Energy Panel of the Royal Society - Interim advice to the MoRST energy roadmap group:

The Royal Society of New Zealand has established an Energy Panel to provide scientific and technological leadership for a secure and sustainable energy future for New Zealanders and our economy. The Panel is an independent group of experts from energy and associated research areas, supported by the Royal Society and lead by President Jim Watson.

The Panel is developing a broad view of sustainable energy resources and opportunities to determine needs for future energy research, taking into account New Zealand's aspirations, growth, innovation and security. The panel provides ongoing independent advice and recommendations on energy research and development, and business opportunities to the public, business and government, and promote education and understanding about energy issues. We aim to publish this research in more comprehensive form in 2006, but we present this interim advice to inform the MoRST energy roadmap group.

Panel Members

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Summary of advice

Our energy resources have been seen as effectively unlimited. However, climate change makes clear that the biosphere is a constrained and closed system, which cannot sustain our current impact. New Zealand must shift its energy base to reflect this fact. Our emissions must fall.

Our sources of fossil fuel can only support a growing economy in the short term. However, investment decisions that may expand thermal generating plant, especially coal, will develop plant that lasts far beyond that short term. Hence these investment decisions must be guided by likely economic and environmental conditions in decades to come. Their use must be controlled to that which the biosphere can accept. Without this,

we are certain of dramatic climate change and we risk abrupt changes to the biosphere that may be irreversible.

We hope for a sustainable economy that continues to provide ever-developing services and quality of life for all New Zealanders. This development must take place without growth in emissions, indeed drastic cuts are needed. We will need massive efficiency improvements, low-carbon electricity generation and drastic changes to transport systems. These will require investment in social and economic areas as well as technological developments. We hope that research advances will enable carbon-neutral, domestically produced fuels to become cost-competitive with imported fossil fuels, returning New Zealand to a position of self-sufficiency in energy by 2025.

This approach will result in benefits to New Zealand through maintaining our environmental credibility with our trading partners, a stronger economy through improved balance of payments, and reduced economic risk through reduced exposure to severe weather events and uncontrollable international factors such as fossil fuel supplies and prices.

1) Our energy resources and opportunities

Resources:

New Zealand has huge reserves of coal, but is also well-endowed with wind, marine, geothermal, biomass and solar power. We have traditionally been self-sufficient in energy, with exports of coal beginning in 1866. The shift to tradable fossil fuels and increases in demand for liquid fuels resulted in New Zealand losing its self-sufficiency in the twentieth century. The economically usable reserves depend upon economic instruments and the price of power. For a small market like New Zealand where barriers to entry and questions of scale exist, they also depend upon particular infrastructure investments (i.e. if an liquidifed natural gas terminal is built, that is likely to have a harsh impact upon the local gas exploration industry).

In the twenty-first century, our energy resources are becoming diverse but fossil fuels will become increasingly supply-constrained.

Infrastructure opportunities and traps:

Renewable growth rates

Wind is now cost-competitive, even without carbon charges. Globally, wind generation has sustained a 30% annual growth rate. In New Zealand there are few reasons why that rate could not be achieved. Forecasts of gigaWatts of wind generation appear in several realistic scenarios, with the eventual limits being grid constraints, rather than available wind resources.

Electrical security limitations on supply makeup

The fluctuating generation from wind implies extra costs in transmission, storage and backup, once wind generation becomes a substantial fraction of generation, more than 20%. However, even with the fastest growth predictions, wind power will take more than a decade to come close to that fraction. With a decade's more research, cost-effective storage and power management will improve. Hence wind power may grow to far more than 20% of generation without incurring excessive extra costs.

The presence of hydro affects the impacts of wind variability, and vice versa. Achieving good matching of hydro and wind management regimes involves matters of market design as well as technical issues.

***C*oal-fired generation**

Our great reserves of coal are limited in their use because of their inherently high carbon emissions, unless radical new technologies are developed. Further expansion is a short-term solution to our energy problem, as there are high chances of current or planned generation plants becoming stranded when prices change/environmental externalities have to be paid for.

Coal-fired power stations have historically had working lives of forty to fifty years, their lives have been limited by technological obsolescence, not through wear or fatigue. Essentially, they become too expensive in comparison with newer coal plants or other forms of generation. It is generally uneconomic to continually upgrade older technologies. The economic lives and sunk capital in these older plants thus depends on their cost of generation (in dollars per kilowatt-hour) as compared with the cost of generation from alternative technologies and fuels.

High-emission coal-sourced electricity is more disadvantaged by carbon taxes or other economic instruments for accounting for the cost of emissions. The proposed NZ$15/t CO_2 tax will add 1.40 ¢/kWh to the price of electricity. This extra cost is expected to make a dramatic difference to the growth of coal-fired generation, in the most conservative scenarios this cost reduces the rate of growth by a third.

As experience and research add certainty to the costs of climate change, the costs will be revised. A prudent expectation is that carbon costs will rise dramatically. In Europe, rights to emit already trade at over NZ$40, more than two and a half times the price in New Zealand. Assuming New Zealand decides to pay those costs at the time of generation, then the cost of burning coal will clearly increase dramatically, by at least 20%, and they will continue to increase as the effects of the carbon burden become ever clearer. Avoiding this charge, through the use of carbon capture and storage at the point of generation, also brings its own costs, potentially doubling the price of coal-fired generation. Some scenarios predict no growth in coal generation, purely on these economic grounds.

The price of alternative sources is another factor controlling the economic lives of coal-fired power stations. Wind power has been halving in cost every fifteen to twenty years. The technology used has had far less development time than coal or other fossil fuel technologies so can be expected to show continued increases in cost-effectiveness. This increasing price advantage will enable competitive installation of wind farms at a large number of New Zealand sites, potentially developing gigaWatts of wind generation.

The availability of renewable sources dramatically affects the economic viability of coal and fossil fuel generators. When they are used as firming plants that do not run when renewable generation does, they are expensive assets that stand idle. They provide security to the generation system but that service is not compensated, with state-ownership of the Whirinaki Power Station, used for dry year reserve power.

In conclusion, coal-fired generation may appear attractive in the short term, but risks rapid obsolescence.

2) The efficiency and intensity of energy use

Our national performance

The National Energy Efficiency and Conservation Strategy has a target in NZ of continual improvement of 2% per annum, which is at the upper end of what is cost-effectively achievable. Evidence is that this figure has not been achieved in the first five years of the NEECS.

However, growth of population and GDP has resulted in energy consumption increase of 2% p.a. with modest efficiencies gained in specific areas. Therefore a greater effort and incentives are required to continue the trend of increased business and transport efficiencies despite the increase in population and GDP.

Drivers of energy performance

The drivers for this performance are the historically low price of energy in New Zealand, which reduces incentives for energy efficiency and has attracted energy intensive industries such as aluminium (Comalco), dairy (Fonterra), fertiliser and pulp production. Transport is another factor, with a low-density population, travel demand increasing and a vehicle fleet that is old and rarely chosen for efficiency. Transport fuel prices have declined in real terms over the last twenty-five years and remain at low levels, despite recent price rises.

Potentials for efficiency improvement within sectors

Larger benefits are clearly possible in the commercial, transport and residential sectors, through the economic use of currently existing technologies.

The low prices that have attracted energy-intensive industries have lead to a low emphasis on energy conservation within those industries. Despite these low energy costs, these industry sectors have shown continued and ongoing increases in energy efficiency. For example Comalco have increased their energy efficiency by 12% since 1990, without significant requirements for action to account for their carbon costs.

A longer-term view of the aluminium smelting industry shows a factor of four improvement in energy efficiency over the past hundred years. This improvement path shows no signs of abating. A wide range of energy efficiency technologies exist for most industries and continue to be developed. Those technologies will be introduced when energy prices rise to a level that justifies that investment.

Overall energy intensity

Our overall energy intensity is affected by both our energy efficiency within sectors and the makeup of the economy. Some predict that pressure to increase energy efficiency through raised energy prices may drive energy-intensive industries off-shore. This reduction in domestic carbon emissions would not result in a reduction in global emissions. However, the low energy prices are not the sole reason for the presence of energy-intensive industries. In comparison with many other nations with low energy costs, we also have a stable political and business environment, a light regulatory regime, a skilled and technologically aware workforce, first-world infrastructure, and significant plant investments. For the diary industry, energy costs are only one source of comparative advantage, other sources lie in our climate and our 'clean, green' brand. These factors all result in "stickiness" of investments. Energy-intensive industries can be expected to overstate the extent and likelihood that they would benefit from moving offshore. Firms are more likely to respond to raised energy prices with energy efficiency measures.

Overall changes in consumption

The impacts of price changes in response to carbon costs are unclear. How will increased energy prices affect land-use, travel patterns and domestic consumption? Energy costs will also tend to follow international prices, and the effect of globally higher energy prices on energy-intensive countries and energy-importing nations like New Zealand may have further effects on exchange rates which may worsen price in New Zealand.

Consumer demand will show some shifts away from carbon-intensive products, as costs for carbon emissions in production filter down to consumers and as awareness of environmental impacts rise. This indirect affect may have a stronger impact on energy-intensive industries than the direct costs of higher energy prices.

Residential, transport and much commercial use of energy is currently unresponsive to price effects. The barriers to economic use of energy are behavioural/attitudinal and informational. Other factors, such as the size of housing, the growth of air conditioning and relative price/usage correlations mean that increasing energy efficiency does not necessarily reduce consumption. Nevertheless, progress in this area is needed to separate ongoing economic development from increasing energy use.

3) A strategic vision for a secure and sustainable energy future

Changes in fundamental assumptions – A finite world and unavoidable carbon liabilities

It is increasingly clear that climate change is occurring and will have a negative impact upon the economy. These costs are being imposed by human activity and will have to be paid, either presently through reductions in carbon emissions, or in the future through climate change leading to impacts on agriculture, severe weather events, droughts, flooding and sea level rise, and indirectly through trade barriers and loss of our clean, green image.

We can make the political decision to avoid paying these costs presently, on the basis of uncertainty about the future costs. However, this approach is losing crediblity and will be increasingly unpopular with our trading partners in Europe, Japan and Asia. We expect that we will continue to have to pay the present costs of emissions, through the Kyoto agreement and the follow-on agreements.

Our potential carbon liability has shifted from an expected gain to a large loss, potentially in the billion dollar range. Committing ourselves to a carbon heavy economy will only worsen this. Our current balance of payments has been negative since 1973 and our trade balance was negative $5.4 billion for 2004. NZ imports of petroleum and oil products made up 70% of our balance of payments deficit. Even if carbon costs are not imposed, this provides us with a strong incentive to reduce our exposure. If they are imposed, and we believe that they will be, then the deficit will worsen, unless steps are taken to make domestic resources cost-competitive.

Fossil fuels are traded at international prices and New Zealand is a price taker. The recent increases in the price of oil have had a large role in the current inflationary spike, outside of normal controls. Similarly, the price of coal has varied by 50% as demand varies. This variability already affects the security of investments in these commodities. Higher variability in price and supply may be more damaging. New Zealand is at the end of a long chain of supply for oil and potentially LNG, should we choose to import it. That chain is outside of our control and may be interrupted by political disturbances, severe weather events or further constraints on the supply of oil. Importing fossil fuels risks national sovereignty.

For environmental, economic and security reasons, we need to make a break between energy use and economic development. The development must continue, the increase in energy use must not. Many of the scenarios briefly summarised below do not make this realisation. With it, our goals for the energy system go beyond reliable, affordable, resilient supply. The new goal is development within constraints of carbon emissions and other externalities. We believe that this will only be achieved by making domestic generation cost-competitive against imported fossil fuels. The clearer impact of fossil fuels, reflected in a rising price, and the declining cost of renewable sources will allow indigenous and no- or low-emitting technologies to become dominant in the market. New

Zealand's vast natural resources will allow us to strive for a return to fossil fuel independence. This will avoid energy-related contributions to the national debt, drastically cut emissions and minimise risks from international events.

Summaries of energy demand growth predictions

		Annual GDP growth	Annual demand growth
MED	reference scenario to 2025 written in 2003	2.5%	0.6%
MED	2005 Briefing for incoming minister		2-2.3% 3% in Auckland
PCE	Fuelling the future		1.9%
	Sparking new designs		1.0%
NZBCSD	high demand	2.5% to 2010, then 4.0%	2%
	moderate demand	2.5%	1.8% to 2010, 1.7% to 2020, then 1.5%
Solid Energy	low growth	1.3%	1.2%
	high growth	2.3%	2.2%
CAE	Baseline growth to 2015	?	1.8% (electricity only)

What might the energy system look like in twenty years time?
In twenty years time, New Zealand could have broken the link between economic growth and energy use. If EECA's target of 20% increase in energy efficiency by 2012 could be achieved, then New Zealand could have high economic growth with a reduced energy demand growth. Aggressive support and ongoing progress in energy efficiency advances would allow that economic growth to continue without increased demands. Our economy will not greatly change its focus but certain industries will suffer from higher transport costs, in particular international tourism and the export of low-value, high-weight commodities.

Hydro, geothermal, and wind will make up the major part of electrical generation, even if electricity demand increases. The growing renewables supply will be well understood and the diversity of renewables will require less firming. This will still be carried out by gas, coal and thermal generation from biofuels. Less electricity will be used for heating and cooling, through healthy, energy efficient houses, and the use of short-rotation biofuels, heat pumps, and solar hot water and direct heating.

Biofuels for transport will be created from large areas of energy crops and from wastes. Land uses for energy crops will compete with food crops, conservation and other environmental services from land and this will cause major rural changes. The cost of liquid fuels will have increased dramatically and aggressive government action will be required to limit the impacts of higher priced transport upon the economy. However, as the rising cost of fossil fuels and the lowered cost of biologically-source fuels will enable biofuels to be cost-competitive, cutting our imports of fossil fuels and limiting our exposure to international events.

4) Determine needs for future energy research

The following recommendations for research are not attempts to micro-manage research agendas. The Panel believes that decisions about research priorities should be set at many levels, but that all decision-makers will benefit from the closest possible connections with the research base. Hence we offer this advice as researchers who have extensive experience in energy or relevant areas. This experience allows us an informed and strategic view.

For each research priority, we advise on the relative importance and the likely timelines for the priority to have an impact. We summarise these two factors for each using a brief graphic and a complete table of our advice is found at the end of this section:

				Higher relative importance
				Medium relative importance
				Lower relative importance
now	Short-term	Medium-term	Long-term	⇦ relative timescale or urgency

Energy is a global problem and New Zealand researchers will only contribute to a small part of the solution. Hence in this work we have concentrated on two criteria: will New Zealand benefit from this work, and will New Zealand benefit from this work being done in New Zealand.

The former explains our focus on uniquely New Zealand problems, such as our renewable endowment and our housing stock problems. These issues will not be researched by others. For the later, we have looked for areas that can contribute to our transition to an innovation economy. Here we focussed on the need to go beyond being a technology taker and the benefits from being a source and owner of the technology, through having access to IP through research partnerships, and from ownership and control of critical IP.

Priorities regarding high level goals

Energy security
High importance, wide timescale

X	X	X	X

The number one issue for government, consumers and the energy industry is security of energy supply, which is a multi-faceted problem. It includes the following key issues:

- Medium- to long-term gas supply
- Sufficient electricity generation capacity from a range of sources
- Competitive selection of long-lived supply infrastructure (generation, transmission and distribution assets)
- Maintenance and capacity upgrades of the electricity transmission system

There is an abundance of alternative options and opportunities for meeting New Zealand's growing demand requirements. There is, however, no consensus on the final selection of the portfolio of options that are developed. As a result, too little investment in R&D or actual construction is taking place. Meanwhile, demand is growing, energy reserves declining and ageing infrastructure are reducing our energy security. There is a growing risk of suboptimal "stop-gap" investments to fill these gaps. Urgent research is needed to support strategic direction and leadership in solutions to the security problem.

High-level research is required that should include:

- Government investments in R&D to support gas exploration, particularly in frontier basins
- Investigation of indigenous energy supply sources and related technologies, including wave, tidal, biomass and solar
- Encouragement of new technological developments in which NZ might develop international leadership
- Research into regional energy solutions and distributed generation systems
- Systems integration and market operation

Investment mechanisms for Government-funded research
High importance, immediately relevant

X			

Currently, Government investment through vote R,S&T require industry linkages. However, these impede the research and development of new energy solutions, particularly when no current industry exists to buy the technology (i.e. wholly new technologies). Our energy industry is small and does not focus on research and development. Transformational research may be threatened by the lack of government funding due to the need to have linkages with such an industry.

The high-temperature superconductors and the Whispergen Stirling engine are examples of research results that were not predicted and did not fit in with pre-existing national goals or existing industry sectors. The superconductor work was initially funded by IRL internal funds; Whispergen was funded by University of Canterbury funds for six years before industrial partners could be found. Such research would be difficult to fund in the present system.

Hence, for energy research that is either new to New Zealand, or that has unexpected possibilities, current funding systems are inadequate. A separate investment system, or changed investment requirements are needed. With the long time-lag between research investments and the development and uptake of transformational technology, the sooner investment mechanisms are improved, the better.

Science for Strategic Analysis of Complex Energy/Environment/Economic Systems

	X		

Medium importance, short timescale

Most energy problems are system-wide and attempts to solve them succeed or fail at a system level. Policy and decision-makers need better tools for finding the solutions, especially when the easy solutions will not be available. Hence systems level interdisciplinary research will be needed to develop new tools and methods. These can be used by local and national planners, and implemented through engineering and business development to develop strategies for achieving CO_2, cost, supply and environmental constraints while maintaining social and economic wellbeing. These will provide a benefit through:

- Feasibility Assessment Methods - so that research can be directed to solutions that are possible, desirable, or relevant
- System Modeling Capabilities - so we can communicate the research outcomes and new opportunities between the researchers and the public/private sector.
- Design Tools - so that we can minimize risk and maximize cost/benefit in the familiar sense with new and unfamiliar design requirements and system integration priorities.

Many of these system-wide issues are specific to New Zealand and need to be carried out here if they are to be relevant. However, New Zealand also has a comparative advantage in the development of these tools and methods, as our systems are more clearly defined than in larger, older nations. This may allow systems to be developed here and exported more easily than they can be developed elsewhere and then be imported.

Planning for the impact of more costly oil

	X		

Low importance, short timescale

Government, local government and businesses will need to have plans in place for higher oil prices. Developing tools and methodologies for this planning is a clear role for government. Enabling these plans is also a role for government, but lies outside research.

Priorities regarding energy efficiency

Making the gains that we know are possible and cost-effective

X	X		

High importance, current timescale

Especially in households, energy use is not very price-responsive. Existing technologies and practises that are economically viable could lead to savings in the residential sector energy use of over 15%. There are social and structural barriers to take-up, even when payback periods are very short. Some research has been carried out into consumer decision making, but policy and action research is needed on technology diffusion, communication and adoption in communities, and also in construction, transport and other commercial areas. This area could quickly realise large, permanent gains.

Direct use of energy supplies

X	X	X	X

Low importance, wide timescale

Daylighting, passive solar space heating and solar water heating all offer direct access to energy and are inherently distributed. Daylighting can reduce peak electricity demands. Solar heat can be stored in building mass or as hot water. All act through offsetting demand and are thus difficult to measure. Similarly, *direct use of gas for heating, district heating in geothermal areas, and combined heat and power plants raise overall efficiencies and offset demand.* Responsibility for research in this area is not clearly defined and more direction would aid enabling research.

Research for these approaches should focus on understanding and increasing uptake, so that schemes to understand dissemination, demonstration and integration may be effective. Integration of solar hot water with heat pumps or with photovoltaic panels may be another area where research could be productive. Developing and improving the domestic markets for these options is another area where policy and social research may inform.

Researching future efficiencies

X	X	X	X

Medium importance, wide timescale

A step change in the rate of efficiency improvement needs to be achieved for New Zealand to continue economic development without increasing energy requirements. This may occur solely due to increased energy prices. However, the efficiency of many commercial and industrial processes will benefit from research, focusing on the total throughput of energy (and water and land) and the externalities of that throughput. Much of this research will be New Zealand specific, especially in farm efficiencies.

Enabling energy services

	X	X	

Low importance, wide timescale

Energy markets revolve around the supply of transport energy, electricity and heat. These could change to markets in lighting, motion, computing and other energy-consuming services. This would internalise energy costs and provide direct incentives for reduced energy consumption. Research is needed around barriers to this, including attitudinal, informational, legislative, and market design ones. We will need to understand information flow and efficiency in service markets. Even defining and measuring these markets pose problems, as they sell less tangible products.

Priorities regarding zero/low-carbon electricity

Wind and hydro
High importance, wide timescale

	X	X	

Research will continue on wind resource assessment, power quality and grid stability issues. Now that wind has passed the takeoff point for large-scale use, much of this investment will be carried out privately. Research should focus on integrating large fractions of wind generation into the grid, and standards and testing for the unusually strong New Zealand conditions. There needs to be better understanding of the technical and institutional impediments to growth of wind generating capacity, including the externalities associated with different wind options, and how to manage them.

Hydroelectricity has provided us with decades of clean power. The current limit on its expansion is public concern over local environmental impacts and water allocation. However, concern over global environmental impacts may outweigh local issues, resulting in further expansion of large scale schemes. This would not have significant domestic research impact. However, there are also research questions around the market design when large amounts of low cost power are normally available, but may be at risk during dry years.

The hydro system already provides a means to even out daily and weekly fluctuations in supply from wind generation. Currently, pumped storage would be needed if wind generation expands to more than 20% of total generation. If the carbon costs of coal increase as we expect, then this could occur within a few decades. With pumped storage it will be possible to bank wind energy for future needs. However, the ability of the grid to manage fluctuating inputs is also increasing. Research will be necessary on both sides of this question, to characterise the potential management problem and to inform the storage option.

Small-scale hydroelectric generation has potential to improve the quality of life in remote settlements and ease strains on rural grids through distributed generation. Questions arise about connection standards and fees, about technology transfer for small and micro-scale technologies and for access to micro-hydro technologies. For these small-scale technologies in distributed generation, research will continue to be needed on information and price flow in fragmented and diverse systems, and on connections, metering of export and performance standards for distributed generation. Substantial growth in distributed generation will need investigation of ways to facilitate investment and means of ownership.

Mediation and dialogue
Low importance, current timescale

X	X		

The rapid growth in renewable generation, especially wind, combined with the low generation density of renewables means that large areas will be developed, with wider impacts. Local people bear significant externalities, such as effects on house prices, noise and visual costs. Companies and the overall general public benefit. When the costs fall on one group but other, larger groups benefit, then some form of mediation is needed. It is clear that the mediation processes currently being used are rarely acceptable to all and research is needed to bridge this gap.

Carbon capture and storage for biomass and coal
Medium importance, distant timescale

		X	X

This is a requirement for the continued use of fossil fuels in the medium term, as well as a key enabling technology that would allow biomass systems to be negative emission, i.e. carbon absorption systems, rather than just zero emission. If the impacts of climate change become so severe that we are desperately contemplating removal of carbon from the atmosphere, then this is one of the very few possibilities for how to do it.

This is a topic of immense global interest and one that New Zealand will not solve alone. We may wish to be partners with the (mainly US and Australia-based) large research projects. This would require some commitment of our own and may be directed towards capture in New Zealand conditions.

A further option for carbon capture and storage from biomass is biological sequestration in soils and forests. This is already our largest carbon sink, contributing greatly towards our Kyoto targets. Research to increase the effectiveness of this sink should offer an easy win with clear carbon cost benefits. However, a system-level understanding is required to ensure that increased carbon uptake in forests does not impose unwanted changes in other parts of the ecosystem.

Geothermal research
Medium importance, immediate to medium timescale

X	X	X	

Investment in geothermal generation suffers from the up-front risk, resulting from uncertainties about field performance. Despite this risk, all scenarios predict substantial growth in geothermal generation. This risk is purely informational, and can be directly addressed by research into characterising the geothermal fields and supported by research into means of characterisation. Better characterisation and understanding of groundwater circulation and heat resources can improve the sustainability of generation, informing on heat resources and subsidence and compaction risks.

Another risk arises from the decline in the domestic geothermal industry, which produced many highly qualified individuals and a great stock of know-how. Many of these people are now retiring, with a corresponding loss in domestic human capability. This sets a barrier against the rapid growth of this industry, should it be required.

Marine research
Medium importance, short to long timescale

	X	X	X

New Zealand has a very long coastline and lies in the path of the Roaring Forties, which create a vast potential wave resource, particularly on south- and west-facing coasts. New

Zealand's tidal range is relatively small and its tidal currents are relatively slow but there are potential sites for ocean current energy extraction.

Much is unknown about the utilisation of this source, but the capital costs and unit electricity costs are falling as reliability is rising, just as they have done for wind. It is not known when wave and tidal electricity generation will become competitive, but in the medium to long-term marine sources could take off as rapidly as wind power is doing at present. Hence New Zealand must, at the very least, remain engaged in this research and should consider building up a research capacity in this area. Current levels of research investment do not meet this criterion and risk New Zealand missing out on this promising area.

Heat pumps
Low importance, near-future timescale

X	X		

Heat pumps are a relatively new technology that has not had much penetration in New Zealand. Commercial and domestic-scale air-source heat pumps are becoming more common in New Zealand and have moderate co-efficients of performance – they produce about three times more heat energy than the electrical energy that they consume. Although they have high initial capital costs relative to other technologies, they become competitive on a life-cycle basis due to their low operational costs.

Ground source heat pumps offer even greater co-efficients of performance, but there are almost none installed in New Zealand. They use ground-circulating fluids to exchange heat or cold as required. They are effectively ambient geothermal sources, taking advantage of the almost constant subsurface temperatures. They may have large-scale commercial applications (e.g. Vienna Airport is heated and cooled by a large-scale heat pump system).

Research needs to improve the uptake of this technology in New Zealand would include social and behavioural studies to understand the barriers facing these technologies.

Priorities regarding the transition from fossil fuels imports

Transition research funding
Medium importance, medium timescale

	X	X	X

Research and development in transport fuels and systems has received little funding in recent years. In a carbon-constrained world, liquid fuels for transport pose the biggest problem. Our economy is dependent upon imported, carbon emitting fuels, hence research to support a transition away from this dependence is necessary.

Better transport
Medium importance, short to long timescale

	X	X	X

Costs of oil and gas are set internationally. Even if carbon costs are ignored, growing international demand means current high prices are expected continue. In lieu of any dramatic cut in demand, the prices will rise until coal-to-liquid fuels become widely available. The South African experience with the SASOL technology suggests this will become competitive at US$60/bbl. The vast supplies of coal as the input to this process set an upper limit on the long-term price oil, if carbon costs are ignored. At this price, changes to transport systems will occur with changes to vehicle fleets being the most obvious. These prices already affect life in rural New Zealand. Research into changing transport options will be needed, especially around suitable policy interventions.

Biofuels for transport
High importance, ongoing timescale

X	X	X	

When the political case for carbon costs becomes undeniable, oil for transport will greatly jump in price. We will remain a technology taker for road and air transport, but that transport already enables the widespread use of biofuels.

Biofuels from animal fats and waste-stocks are already cost competitive in New Zealand. However, total production from waste sources will only ever meet a small fraction of current usage and large scale energy cropping will be needed to make the substantial changes required.

Biofuels from short-rotation crops are becoming cost competitive in Europe, with sales of biodiesel in Germany expected to reach 2 million tonnes in 2006. As oil increases in price, this sector will grow rapidly. The production of liquid fuels from cellulosic sources (woody biomass) will enable a step-change in the output from a given land area. Even without regulatory support, large land use changes are expected. Should government decide to support this option strongly, then the land use changes would be immense. Hence research is strongly needed in:

- Processing and production of gaseous and liquid fuels from woody biomass, including pyrolysis and hydrolysis

And also in:

- Production of fuels from food production and other wastes, including landfill

- Suitable species and growing techniques for New Zealand
- Economic uses for energy crop byproducts
- Biosecurity concerns over potential imported species
- Fuel standards and uptake
- Overall system efficiency and carbon inventory effects
- Land use modelling and change management
- Environmental effects of land use changes, on water supplies, groundwater, and fertilizer use

The current research has not been well co-ordinated since the break-up of the Forest Service. A central body is needed for research efforts and to give direction and push to the fledgling industry.

There is substantial overseas research and we may wish to develop collaborations with well-funded international programmes.

Bioenergy for heat and power
Low importance, current timescale

X	X		

Combined heat and power generation has grown rapidly over the last four years and could contribute greatly to replacing fossil fuels. This technology is reasonably mature and research needs are small but many of the research topics for transport biofuels could inform this sector, especially regarding the aggregation and use of woody wastes and short-rotation cropping.

Domestic fossil fuel supplies
Medium importance, short timescale

	X		

The high price of oil and gas justifies ongoing reserve exploration and evaluation of frontier basins. Another Maui find would greatly reduce the pressure to expand coal and thus would prevent a worsening of our emissions intensity. More smaller fields will contribute. Nevertheless, domestic oil and gas remain a short- to medium-term solution, with decreasing acceptability and carbon costs.

Coal-To-Liquid fuels
Medium importance, distant timescale

		X	X

Our vast resources of coal prompted research in the 1970s into Coal-To-Liquid fuel transformation. The high price of oil will cause a global resurgence in this technology, if the carbon externalities are not included. However, the expected price path of carbon may significantly limit this technology, which results in higher carbon emissions than oil-based liquid fuels.

An intermediate option involves the production of liquid fuels from hydrogen extracted in-situ from coal reserves. This would give New Zealand a potentially unlimited source of liquid fuels for transport, or hydrogen for direct use in fuel cells. This reward is sufficient to justify investigation, even though the technology needed is unknown and the likelihood of success unpredictable.

Zero-emission coal use
Low importance, distant timescale

		X	X

Rather than burn the coal, then capture the emissions, one route already investigated in New Zealand is to utilise the energy stored in coal in other ways. In-situ hydrogen extraction is one option that could unlock vast reserves of clean power, releasing hydrogen directly from coal seams. This technology is yet to be thoroughly investigated and as such, the development path and costs are unknown, and the risks correspondingly high.

Non-fossil fuel sources of hydrogen and hydrogen storage
Low importance, distant timescale

		X	X

The much touted transition to a hydrogen economy as a clean energy intermediate, though attractive in many ways, faces serious stumbling blocks related to the generation, storage and distribution of hydrogen. Research into biological generation of hydrogen, catalysis (both biological and non-biological), and conversion from biomass to hydrogen is important to develop non-fossil hydrogen sources. The energy to drive these processes must come from renewable energy sources such as solar (via photovoltaics or biological photosynthetic sources), geothermal heat or wind & tidal generated electricity. Equally important is research of storage materials and hydrogen handling techniques. These include its storage as clatherate hydrates, as metal hydrides and in microporous metal-organic frameworks, in glass microspheres and also possibly in carbon nanostructures. In the longer term, hydrogen could factor in many of our energy systems both transport and non-transport. Much of this research will take place outside of New Zealand and we may wish to partner with international programmes.

Summary tables for priorities

Priorities regarding high level goals

<table>
<tr><th>Importance</th><th colspan="4">Time of impact</th></tr>
<tr><th></th><th>Immediate</th><th>Short-term</th><th>Medium-term</th><th>Long-term</th></tr>
<tr><td>Higher</td><td colspan="4">Energy Security</td></tr>
<tr><td></td><td>New research funding mechanism</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td>Strategic analysis of complex systems</td><td></td><td></td></tr>
<tr><td>Lower</td><td></td><td>Planning for costly oil</td><td></td><td></td></tr>
</table>

Priorities regarding energy efficiency

<table>
<tr><th>Importance</th><th colspan="4">Time of impact</th></tr>
<tr><th></th><th>Immediate</th><th>Short-term</th><th>Medium-term</th><th>Long-term</th></tr>
<tr><td>Higher</td><td colspan="2">Implenting current gains</td><td></td><td></td></tr>
<tr><td></td><td colspan="4">Researching future efficiency gains</td></tr>
<tr><td></td><td colspan="4">Direct use of energy supplies</td></tr>
<tr><td>Lower</td><td></td><td colspan="2">Enabling energy services</td><td></td></tr>
</table>

Priorities regarding zero/low-carbon electricity

<table>
<tr><th>Importance</th><th colspan="4">Time of impact</th></tr>
<tr><th></th><th>Immediate</th><th>Short-term</th><th>Medium-term</th><th>Long-term</th></tr>
<tr><td>Higher</td><td></td><td colspan="2">Wind and hydro</td><td></td></tr>
<tr><td></td><td colspan="3">Geothermal</td><td></td></tr>
<tr><td></td><td></td><td colspan="3">Marine</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Carbon capture and storage</td></tr>
<tr><td>Lower</td><td colspan="2">Mediation and dialogue</td><td></td><td></td></tr>
</table>

Priorities regarding the transition from fossil fuels imports

<table>
<tr><th>Importance</th><th colspan="4">Time of impact</th></tr>
<tr><th></th><th>Immediate</th><th>Short-term</th><th>Medium-term</th><th>Long-term</th></tr>
<tr><td>Higher</td><td colspan="3">Biofuels for transport</td><td></td></tr>
<tr><td></td><td></td><td>Domestic fossil fuel supplies</td><td></td><td></td></tr>
<tr><td></td><td></td><td colspan="3">Transition research funding</td></tr>
<tr><td></td><td></td><td colspan="3">Better transport</td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Coal-to-Liquid fuels</td></tr>
<tr><td></td><td colspan="2">Bioenergy for heat and power</td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td colspan="2">Zero emission coal</td></tr>
<tr><td>Lower</td><td></td><td></td><td colspan="2">Non-fossil source of hydrogen</td></tr>
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