a strategic reserve of 48,000 tonnes of diesel was established and stored in the tanks of the mothballed Marsden B power station. In November 1986, tenders were called for the sale of this, and it was disposed of in January 1987.

Indigenous supply and fuel mix

Once stocks were used, *all* transport fuels would depend 100% on production, treatment and distribution of products from the oil and gas fields.

Full production under 1987 conditions would yield 45% of current refinery feedstocks and 100% of Motunui feedstock. Additional gas supply to Motunui could increase its throughput by 20% and would be within the present deliverability of the Maui field.

Closure of export industries would result in a 20% drop in gas demand and an associated 10% reduction in refinery feedstocks. A decision to cease using gas to produce electricity (either as a policy decision to extend future gas supplies for transport, or because thermal generation was no longer needed to supply electricity demand, or after a year or two if thermal power stations had failed for lack of spare parts) would result in a more severe drop in condensate supply to the refinery. The effects of these four different rates of gas-use on petrol and diesel supply are summarised in Table 2.

These results are, however, rather simplistic as they assume the ratio of petrol/diesel production at the refinery would remain the same as now. In fact, there is some scope to vary this, especially if diesel specifications are relaxed. A barrel of crude oil can be "cracked" in various ways at the refinery to yield different proportions of "light" or "top of the barrel" products such as petrol, and "heavy" or "bottom" products such as fuel oil and bitumen. The extent of this variation will depend on the type of crude, and the extent to which fuel specifications and overall energy efficiency are compromised. Diesel, however, would always remain in shorter supply than petrol, as no diesel can be made at Motunui.

TABLE 2 - Effects of various gas-use policies on petrol and diesel supply

Gas-use Policy	% of 1987 fuel supply	
	Petrol	Diesel
Full production from oil and gas fields under 1987 conditions (i.e. gas flared to waste or used to base-load power stations)	65	45
Additional 20% throughput at Motunui synthetic petrol plant	73	45
Gas production reduced 20% by closure of export industries	62	40
No gas supply to electricity generation	58	34

Diesel is strategically more important than petrol as it is the main fuel for heavy machinery, construction, agriculture and freight. Most petrol is used in private cars. Railways use about 4.5% of present diesel supply and coastal shipping about 6.5%. Diesel is essential in both on- and off-road uses for the continued supply of electricity, water and gas, but together these use less than 1%. Any attempt to build new industrial capacity to substitute for imports would be heavily reliant on diesel.

Supply and demand of aviation fuel has not been addressed by contributors, but it appears likely that demand reduction would be so great that the reduced refinery operation would suffice.

Several contributors have pointed out that bitumen and many fuel oils are made only from imported crudes. However, the New Zealand Refining Company (Brehaut, 1987, pers. comm.) advises that these products could be made from local crude oils. The New Zealand Roads Board prefers not to accept bitumen from a changed feedstock or process until it has been road-tested for several years, but in an emergency this requirement would probably be relaxed.

Even with such reorganisation at the refinery, shortages of heavy fuel oils for coastal and inter-island shipping and oil-fired or -started power stations are possible.

Outside all these figures, which so far relate to *liquid* fuels, is the use of CNG and LPG in transport. More than 100,000 petrol-engined vehicles have been converted to CNG (while retaining dual-fuel capability), with the percentage highest among light commercial vehicles. CNG is the most efficient use (in energy terms) of natural gas, and it takes only about 3% of current gas supply to fuel these vehicles. It should not suffer even from major supply reductions, and is not dependent on highly complex processing at the refinery or Motunui. However, it is only available in the North Island within range of the pipeline network. This includes about 65% of all New Zealand petrol vehicles. (Fitzsimons, 1981.)

LPG is a by-product of the separation of the gas and liquid streams. Its availability is limited by the rate of gas flow. About 40,000 vehicles have been converted in both islands.

Effects of loss of Maui platform

A previous section considered the effects on gas supply of the loss of the Maui platform or on-shore pipelines. This section considers the effects on liquid fuels. The first effect would be the closure of the synthetic petrol plant, which uses very large quantities of gas, and the approximate halving of petrol supply. Reduction of refinery feedstocks would be less than 50%. Diesel supply would be reduced still less, as the on-shore crude oils are richer in middle distillates. Thus, although diesel supply would be reduced, the primary effect would be a crippling of petrol production. LPG production would reduce at a rate roughly proportionate to the loss of gas, but CNG supply would not need to be affected.

Demand effects

It is extremely difficult to estimate by how much demand for transport fuel would decline as export industries and their associated production, freight, financing, insurance, marketing, personnel and other requirements ceased. A first attempt to derive such estimates from detailed data sets (e.g. Beca, Carter et al 1986) has failed; partly because many categories include both domestic and export activities (e.g. "food manufacturing"); partly because large aggregated figures for licensed road transporters give no clue as to who their clients are; and partly because of large categories termed "other". A second attempt could be made in subsequent research using input - output data for New Zealand industry, developed by Dr. J. Peet at Canterbury University.

It is also unclear how much use of personal motorcars is related to work activities, and what would replace it if "work" were no longer there.

Some 13% of diesel, as well as about half this quantity of fuel oil, is used by overseas shipping. Much of this would be available for other purposes. Forestry, mining and pastoral farming are all significant users of diesel and these activities would probably decline. The largest category is heavy road transport, and it has not been possible to allocate this to sectors of the economy in the time available.

Very little petrol is used off-road, and most is used by cars, of which 20% are registered by businesses. Business vehicles are generally new and do high mileages, so use more than their 20% share of fuel, but substantial private use of company vehicles is masked by these figures.

In summary, if full production from New Zealand sources were maintained (except for the 20% drop in gas off-take described earlier) petrol supply would be adequate for a post-nuclear war New Zealand. Diesel supply would not be, and severe restrictions would be necessary. Fuel production would depend in the longer term on the supply of spare parts, chemicals and catalysts for the two most complex processing plants.

The long term: spares and catalysts

Both the refinery and the synthetic petrol plant rely on parts such as valves, pumps, heat exchangers and electronic instrumentation which are not normally made in New Zealand. No information was received about stock-levels of parts for the more common failures, and opinions differed about the ability of local industry to make them under post-nuclear war conditions. As both plants are unique to New Zealand, their ability to cannibalise parts from elsewhere would be limited. Motunui has two methanol trains and five methanol-to-petrol reactors, so could possibly operate at half output for a considerable time, using spare parts from the other units. The Ministry of Energy advises that the synthetic petrol plant could run for about two years before it would be necessary to close half the plant in order to provide spares for the continued operation of the other half. Breakdowns in the electronic control systems might be harder to repair.

Both plants also rely on imported catalysts, which are regenerated locally but replaced from overseas every 2-3 years. The Liquid Fuels Trust Board believes that workable, although less efficient, catalysts could probably be made in New Zealand within the lead-time probably available (1-2 years).

The Ministry of Energy points out that renewal of the catalyst in the refinery hydro-cracker would not be a problem, as it exists only to process imported heavy crudes, and would close down once these stocks were processed. They believe that processing of indigenous crudes and condensates would be carried out by the distillation unit and the catalystic reformer, and suggest it is possible that a usable catalyst for the latter could be developed in New Zealand.

The New Zealand Refining Company advise that waxy McKee crude *is* suitable for the hydro cracker and that it would be kept running in order to achieve a suitable product mix. In this case, catalyst replacement would be a problem (Brehaut, 1987, pers. comm.). However, waxes would be valuable in their own right, being easily stored compared with liquid petroleum products. Wax would have a high value in the Northern Hemisphere for candles and could become a new export commodity if a restoration of trade were possible.

Lubricating oils

At present almost all lubricating oil is imported. Stockpiles are enough for 2-3 months. Lack of suitable lubricants is a problem which would affect all machinery and vehicles everywhere, including the electricity grid.

A small amount of re-refining of used oil is done now, and this could be expanded. The oil additives used at present would not be available, but these would be critical only for very high performance engines operated under stressful conditions (J. Peet, pers. comm., Feb 1987).

Likely effects on coal production

Demand

Export markets for coal would be lost, possibly causing some mines to close. In addition, markets would decrease significantly in the dairy, freezing, cement, paper and steel industries. Domestic and hospital demand might increase because of colder temperatures. The Maramarua mine would still need to run at full production to supply the Meremere power station, which would be vital if gas were to be reserved for other uses, or if the Cook Strait cable became inoperable. As a conservative estimate, demand would drop by at least 30%, but this would not affect all mines equally.

Spares and Materials

Roof bolts and steel sets for mine support are imported, and shortages would develop in the first six months, particularly in the Huntly and Wairaki underground mines. West Coast mines use some locally-grown timber supports, so are less dependent. Highly mechanised mining and transport equipment at the Huntly mines is very import-dependent, while West Coast underground mines use less sophisticated machinery and parts could more easily be made locally, though the recently formed Coal Corporation may be cutting back on underground mining. However, all underground West Coast mines use explosives, which because of their special requirements are imported. These would be in short supply within six months. Electric detonators used to initiate explosions are imported from Australia. This might be possible again within a few months, but depends on the import-dependence of Australian industry, which has not been analysed.

Explosives are also used in opencast mines in the Huntly area, to remove overlying rock. Two suitable products are manufactured in New Zealand, but from imported ingredients. Manufacture from locally available ingredients might be possible, but with reduced efficiency and safety.

Diesel

Diesel is crucial to drive opencast mining machinery, for transport of men and materials down underground mines and for transport of coal to markets, by either rail or road. The Huntly power station is supplied from the Huntly West mine by electrically-powered conveyor belt, but households, hospitals and industries would rely on diesel for coal supply. Enough diesel for such a priority should be available under all conditions except closure of the refinery.

LIKELY IMPACTS WITH AN EMP

While the energy system could, in general, survive some months with lack of imports, giving some time for adaptation and improvisation, the effects of an EMP would be immediate, universal and devastating. All energy production systems (except perhaps small-scale rural wood-burning) rely on electronic control systems or a supply of grid electricity, or both. As can be seen from the previous sections, a complete failure of the electricity grid would paralyse virtually everything else.

Effects on the electricity grid

The electricity grid, and all electrical equipment connected to it, would act as a giant collector of EMP energy which would simultaneously be conducted to all connected apparatus: computers, plugged in radios, televisions and home appliances, telephone, broadcast and industrial control systems. Thus for electronic equipment, the pulse would reach it both by direct diffusion of the field, and by conduction via mains.

The first effect would be the instantaneous failure of all electrical and electronic equipment. The second would be that much of it would be permanently damaged. It appears at this stage that transformers, generators and motors not on at the time of the pulse are unlikely to be damaged. Two informed contributors disagree over whether or not transmission lines would be damaged.

Electricity Division have summarised their assessment of electricity availability after an EMP thus:

> "At the very worst, it is expected that 20% of the hydro generating capacity could be restored in about ten days and that substations at centres where there are local maintenance personnel would be ready to accept this power. This is enough power for public lighting, communications, water and sewage pumping and a small amount for hospitals. There would be little power for domestic use, heating, cooking or industry. Increases to twice this level may take another year.
>
> "However, there is a second and somewhat more likely EMP scenario. In summary, 20% of generating capacity is available in about 48 hours with a further 10% available in another week. This implies that there is very little power available for heating. The underlying assumption is that major equipment damage will be random and that auxiliary and control equipment damage in hydro stations can be repaired, replaced or eliminated, which implies an increased chance of short duration loss of power (decreased reliability).
>
> "The control equipment required in a thermal station is more extensive than a hydro station and it would take about two years before they produced any power. It is an open question whether society could afford to spare man-power and resources for this length of time before getting a return on its investment.
>
> "Under some (credible) situations the inter-island power link could be restored, but for planning purposes it cannot be relied upon at this stage."

The difficulties of deciding priority users in a situation where communications were severely disrupted and most users would have suffered EMP damage themselves, would be compounded by possible imbalances between geographical areas, and particularly between the two islands. Priority needs such as water and sewage pumping, public lighting and hospitals would be greater in the North Island because of population distribution. In addition, if gas distribution became possible again, that would increase North Island demand. Hydro stations are concentrated in the South Island, and at least in the short term the cable would not be operating.

Effects on the natural gas system

If an EMP occurred, all surface gas production and treatment facilities, and pumps and compressors on the pipeline system, would cease immediately. It would probably be possible to restart partial production at Kapuni and McKee by operating manually, using pneumatic control loops rather than electrical ones which contain solid state components. The Maui wellhead and Oaonui production facilities might possibly be restarted the same way, but would be more difficult because they have more complex electronic equipment. However, it is likely that the total lack of communications and electric power in the first few days, and the severe disruption of them for a long period after that, along with the crippling of all industrial production, would hamper such efforts more than anyone has recognised.

It is possible that the automatic shut-down equipment which exists at all parts of the gas production and reticulation system might not operate 100%, especially on the pipeline network if all parts of it were challenged simultaneously. Manual shut-down where automatic systems failed would require an immediate and highly efficient response from staff who could, like the rest of society, be in a state of shock.

EMP would wipe out the central control system for gas transmission in New Plymouth. The Natural Gas Corporation would need some hours to get experienced people into place to operate manual control, even under normal circumstances. Without normal communications and with the expected social chaos, locating and deploying these people would be much more difficult.

As pressure dropped in the gas main, air would tend to leak in, particularly in Auckland and Wellington where gas mains are large and rather leaky. A large pressure drop could lead to a sufficient dilution of gas by air that the mixture would become flammable with severe risks of explosion. If de-pressurising and purging were required of all lines in the country, it would be a very long time before delivery could begin again.

It is likely that, despite all these problems, gas production and delivery could still resume before the refinery became operational again. In this situation, storage for the condensate which would accompany gas production would be a problem. The refinery has storage for 20 days' worth of feedstocks (imported and local) at normal production.

If gas production were restored, demand would be considerably lower than in the case of no EMP because Motunui would not be operating at all and thermal power stations would take about two years to be restored, given adequate resources and personnel.

Although there are still many uncertainties, it is clear that gas supply would not be restored quickly, and that there would be some possibility of severe fires and explosions, unless a detailed plan of action, and training, had been implemented.

Effects on liquid/transport fuels

An EMP would result in immediate failure of, and damage to, the refinery, the synthetic petrol plant, ship loading and unloading pumps, the Marsden-Auckland pipeline control equipment, and retail petrol pumps.

Consideration of the longer-term fate of all these components should bear in mind that none of them can restore a fuel supply (except for short-term handling of existing stocks) unless the gas production, treatment and distribution system is also restored, as outlined above.

The refinery

The Ministry of Energy advise that

> "On the assumption that EMP destroys the control centre, the refinery would be inoperable in its existing form. It is possible that a proportion of the control equipment would survive owing to the shielding effect afforded by earthed metal cabinets and enclosures. It would however require a major reworking operation, cannibalising existing equipment to enable the refinery to function at even a very low basic level. Most of the more sophisticated equipment operation would be lost and only basic distillation equipment usable. This level of operation is only likely after a considerable period of plant shut-down to carry out repairs and modifications."

Some areas of the refinery have steam-driven turbine pumps which might make possible limited production of fuel oils and bitumen from stocks of imported crude in the absence of an electricity supply. The refinery normally requires 30 MW of grid power.

Each of the three processing units at the refinery (two catalytic crackers and one hydrocracker) is incapable of operating below about 50% of design capacity. Thus, if the supply of condensate fell below about 35% of 1987 fuel production, the refinery would be incapable of processing the remaining trickle. (Brehaut, 1987.) This situation could possibly be caused by:

1) The nuclear war taking place towards the turn of the century, when total indigenous refinery feedstocks will be less than half what they are now; combined with reductions in even that level of production because of EMP damage.

2) A loss of Maui combined with reduced on-shore production from cannibalisation of some parts of the system for spares.

The Synthetic petrol plant

> "The Synfuels plant would stop suddenly under this scenario and would never start again. It is assumed that all control gear would be destroyed. There are not the spares nor the possibility of making them in New Zealand to

allow any measures to be taken. The purchase and storage of control equipment to such a level that this part of the plant could be repaired would be prohibitively expensive." (Ministry of Energy.)

Thus, even if some make-shift, small-scale refining became possible at the refinery, the principal source of indigenous petrol would be gone. The lack of this major gas use would further reduce condensate supply to the refinery.

CNG and LPG

CNG would become available as soon as some gas production and distribution was restored, depending only on compression and filling equipment being operable. The existence of many compressors and filling stations throughout the North Island makes the restoration of a partial system, with cannibalising of some units to restore others, easier than at a single large plant such as the refinery or Maui platform.

LPG would become available as soon as the surface production facilities were operating again, but this implies some restoration of reticulation in order to receive the gas. LPG supply to transport would depend on the continued operation of the designated coastal ship, electronic control systems at bulk storage depots, the operation of rail and/or road tankers, and pumps and filling equipment at service stations.

Distribution

Petrol station pumps with all their electronic componentry would be inoperable, creating an immediate shortage of transport fuels. It is possible to manually extract the petrol from the underground tanks using hand pumps. Measuring cans could be used to dispense and meter the fuel, allowing the conventional dispensing system to be by-passed.

Petrol station stocks could last up to one week, depending on station size and location. While distribution of fuels by coastal tanker and road tanker could continue, distribution to Auckland via the refinery pipeline would suffer major disruption. A computerised system controls product flow. The initial disruption, together with Auckland's lack of port tankage, could mean more severe shortages than suffered elsewhere.

Vehicles

All vehicles with electronic ignition would stop suddenly at the time of an EMP. At present this is only about 5-10% of cars, mainly the newest ones, but if the event were to happen during rush-hour traffic main arterial roads in cities and bottlenecks such as the Auckland Harbour Bridge could be blocked by the seized vehicles and the multiple crashes that would be caused by such a sudden event. Clearing the roadways would be complicated by lack of radio and other communications, lack of street-lighting and power. This would seriously impede the movement of emergency personnel, fuels, and equipment.

Effects on coal supply

Demand

Industrial consumers would close for an extended period after an EMP so demand for coal would drop. Domestic and hospital consumption would be very important and likely to increase significantly in the absence of electricity and/or gas, beyond the present 445,000 tonnes a year. While domestic demand is highest in the South Island at present, this might be overtaken by North Island demand, given the higher population and the scope for disused open fireplaces substituting for electricity and gas, both for space-heating and limited cooking. It would therefore be important to keep some mines open in each island.

If repair of thermal power stations were possible, Meremere might well be easier to restore than Huntly, which is newer and more sophisticated. This would add about 120,000 tonnes/year to demand.

Lack of electricity

Underground mines depend on electricity for ventilation (removing methane gas which would otherwise cause explosions or suffocation), transport ropeways, air compressors to drive mining machinery, and pumps to prevent mine-flooding. Underground mines would cease immediately upon an EMP, and could not resume until electricity supply was restored. There might not be any electricity to spare from the 20% that would be restored within days, but coal stockpiles would last 6 months even at present rates of use. With post-EMP demand they could well last a year, giving time for restoration of electricity, repair of damaged plant, and reversion to more manual methods. Availability of diesel to distribute the stockpiles would be crucial during that first year.

Surface facilities such as sub-stations and cableways are likely to be damaged by EMP and take some time to repair. Underground equipment may be protected from EMP damage. The West Coast mines would probably be restored first as they use less complicated equipment than Huntly and Ohai, which use longwallers or continuous miners. The West Coast might also have access to electricity faster than Huntly, where the lack of thermal capacity and the DC link would be creating intense competition for whatever electricity there was.

LIKELY ADJUSTMENTS WITHOUT AN EMP

There would be more time to make adjustments if the country was not affected by an EMP. Thus, lack of pre-planning, although still a limitation, would be less critical. It is assumed that although there would be widespread shock, key personnel, after a short adjustment period, would be able to carry out essential functions. Likely adjustments fall under a number of headings which are set out in the section "Pre-planning Options".

A centrally directed or decentralised society?

The immediate crisis would be an institutional one. Energy systems involve a complex web of relationships between the public and private sectors. These are becoming more complex and less predictable with the corporatisation of energy-producing government departments, and with strategic and social goals increasingly giving way to commercial ones.

Most contributors to this study assume army and police control over key resources and productive capacity, with industry abandoning commercial objectives and working for the national good. With no pre-planning, this would not be a smooth transition. The less planning, the more need for draconian state control. The less flexible this control, the more it would tend to stifle local self-reliance and initiative, and decrease the willingness to work for the common good.

Although there would be no technical reason for immediate disruption of energy supplies if there were no EMP, the initial period of shock and despair could well be characterised by panic petrol-buying and aimless driving around in mistaken attempts to evacuate cities, or simply to fill in time when normal workplaces have closed.

A feeling of despair and helplessness about the future, especially if accompanied by fears of radiation, could well lead to reckless waste of the resources which would be most needed for a viable future. This could be counteracted by a deliberate strategy for a gradual transition to sustainable systems; cars and trucks would yield eventually to bicycles and even sailing ships. This should be promoted at all consultation levels, hence local civil defence networks would need prior guidance.

Stock-taking and inventories

An immediate task for government and essential industries together would be to establish stocks and location of refinery feedstocks, refinery and Motunui products, LPG, coal stockpiles, and key spares for each energy sector, for essential industries and for important vehicle fleets. This would be a very time-consuming process, especially for spare parts, and yet the government would have to act quickly to establish control over such stocks to prevent their being directed to non-essential uses.

Priorities, rationing and requisitioning

The most urgent rationing would be of diesel and fuel oils. The needs of other energy production systems - electricity for patrol and repair of transmission lines and as a start-up fuel for coal power stations; coal for transport to users; the Maui platform for its emergency generators - should be top priority, along with water supply and sewage disposal, coastal and inter-island shipping, and railways. Food production for New Zealand consumption would be a high priority for energy, as would public transport (which uses little), but pastoral and horticultural farming would probably have to accept cuts, as would non-essential road freighting.

It might be possible to avoid petrol rationing, given the high degree of self-sufficiency, if people could be persuaded early to conserve, but in an unplanned situation it is likely that petrol consumption, too, would have to be forcibly curtailed.

It is very important, in order to maintain social cohesion, that any fuel rationing system be seen as equitable. The system set up after the 1979 oil crisis was widely resented because of the advantages it gave to 2-car families (rationing was per car, rather than per person) and for the priority it gave to business-related needs, of whatever kind, over personal needs. If a positive spirit of co-operation is to be maintained despite much personal grief, the needs of people to maintain contact with their families and friends must be recognised as important. Given the amount of indigenous petrol likely to be available, there is no reason why non-essential commercial and industrial activity should not share the cut-backs with private motorists. Rationing per household disadvantages women and children, who are often the ones most in need of car transport.

There would be no point in rationing CNG and LPG to vehicles. While this might create some resentment from other motorists suffering petrol rationing, it would also create a powerful example of the advantages of converting to CNG or LPG, which would presumably be promoted by a post-war government. In this scenario, petrol is unlikely to be scarce enough to justify requisitioning such alternative fuel vehicles for essential purposes, especially as they cannot generally substitute for diesel use.

A gas-use plan would be an early priority to ensure wise use of our most valuable single resource. There would be a direct trade-off between easing the short-term adjustments and transition, through a fast rate of gas use, and security in the longer term, achieved by a slower depletion policy.

It is assumed that the Maui take-or-pay agreement (which commits us to a fast rate of gas use) would cease to have any effect and that the only limits on depletion policy would be technical ones associated with the wells, platform and treatment facilities. If the physical life of the Maui platform(s) existing at the time was likely to be less than the preferred depletion time of the field, one option would be to run Maui at capacity before the equipment began to deteriorate, reinjecting some of the gas into the Kapuni field where it would be recoverable later. The on-shore facilities will always be easier to maintain than off-shore, and it would make sense to save on-shore gas for the future. This policy is only possible within the limits of the physical size of the two fields, Kapuni being very much smaller than Maui.

If a nuclear war took place some years hence and gas fields were nearing depletion, more stringent policies on gas use might be needed. If it happened in 1987 we could afford to keep supplying some gas to electricity during a transition period while we developed alternatives.

It is likely that spare parts held by redundant and non-essential industry would be requisitioned to supply essential activities. Compulsory closure and temporary cannibalisation of some plant is even possible, to establish the required industrial capacity to produce spares which are currently imported, with replacement of the "borrowed" equipment at a later date. Both the physical and the institutional arrangements for this would be difficult to organise on an unplanned basis.

Mothballing

A number of industrial plants would have to stop operating within weeks or months because of unavailability of either raw materials or markets. It would be important to protect these installations either as a source of components for similar plants, or because after an initial period of adjustment they could start up again for the same or a different purpose. A planned shut-down would protect against corrosion and other forms of deterioration and security would be needed against unauthorised cannibalisation. The list might include one of the two catalytic cracking units at the refinery, the Waitara methanol plant; some units of the Huntly, New Plymouth or Stratford power stations; the Stockton coal mine; some parts of the Glenbrook steel mill; dairy factories, freezing works, pulp and paper mills. It might even be possible to protect a few pots at the aluminium smelter, but this needs further investigation. These would all need negotiation between the government and industry.

Conservation, recycling and refurbishing

Well-informed conservation strategies (in the sense of improved efficiency rather than curtailment) could greatly reduce the need for both energy and materials. In the absence of prior planning, realisation of this potential would be both slow to take effect and incomplete, but if information were promptly circulated about which materials would become scarce, many people would be capable of devising their own strategies to use them more efficiently. It would be important to persuade people that it would be worthwhile trying to rebuild for a future. Some energy conservation requires investment in products such as insulation or thermostat controls, which might not be available, but much is achievable by changes in behaviour without any real deprivation - for example car pooling; using appliances like ovens and washing machines to capacity, and thus for fewer total hours; and turning off industrial machinery and commercial equipment while it is not being used.

Energy production and distribution is dependent, among other things, on many metals, which apart from ironsands are not mined in any quantity in New Zealand. There would need to be immediate bans on destroying imported materials which were capable of re-use or recycling, and stock inventories of these would be needed. Among the most important materials to conserve and recycle would be lubricating oils, copper (for electrical uses) and lead (for batteries), synthetic fabrics (for sails) and aluminium.

Recycling capacity for most metals, including steel, exists in New Zealand and could undoubtedly be expanded. Some of the newly unemployed would find work scavenging such materials. Industrial waste exchanges would become more important.

Although the lead-time before shortages became critical would allow a degree of preparation, prior investigation of the possibilities would make possible a faster response and a greater degree of materials recovery.

Substitution (by current technologies)

An immediate priority would be a programme to increase the number of vehicles able to run on CNG. This would require large numbers of conversion kits, which are at present imported, but it is understood that both the equipment and the expertise exists to make them in New Zealand. With post-war shortages, however, and no prior planning, it would not be easy or fast.

Conversion kits exist to allow diesel vehicles to run on a mixture of up to 50% CNG with diesel. The problem is more difficult than with petrol engines, and mechanical or electronic devices are necessary to control the fuel mixture. More difficult again is the conversion of diesel engines to spark ignition and then to 100% CNG. No study has been done of how fast such a programme could be implemented or how far it could go, but it would of course only be available in the North Island.

An increased rate of conversion of vehicles to LPG is also likely, although quantities of LPG available from the gas stream will always be limited compared with CNG. LPG might be made preferentially available to the South Island.

There would be large quantities of wood available with the closure of export industries, but transport of it to cities would require considerable diesel fuel, compared with the energy yield from the wood. Kiln drying of firewood would reduce transport costs and greatly increase the burning efficiency in most uses. Wood located within reasonable distance of population centres could progressively be used as a home-heating and cooking fuel as electricity supply decreased for lack of spares and materials. Domestic wood-burning appliances could be made in New Zealand, and the engineering capacity exists to redesign boilers. Two small changes in how open fires are used can greatly increase their efficiency. This would need supervision by local advisors in order to maintain safety. (See Melhuish, 1979, for description.)

Wood could also be used as a material to replace some imports - for example coal mines would probably revert to wooden pit props as steel head-sets became unavailable.

The Electricity Division commented on substitution by older technologies as follows:

> "the above discussion assumes that most of the technology used in the power system will gradually "roll back" to the level of earlier years which is capable of being sustained by local New Zealand industry. Thus the performance of industry is critical. At the very worst New Zealand will have a pre-World War II level of technology in the electricity supply industry.
>
> "Within the Electricity Division there were two broad attitudes towards both scenarios. Obviously, the postwar electricity system would differ from the present day. Those people who are exposed to a wide variety of ways of running the power system were the most optimistic. The optimists were either older, senior people who have seen the power system develop over the last 30 or more years, or the people who have been involved in examining and planning change. The other people without this exposure have experience of only one type of power system and their concern was in maintaining the present form of the power system, which would not be a viable alternative."

Technological change/innovation

Manufacture of spare parts previously imported would be a major challenge to an increasingly impaired New Zealand engineering industry. Electricity Division comments:

> "The electricity system contains a number of specialised components unique to the electrical supply industry. The scale and quantities of the

components required is too small to maintain their supply as a viable industry in New Zealand. Instead, much of it could be produced in essentially one-off operations on a scale just slightly larger than a laboratory. Suitable production areas could be research laboratories at Universities and DSIR etc. It is seen that these specialist laboratories will play a critical role in sustaining the viability of a post war power system."

A number of technologies to provide alternative fuels to petrol and diesel are well proven, but not commercialised. They would be options in the longer term.

Methanol could either be blended with petrol or used straight as a fuel. Up to 15% blended with petrol would require no changes to vehicles or the distribution system and could be an immediate use for the Waitara methanol plant. If the Mobil ZSM catalyst used to convert methanol to petrol at the Motunui synthetic petrol plant were to defy replacement from within New Zealand, a very large amount of additional methanol would also be available from that plant.

Use of 100% methanol in petrol engines would require modification of carburettors and the setting up of a distribution system. Petrol tankers, service station tanks and pumps could be used to distribute methanol but would have to be cleaned out first. Leaky ones would have to be repaired as methanol is miscible with water. Some service stations would not have tank space for both methanol and petrol. Once converted to methanol a vehicle does not have dual-fuel capability, which makes the introduction of the new fuel much more difficult than for CNG.

The use of methanol in diesel engines would require an ignition enhancer. The Liquid Fuels Trust Board advises that this would require a nitration facility in New Zealand to make nitric acid. Whether it would be possible to set up such a plant in a post-nuclear war New Zealand has not been studied.

Eventually, as natural gas was depleted, methanol could be made from wood, but there is a question whether a plant on the scale needed for transport fuel could be built in a post-war New Zealand.

Methanol is also the key to making some agricultural products useable as diesel substitutes. Tallow from meat works, butter, and rape seed oil can all be esterified with a small percentage of methanol to produce acceptable diesel substitutes, or to blend with diesel. Tallow could provide 10% of current diesel use, but this assumes current production levels of livestock and meat, so its post-war contribution would be much less. It would take about 6 months to set up production. Butter, at current production levels, could provide about 15% and would take 6-12 months.

Rapeseed is grown in Southland now and the oil extracted in a farmers' co-operative plant near Bluff. It is possible to use straight seed oil in place of diesel but effects on engine durability and performance can be severe. Esterification overcomes these problems.

The lack of natural gas in the South Island could be substituted for by the production of biogas from municipal waste, sewage, manures, agricultural wastes, and specially-grown crops. The technology is well established. Vehicle conversions and compression and filling equipment are as for CNG.

Eventually, such a development in the South Island would provide a basis for gradual replacement of natural gas in the North Island as the gas fields are depleted. Production, however, is most efficient at a fairly small local scale and quantities achievable could never replace the present high volumes of gas use.

Solar technology would undoubtedly continue to develop. Very efficient New Zealand-designed solar water-heaters which require no copper are now made in Christchurch, and would gradually substitute for part of the present electricity load.

Wood gasifiers would be an option for some rural transport. They are built locally at present. Using them to run vehicles, although it has been done in New Zealand, involves some technical problems.

Trade with Australia

No mention has been made so far of trade with Australia as it is suspected that their industry would suffer in many ways similar to ours. Spares and materials currently available from Australia might no longer be available if their Australian manufacturers depend on materials or components from the Northern Hemisphere.

Limited trade could be re-established with Australia eventually, but this would depend on our having products they could not produce for themselves, as well as on their capacity to supply our new needs.

Australian investigations into *their* ability to survive a nuclear war reveal that although they are a net exporter of oil, they are dependent on heavy imported crude oils for all types of lubricant, and for about 40% of diesel requirements. We should not, therefore, expect to import these products from them (*Search*, 1986).

LIKELY ADJUSTMENTS WITH AN EMP

Most of the adjustments described above would not be possible after an EMP. Lack of communications and power would prevent centralised control over resources and productive plant. Concern with personal safety and survival in the absence of electricity, sewage pumping, water supply and transport of food, combined with concern about family and friends who could not be contacted, would prevent many people from turning up for work in essential occupations.

Electricity Division has examined this question and postulates that:

> "...because the electricity workforce routinely works together as a group, they will remain cohesive and effective under severe strain. Also, restoration work will not begin until the safety and security of workers' families are seen to. These observations come from experience with restoring power systems after disasters. It may be that some workers will require special privileges so that they can work worry-free on restoration."

Prompt stock-taking of key resources would be almost impossible without computer access to data. By the time this was restored, resources might well have been commandeered locally. No equitable fuel rationing would be possible, but those supplies which could be readily located would have to be requisitioned for essential uses.

A system of priorities would be needed for restoration of electronic equipment in the electricity grid, gas production and delivery system, and transport fuel system. Location of spare electronic components would be urgent and very difficult. Planned mothballing would not be possible because all plants would fail instantly. Some would never start again, and others would have severe technical problems even after restoration of electricity and fuel supplies.

At a local level, some small communities would be likely to share facilities such as wood stoves to provide basic cooking and warmth for neighbours and friends. Rural households would fare best, with on-farm firewood supplies, independent water from bores, underground springs and roof tanks, sewage disposal to septic tanks, and at least some on-farm food. In some places horses would provide transport for people and goods, but numbers are too small and distribution too uneven for them to provide an adequate vehicle substitute nationwide. Within a few months their usefulness could be limited by lack of shoes and nails.

PRE-WAR PLANNING OPTIONS

Without an EMP, there would be time for emergency planning to be done after the event, because there would be a period of months before there were major breakdowns in the energy system. However, some prior planning would enable a much more efficient response, make it possible to look at the long-term future much sooner, and ensure a higher quality of survival, especially in the long term.

If there was an EMP, prior planning could make the difference between total social disintegration with large-scale waste of resources, and the maintenance or restoration of a basic level of communications and energy supply.

Social organisation

Prior discussion between government and key industries would help reduce the institutional crisis. This could include defining areas of responsibility and methods of making and enforcing decisions.

Social behaviour would depend to some extent on the information that is available and whether people believe it. If the event were to happen now, many people would simply not believe a post-war announcement that the radiation hazard was minimal and people should not be afraid to drink the water. One contributor has pointed out that increased sunburn in outdoor workers, due to increased UV light, could be misinterpreted as an effect of ionising radiation. Basic information like this would be more easily conveyed before the event than after.

Social organisation at a decentralised level would be equally important. Existing neighbourhood groups - Neighbourhood Watch and Support groups, or school associations - could be encouraged to discuss how their community would be affected, list local resources such as firewood supplies and wood-burning appliances, CNG vehicles, independent water supplies, amateur radio operators, and various types of technical expertise. Plans could extend to sharing the contents of freezers and refrigerators thawing after an EMP, and conserving everyone's supplies of canned foods and dry goods for later. This kind of exercise would have social benefits even if the event does not occur.

Resource inventories

Information already exists in an uncoordinated and decentralised way in industry about the day-to-day size and location of stocks of materials. If a system could be devised to feed this information regularly into a manually-accessible, centrally- and regionally-based data system, post-nuclear war responses could be dramatically improved.

Essential industries, and particular plants within them, could be encouraged to keep up-to-date, manually-accessible inventories of key spares and materials, and to investigate possible New Zealand substitutes for these when stocks run out.

Stockpiling could be considered for imported crude oil, diesel, catalysts for the refinery and synfuels plants, scrap materials such as copper, and key spare parts for the electricity and gas networks. This would have to be planned on an industry-by-industry basis. Such stockpiling is generally contrary to commercial objectives and criteria would be needed for the degree of security to be sought, and who should pay the extra costs. Some centrally-organised stockpiling of key components used by all industries and not made here, such as ball-bearings, would be a further possibility. The trade-offs between present costs and future security would need public discussion.

Priority and rationing plans

Accurate knowledge of size and location of stocks is a prerequisite to their efficient allocation. Advance allocation plans therefore would tend to identify priorities rather than allocate actual quantities.

An advance fuel rationing plan would make possible the immediate conservation of stocks, and if perceived as equitable would do a lot to establish public trust in central authority. Preparation could also establish the size of regional needs in a post-war economy so that stockpiles could immediately be directed to appropriate places. The stand-by petrol rationing scheme developed several years ago would not be appropriate for a post-war situation because many of the priority users it establishes are related to export activity. A new system would be needed.

Plans could be made now for a system to allocate the initial 20% of electricity supply that would be available a few days after an EMP, and then for further allocation of additional restored capacity. A decision about gas use and depletion rates if the country was *not* affected by an EMP would enable the Electricity Corporation and the Refining Company to plan their operations. Prior study of which non-essential industries could donate and/or "lend" parts or materials to essential activities could greatly facilitate the implementation of this strategy. An agreed priority list for restoration of EMP-damaged equipment would also be useful, given that all damaged facilities will tend to draw on similar materials, spare parts and expertise.

Mothballing

Plants likely to be forced to close, as listed in the previous section on mothballing, could be asked to prepare a mothballing plan, to include provision for long-term preservation of equipment and protection from pillaging.

Conservation and recycling

The general encouragement of a conservation and recycling ethic would have considerable benefits in peace time, and would increase the likelihood of appropriate responses after a nuclear war. At the very least, some public education of what materials would be valuable could be worthwhile.

Existing recycling industries could be asked to investigate how far they could increase their throughput after a war, and to investigate any key shortages they would face.

Substitution

A large-scale transition to the use of CNG in all possible vehicles would be easier to accomplish if planned in advance. Data probably already exists in the industry of stocks of kit components and numbers and distribution of trained installers. Although it is believed that the technical capacity exists in New Zealand now to make all the components, it would be safer to investigate where, by whom, at what rate, and what key materials might be unavailable post-war. For example, if metal specifications of cylinders and other parts could not be maintained, it might be necessary to reduce filling pressures to preserve safety, further reducing the already limited range of vehicles. More work on diesel engine conversions to CNG would have benefits now as well as post-war. All of this work would contribute to an eventual contribution from biogas, extending the benefits to the South Island.

There are many older, more manual technologies which would be within New Zealand's post-war capability, but which have been abandoned in favour of high-tech innovations requiring fewer people to operate them. A return to these technologies would be necessary after a nuclear war, and this would be greatly facilitated if information was available on people who understood and could teach these older skills, and enhanced still more by some actual training, in places like technical institutes, before the event.

Planning for import substitution would hasten a post-war recovery. For example, Electricity Division suggests:

> "Postwar, the Electricity Division would be forced to solve many import substitution problems. Pre-war stockpiling would be of limited benefit. Far more useful would be the identification of several viable processes to substitute for imports. Prior identification of problem areas and possible solutions would ease the transition into the postwar era."

Technological innovation

Even in the best scenario, transport fuels will be a major problem when local gas and oil fields run out round about the turn of the century. Replacements have long lead-times anyway, and these would be much longer in an unplanned post-war situation. Preparation which could be done in advance includes reviewing the quantities and locations of surplus biomass (i.e. farm and forest products at present exported) which could be available for conversion to fuels, and planning and locating key resources for the esterification of tallow, butter, and seed oils for diesel substitution.

Wood resources would be so large, and so far from energy users, that conversion on site to pipelined gas could be investigated.

Trade with Australia

If any similar studies are initiated in Australia it could be worth exploring what the two countries would have to offer each other in post-war trade. This might prevent the closing down of an export industry which could enable us to buy needed supplies from Australia.

Protection against EMP

There are three possible methods for protecting against EMP:

1) metal shielding of vulnerable equipment to prevent the pulse reaching it;

2) stockpiling of sufficient spares to replace damaged equipment; and

3) ensuring that sufficient equipment is always disconnected, to restore a skeletal system after operating equipment has been damaged.

All three methods are expensive and some combination of them is probably the best strategy to adopt.

Shielding of an entire nation-wide network such as the electricity grid is clearly impractical. Major plant items can be protected with metal oxide surge arresters, which are becoming increasingly common for over-voltage protection from within the system. Making them capable of resisting EMP would impose little extra cost, but the analysis and design work would be difficult and expensive. Improving over-voltage protection in the electricity system would not prevent a black-out, but would make it possible to restore all the hydro stations eventually. The entire system could be protected by shutting it down if there was sufficient warning, but that in itself would cause a total blackout. With prior planning, a significant part of the system could be made safe in 2 hours, and all of it in 10-14 hours. It would seem unwise to rely on having this amount of prior notice.

New equipment can be built with EMP sensors which activate a shut-off before the equipment is damaged by a pulse. Again, design work would be expensive.

An EMP-protection plan would need to establish priorities for such protection. A significant proportion of power stations and a grid of transmission facilities would seem to be a top priority, as would equipment at the Maui and on-shore production facilities and the refinery. Given that liquid fuels can be stockpiled where electricity and gas cannot, the refinery might be a second priority.

Then decisions would be needed as to the most cost-effective mix of screening, stockpiling and disconnection for each system.

Rationale for consultation

New Zealand society after a Northern Hemisphere nuclear war could move quickly towards chaos; alternatively it could move, probably piecemeal, towards successful policies of crisis management. The main difference is psychological, and the pattern could well be set in the days or hours before war actually broke out.

If any advanced planning is done for a consultative process, it should probably be focussed on the two extremes where activity must be initiated - the top level and the most distributed level. At top level, a list of likely priorities should be prepared; at local level, a recognition of both strategic and psychological needs should be part of civil defence planning.

Only at the local level can the personalised, interactive process of crisis management actually take place. The only sure thing is that objectives of such management will be changed as circumstances change, and will have to adapt in turn to the needs of the people involved.

At local levels, stocking of strategic items could be done from the start; the more decentralised the better. Refugees from other countries would be sure to raid any centralised stockpiles. Exchanges of essential items would be expected whether by purchase or barter.

More important is a house-by-house consultative process, aimed to not only maintain standard of living, but to offer people constructive ways to help each other. Without this, people may waste vital resources simply because they see no future.

Consultation throughout Maori communities would be easier because of the existing formal and informal structures ranging from district and tribal councils to whanau.

At top level, consultation would aim to determine strategies for creating bridges from an import-dependent society to an essentially self-sufficient one. The aim again is interactive; draconian measures at the outset would probably cause waste themselves, but priorities must be set and changed as appropriate.

A third, poorly appreciated, area of local consultation is in productive industries and the provision of essential services. This could be adapted from a well-defined interactive process called Quality Assurance, developed by industries with special needs beyond what ordinary manufacturing processes could meet. In manufacturing it works essentially as follows -

- consultation between buyer and producer on the quality of product that is wanted;
- inspection by the buyer to convince him/herself that the producer can achieve that quality;
- documentation throughout the production process to satisfy both parties that the agreements are being followed.

However difficult communications may be in a post-nuclear war New Zealand, such consultation, inspection and documentation may be a cost-effective use of the country's resources in times of great uncertainty.

UNCERTAINTIES, FURTHER RESEARCH

There are major uncertainties associated with every step of this analysis. The most important ones relate to areas outside the energy sector, but on which it depends: principally questions of social behaviour by people in essential occupations, of the capacity of engineering workshops and of continued functioning of industry generally. Directions for further research will be more easily chosen when all the Background Papers can be seen together and connections established, and when public reaction to this study throws up new information and questions.

A few matters however already stand out as important.

Industrial Processing

The DSIR contribution has described very clearly the interdependencies among industrial plants, and the difficulties of estimating how long or how well they could continue to function, by using as an example the universal need for ball-bearings:

> "For economic reasons, ball bearings (rolling element bearings) are manufactured in only a few specialised factories around the world. As far as is known, these are all in the Northern Hemisphere. Bearings are thus imported into this country, (and Australia) built-up into units of various sizes for various applications. These bearings are necessary in nearly all kinds of rotating machinery.
>
> "This rotating machinery may be built up in New Zealand from many components. These other components may be made in other New Zealand factories or they may be, again, imported as units.
>
> "The rotating machinery so produced may again be utilised by a second New Zealand manufacturer as part of another manufacturing process which provides, say, a consumer product for which society has a demand.
>
> "For the sake of argument, let us say the bearings are installed in New Zealand into electric motors. These electric motors must of necessity find a wide enough market to sustain the manufacturer. Thus these motors would reach a substantial number of industrial users. Some motors may be installed, in the second stage, in (for example) washing machines and in industrial pumps. The end point for washing machines is obviously the public, but pumps may in turn be used as process control equipment in power stations, the refinery, chemical works, pulp mills, and indeed the majority of factories using power and process control.
>
> "Back at the first New Zealand factory producing the motors, bearings play only a small part in the construction of a motor. Cables, shafts, wire, chemical resins and nuts and bolts are used. These components will be sourced according to the economics of supply, some also from overseas and some from local factories. But if overseas supplies are cut, and local factories which produce cables, shafts, wire, chemical resins and nuts and bolts need a continuous supply of motors and pumps for their daily operation, then a problem arises as soon as maintenance demands in these factories throughout New Zealand have expended our stocks of bearings.

"The time period for this to happen is unknown. The degree of interdependence is also unknown (i.e. does it matter whether it is the nuts and bolts factory or the resin factory which goes down first?) Thus, it is suggested, the example of supply interruption of a single imported commodity such as bearings shows that disruption is soon fanned out to networks across the whole of New Zealand industry and production.

".... there are many more strategic components which we presently import, such as tube, pipe, plate, switches, alloy steel, precision forgings, sheet, strip, heavy forgings, and power cable which also enter the present balance status, giving similar results to the bearings example."

DSIR continue with an outline of the research that would be needed to understand these complex pathways better and to see how to build more resilience into the system:

"1. Consult with the plant maintenance engineers or equivalent personnel at key locations such as:

- all Electricity Division power stations
- electricity transmission facilities
- Shell, BP, Todd production facilities (Maui platform, Oanui, Kapuni)
- Telecoms
- Gas to gasoline plant
- Methanol plant (liquid gas)
- Marsden Point Refinery
- State Coal
- McKechnie Bros
- NZ Steel
- Pacific Steel
- Petrocorp (natural gas)
- Liquigas
- Watties
- major foundries
- major heavy engineering works
- Defence production/engineering
- NZ Forest Products (sawn timber).

The objective of consultations would be to request the nature and volume of essential maintenance supplies as well as raw material needs. This should then be compared with data on stock levels from the Department of Trade and Industry to give time scale requirements.

2. Having identified essential supplies, evaluate the available capacity for their local manufacture, and the shortfall if any.

3. Consult with representatives of such local manufacturers in No. 2. to identify their essential maintenance supplies and raw materials which are necessary to provide the volumes identified in No. 1., and the shortfall if any.

4. Reiterate this process until basic raw materials are reached. (That is, natural resources rather than manufactured items.)

5. Put together the requirements for raw materials in No. 4. with the shortfall in Nos. 2., 3. and reiterations. This gives the size and type of industrial capacity which is not presently available.

6. Making extensive use of improvisation and knowledge of process needs, establish a list of needs in order of priority (as far as possible) to satisfy the requirements in No. 5. For priorities, the time scale in No. 1. is of value.

7. Add to that list the needs of quite new industrial capability to produce the items which are presently wholly imported (such as aircraft, motor vehicles, armaments, shipbuilding) but which would not be needed until the medium/long term to replace or add to existing stock.

8. Consider the means by which the needs may be met using stocks of imports and recycled plant taken from other industries, to produce a contingency plan."

The steel industry

NZ Steel is largely export-oriented. Its ability to produce a range of steel products for local use would be crucial in a post-nuclear war economy. Research is needed to establish

1) What steel products it currently makes for the New Zealand market

2) What extra products it could make post-war without prior planning

3) How much this level of self-sufficiency in steel could be raised by pre-war planning and preparation

4) What steel types/products would still be unavailable post-war.

A study of the energy needs of a reorganised steel industry (both New Zealand Steel and Pacific Steel) after a war would be useful, as would some assessment of its ability to use more scrap in its production. A study of colorsteel as a cost-effective means of corrosion prevention if resins are in short supply would also be useful.

Expanded CNG

It would also be useful to discover what the principal constraints would be on a rapid expansion of the CNG industry in the North Island. Does New Zealand in fact have the capability now to make all the components of conversion kits; if so, how fast could they be turned out; would we need to stockpile any materials, e.g. special steels, in order to do so?

Biogas

Biogas would be the most easily developed renewable alternative fuel for the South Island. Once the gas is produced it uses CNG technology for compression, filling and vehicle conversion. Because of its decentralised local production, there would be no pipeline network to maintain. It would not be universally available but converted vehicles retain petrol capability.

The unanswered questions are:

1) What components for digesters, scrubbers, compressors and storage cascades are import-dependent?

2) What preparation would be needed to make the rapid deployment of biogas in the South Island feasible within the first, say, 2 years after a nuclear war?

3) How much biomass would be available from wastes and crops currently grown for export, and how much land currently contributing to export products could be available to grow biogas feedstocks?

This material could probably be fairly quickly compiled by Dr David Stewart of MAF Invermay Research Station.

Fuel issues

It would be useful to have a more thorough and reliable analysis of post-war demand for diesel and heavy fuel oil. Any advance rationing plans would be helped by knowing approximately the magnitude of the likely shortfall. Also, an investigation could be made into the relative worth of petrochemicals as feed stocks for paints and glues, as opposed to their worth as fuel.

CONCLUSIONS

1. The energy sector is so interdependent that a loss of electricity, gas or transport fuels would severely cripple the production of all major forms of energy.

2. Demand for all forms of energy would be reduced after a nuclear war because of export-related activities. This reduction is most difficult to predict and quantify for transport fuels.

3. Unless an EMP occurred, it should be possible to continue to supply all forms of energy in adequate quantities for the changed economy for several months, with the exception of diesel, which would be in short supply. Thereafter, lack of spares, materials and catalysts would tend to affect production in terms of both quantity and reliability, with a steady decline in both for the electricity system, and the possibility of sudden loss of major gas and liquid fuels facilities.

4. New Zealand's self-sufficiency in transport fuels will peak in 1987/8 at 55% and decline thereafter to about 27% in the year 2005 (see background information on liquid/transport fuels). Barring new discoveries or major unforeseen technological change, the later a nuclear war occurred, the less well-placed we would be in this respect.

5. Availability of liquid fuels would depend heavily on depletion rates chosen for the Maui gas field and the various on-shore fields. A decision to use gas inefficiently in the short term, or in the extreme case to flare it to waste in order to maintain condensate supply to the refinery, would seriously compromise the long-term supply of pipeline gas, CNG, methanol, chemical feedstocks, and of course condensate.

6. Diesel supply would drop to 34-45% of present levels, depending on gas depletion policy and adjustments to product mix at the refinery. This would necessitate strict rationing to maintain essential uses. Such a rationing system would be established more quickly, easily and fairly if some advanced planning were done.

7. Bitumen and heavy fuel oils are at present made only from imported crudes but with some change in specifications could be made from McKee crude.

8. Of all indigenous transport fuels, CNG is least dependent on complex petrochemical plants. At present some 100,000 vehicles are converted to use it. It appears that an expanded conversion programme using New Zealand-made kits would be possible. It is only available in the North Island but the same technology is used by compressed biogas, which could be developed in some areas of the South Island.

9. LPG is less vulnerable than petroleum fuels to the breakdown of complex petrochemical plants and is available in both islands, with 40,000 vehicles converted at present. Some expansion is possible but total quantities are limited as it is a fixed small proportion of the total gas flow.

10. Gas and condensate might be better used as chemicals (i.e. urea could be used for making fertilisers, glues, or resins) than for fuels.

11. The present imbalance of electricity supply and demand between the two islands would be increased by the closure of the aluminium smelter, the eventual loss of the Cook Strait cable, and decreased production from thermal stations, whether resulting from fuel allocation policies or their greater vulnerability to loss of inputs.

12. The ability of all energy sectors to maintain their plant on locally produced and adapted spares would depend on the capacity of light and heavy engineering workshops to operate without imports. This is still largely unknown but it is suspected that shortages of a wide range of inputs, from ball-bearings, solder and drill bits, to major spare parts for complex machine tools, could virtually cripple them.

13. Any repairs to the Maui platform or undersea pipelines which required diving below 50m would be very difficult, although this need would be unlikely to arise in the short term.

14. An EMP would cause a total electricity blackout and the immediate failure of all major energy systems. All of them would suffer some damage which would take time to repair, in those cases where it could be repaired at all.

15. After an EMP about 20% of electricity supply could be resotred in 2-10 days. This would be enough only for essential services such as water and sewage pumping, public lighting, communications where they had survived, and a small amount for hospitals. There would be no domestic, industrial or commercial supply.

16. A further 10-20% might take from a few more days to a year to restore. There would be considerable regional variation if transmission lines had been affected.

17. There would be considerable damage throughout the gas production and distribution system which would be very slow to repair in the absence of usual communications, power and fuel.

18. It is likely that the on-shore facilitites could eventually be restored, and possibly the Maui platform as well.

19. The synthetic petrol plant would be impossible to repair and restart after an EMP.

20. The refinery would be shut down for an extended period. Parts of it might eventually be able to operate again at a very basic level.

21. CNG would be the easiest transport fuel to restore after an EMP, followed by LPG.

22. If an EMP occurred during times of peak traffic-flow, road blockages from accidents caused by the immediate failure of all vehicles with electronic ignition might seriously hamper the use of even those fuels which could be manually extracted from storage.

23. While prior planning would be an advantage under the assumption that there would *not* be an EMP, it is essential to even a limited reconstruction if there *was* an EMP.

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