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East Harbour Management Services Limited

Renewable Energy and the Efficient Implementation of New Zealand's Current and Potential Future Greenhouse Gas Commitments

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Abstract

The purpose of this project is:

- to identify and assess possible rationales for government action, in addition to general climate change policy and during the period 2002-2012, directed specifically at renewables as part of the overall strategy to achieve efficient implementation of New Zealand's current and potential future greenhouse gas commitments; and
- if there is sufficient justification, to identify the nature of such government actions and their relative priority.

The report examines the justification, in terms of benefits (or avoided costs) to the nation associated with achieving New Zealand's current and potential future greenhouse gas commitments, for making a transition to renewable sources of energy more quickly than would occur if the only government policy intervention were climate change policy. The discussion is intended to be qualitative rather than quantitative but draws on the latest assessment of renewables options.

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1 EXECUTIVE SUMMARY

This report has sought to identify renewable energy options that should be implemented as part of an efficient response to New Zealand's Kyoto targets but might not be implemented because of the specific climate policies introduced by government, or because of market failures or regulatory barriers.

The analysis in the report was undertaken over the period January-March 2002. It is based on a Climate Change policy scenario provided by the Ministry for the Environment. The scenario includes NGAs, a carbon charge from 2004 and projects. This scenario differs from the Government's climate change preferred policy package released on 30 April 2002. The principal differences are the assumptions in the report that a low-level carbon charge of \$5/t CO_2 may apply 2004 to 2007, that projects would be aimed only at addressing market failures and reducing social impacts, and that a carbon charge from 2008 might be \$20-40/t CO_2. The Government has yet to make final decisions on the climate change policy package.

Also, the report makes assumptions about the criteria that might be used for determining 'at risk' industries and which particular industries might be 'at risk'. In addition it makes the assumption that 'at risk' industries will be shielded from any increases in electricity prices that result from a carbon charge. However, although the Government's preferred climate change policy package proposes a category of 'Competitiveness-at-risk' it does not go to the level of detail contained in the assumptions made in the report. It merely proposes three high level criteria for determining Competitiveness-at-risk status and notes that they will require further development following consultation and prior to final policy decisions.

Increased uptake of renewable energy largely involves development and adoption of new technologies. Consequently, the report provides a theoretical discussion of the process of invention, adaptation and diffusion of new technologies. We identify a range of reasons why these processes might not occur efficiently when the policy response to Kyoto is limited to a carbon charge on some sectors, and negotiated greenhouse agreements in others. True dynamic efficiency in this area requires an appropriate path of abatement over time, appropriate structural changes in the economy with appropriate timing, as well as efficient innovation and diffusion of new and existing technologies.

Table 1 Sources of Market Failure and Regulatory Barriers

Invention and Adaptation	Inability to capture benefits High risks / Intangible Assets Thin skilled-labour market
Diffusion	Information availability and diffusion Increasing returns / learning externalities Agency problems High discount rates Market power Regulatory barriers

Engineering, environmental, and economic factors dominate identification of feasible renewable energy options. We assess a wide range of renewable sources, considering the quality of the resource, the location, consentability, technical and regulatory issues, and the economic feasibility of the resource given the nature of the energy provided (electricity vs. heat, reliability) and fuel used (convenience and cleanness) and the potential energy end users. Renewable energy options are available at a cost for all four energy sectors (electricity, process heat, low grade heat and transport).

We assess the likely response of potential investors in these options when faced with a change in economic conditions, namely the imposition of a carbon charge of up to $40 per tonne CO_2. From this analysis we come up with a list of additional major projects/groups of renewables opportunities that are not currently feasible but would likely be efficient if a carbon charge were to be imposed. A range of process heat options would appear viable, but only one major electricity project (Project Aqua) might be assisted by this level of charge. If gas supplies were perceived as restricted then a wider range of hydro, wind and geothermal electricity projects would become attractive. Solar hot water heating would become more attractive as a means of supply of low-grade heat. These options are summarised in Table 2. This list represents renewables uptake in an 'ideal' world. The following sections discuss why the opportunities might not happen and what government could do to assist more efficient uptake.

Table 2 Major Renewables Options that would Probably be Efficient with a Carbon Charge Throughout the Economy

Energy Form	Renewable Source	Sector and Location
Electricity	Hydro	• Mostly available in South Island
	Geothermal	• Predominantly Waikato and Bay of Plenty
	Wind	• Predominantly Wellington, Wairarapa, Manawatu
Process Heat	Biomass	• Forest Processing, Dairy Processing, Meat Processing, Industrial Estates, Cement in Northland
	Geothermal	• Forest Processing
Low Grade Heat	Solar water heating (displaces electricity)	• Feasible at current prices • Possible in range of locations
	Geothermal	• Current applications could be expanded • More fields available for low-grade heat than for supply of process heat.
Upcoming Technologies (Long Term)	Hydrogen (from renewables)	• Research needed
	Wave / Marine current	• Research needed
	High-temperature solar (electricity and process heat) and photovoltaics	• Research needed
	Biofuel for transport	• Whey available immediately (limited scale) • Biodiesel from tallow – research needs to be recalibrated

In general the renewable technologies are either well established and mature (hydro, wind, geothermal, bioenergy, solar water heating) or upcoming (photovoltaics, wave). The opportunities based on the mature technologies have been thoroughly investigated over the years and generally are not currently proceeding to investment because there are other more economic ways of obtaining the consumer energy. Because of this there has been a lack of incentive for further investigation and development, particularly as New Zealand is living on the legacy of knowledge last funded during the 1970s-1980s period. Renewable projects such as hydro suffer from the fact that no recent investigations have been undertaken and the data, concepts, and designs are now very dated.

Increased uptake of renewables will depend on the funding of new smart thinking, and a relative change in the cost of energy from all services. Essentially we are dealing with a sector that is characterised by having a large number of small/medium players who do not have the cashflow to individually fund work that collectively needs to be undertaken. This puts the industry into the category that most justifies government intervention from a macro efficiency perspective, albeit for co-ordination and initial stimulation.

The analysis shows that, unless very significant, climate change initiatives will affect the uptake of renewables only at the margin. The efficiency improvements that will arise through addressing market failures and regulatory barriers will have micro rather than macro affects.

Preferential treatment of some sectors (possibly for good reasons) could hinder uptake of renewable energy if at-risk sectors do not face the full carbon price. Potential losses of opportunity are primarily for process heat from either biomass or geothermal energy. Good options exist in the cement, forest processing and dairy processing industries. Government could encourage efficient uptake for at-risk sectors by building renewable options into negotiated greenhouse agreement targets. For example, at-risk sectors where renewables use seems feasible would have more stringent carbon per unit output targets. Renewables uptake also could be encouraged through the use of 'projects' that reward reductions in carbon usage per unit output beyond an agreed baseline.

The other reasons that even feasible and economically efficient renewable energy investments might not be made relate to market failures. We identify four main areas for potential policy attention, along with general incentives to encourage renewables:

- adaptation / early adoption assistance,
- electricity market structure and interconnections,
- resource consent issues and
- government-controlled uncertainty.

For adaptation/early adoption we outline potential solutions to assist those sectors of the renewables industry that are fragmented and too small to fund their own research and information dissemination. This includes a contestable fund focused on specific technologies and options where learning and development of role models is important. This fund could potentially be run with the involvement of the relevant industry associations with responsibility for running the programme gradually passed to them as the sector matures. Additional policies would involve actively seeking good renewable role model opportunities within government's own activities, direct information provision by government, and facilitation and possibly funding of training. All of these policies would aim to speed up the early stages of the adoption process so that the industry overcomes start-up hurdles to reach critical mass and/or is well placed for more rapid adoption in the event of unexpectedly high carbon prices or changes in relative energy costs.

For the electricity market issues we simply point to the need for greater representation of the small companies that have renewable interests when making decisions on the market regulatory and interconnection rules.

The solutions to any consent issues are primarily based around the provision of credible information on common problems (e.g. noise from wind farms) to all parties, and encouraging long-term planning on the part of councils to help identify good locations for renewable energy projects.

Government has the ability to reduce the significant uncertainties affecting the sector. Given the importance of climate change policy in the economic feasibility of renewable projects, any increase in the certainty and credibility of government climate change policies would help. Government also has the ability to clarify property rights in the case of areas where Treaty claims are critical, or property rights are simply not defined.

We consider the impacts of broader policies on renewable energy. We conclude that the form of revenue recycling, when aimed at improving the efficiency of the tax system, is unlikely to be important for the renewable energy sector. In contrast up-front subsidies to renewables either through cash grants or accelerated depreciation might significantly enhance renewables uptake. They may not, however, be well targeted to areas with genuine inefficiency so may simply end up subsidising unprofitable projects. We do not believe a renewable portfolio standard would be an efficient instrument in New Zealand.

Finally we discuss the optimal timing of policy. As mentioned above, resolution of uncertainty about government policy, even if only the form and sectors affected can be decided, should be done as early as is feasible. This requires not only that government makes robust decisions that are unlikely to be reversed but that they create credible signals that make the policy clear to market players. Other early action should focus on overcoming the barriers that make adoption of new technologies very slow in its early stages and facilitating the regulatory processes that can resolve electricity market and property rights issues.

Early action may also allow advantage to be obtained from other countries prepared to accept emission reduction in New Zealand as part of an international market of emissions credits.

Overall we identify some potential roles for policy to supplement and complement the proposed climate policies. These are very focused roles however. Any renewables policies related to climate change policy should address clearly identified problems with respect to a narrow range of renewable options.

The analysis done for this report has largely been qualitative rather than quantitative. All the proposed options need considerably more analysis before firm recommendations can be made.

1.1 POLICIES THAT MERIT FURTHER CONSIDERATION

1. More stringent NGA targets for firms with good renewables options;
2. Use of renewable projects to complement NGAs and reward reductions in carbon per unit output;
3. Establishment of a contestable fund for 'soft projects' to address adaptation research, information diffusion, and demonstration projects for renewable options that show significant potential, but where the current industry is fragmented and in early stages of development;
4. Government use of renewable energy in its own activities where efficient;
5. Use of Industry Associations to provide a critical mass for activities related to barriers to uptake;
6. Government provision of common information to speed adoption of new technologies;
7. Government facilitation of specific training needs for nascent renewables options;
8. Effective representation of smaller renewable interests in the Electricity Governance Board;
9. Government provision of common information to enhance consent processes;
10. Policies compatible with other governments interested in the sale of early emissions credits; and
11. Reduction of government controlled uncertainty: climate change policy, Treaty claims and geothermal well ownership.

2 INTRODUCTION

The New Zealand government is developing a renewables policy in the context of the National Energy Efficiency and Conservation Strategy. The key issue addressed in this paper is whether, in order to achieve efficient implementation of New Zealand's climate change commitments, a separate renewables policy is required once the government has implemented its general climate policies and if so, what form that policy might take.

We are considering the effects of climate policy related only to carbon-dioxide emissions (not carbon sinks, methane or other greenhouse gases (GHGs)) and the complementary role of renewables in relation to reductions in fossil fuel use.

2.1 ASSUMPTIONS ABOUT NEW ZEALAND CLIMATE CHANGE POLICY

For the purposes of this report we will assume that the government will implement the following set of climate change policies.

Industries will be divided into two groups: 'at risk' industries and all other.

At-risk industries are those that either:

A Face temporary loss of competitiveness stemming from the fact that some overseas competitors will not face a similar price for carbon

or

B Face substantial contractions in output because of the transition away from carbon-intensive activities.

Group A may need differential treatment only for a finite period of time, until the other countries join the agreement or it becomes clear that they won't join for a very long time. The differential treatment for group B would be aimed at smoothing their transition and hence reducing the adjustment costs to the economy.
The assumed policies are summarised in the table below.

Table 3 Climate Change Policy Assumptions

	From 2002	From 2004	From 2008	From 2013
"At risk" industries	• Negotiated Greenhouse Agreements (NGAs)	• NGAs • Projects (receiving recycled carbon charge revenue)	• NGAs • Projects (receiving assigned amount or recycled carbon charge revenue)	• Face world price • If government revenue is generated, the extra over what was generated by the \$5/t CO_2 goes to reduce company tax
Other industries	• Have full knowledge of upcoming regime	• \$5/t CO_2 • Projects (receiving recycled carbon charge revenue)	• Face world price OR • Face world price up to max of \$20/t CO_2 If government revenue is generated, the extra over what was generated by the \$5/t CO_2 goes to reduce company tax	• Face world price • If government revenue is generated, the extra over what was generated by the \$5/t CO_2 goes to reduce company tax

For section 3 we assume that a low-level carbon charge of up to \$5/t CO_2 may apply from 2004, and that a high-level carbon charge in the range \$20/t CO_2 to \$40/t CO_2 (averaged at \$30/t CO_2) may apply from 2008.

The 'projects' are aimed at addressing market failures and reducing social impacts. They could include 'soft' projects (training, information provision, behaviour modification, addressing social impacts) and 'hard' projects (investments in plant and equipment or in renewable energy production). To a certain extent this paper can be seen as providing input into the type of projects that could be useful as complements to general policy.

2.2 STRUCTURE OF REPORT

The report begins with a theoretical discussion of possible problems that could arise in the uptake of new technology. Where possible it draws on international empirical evidence on the importance of different aspects. Section 4 focuses on New Zealand-specific opportunities for the use of renewable energy. It considers technical and economic feasibility as well as considering regional and location constraints that can limit the applicability of otherwise attractive renewables options or enhance the attractiveness of otherwise unattractive renewables options. It presents an analysis of the renewable energy options that would become feasible with a carbon charge set at either \$20 or \$40 per tonne of CO_2. It concludes with a list of key renewable opportunities that we predict should be taken up in response to Kyoto if the market worked well and no sectors were exempt from the carbon charge.

Section 5 combines the theoretical analysis with the practical knowledge of renewables to consider reasons why renewables may not be efficiently adopted in response to the assumed Government climate change policy. In particular we look at the effect of sheltering some 'at risk' sectors and the effects of more general market failures or situations where additional government action is needed. Section 5.2 takes the key problems identified in section 5 and proposes possible policies that could address the inefficient dynamic uptake of renewable energy options.

3 OPTIMAL RENEWABLES UPTAKE AND REGULATORY AND MARKET LIMITATIONS

This is a theoretical section and draws on international evidence. In particular it draws heavily on a recent survey article by Jaffe, Newell and Stavins (2001). The section begins by defining dynamic efficiency and the types of actions that need to occur for dynamic efficiency to be achieved. Then we discuss two basic reasons why dynamic efficiency may not be achieved simply through possible climate change policies that may be favoured by government.[1]

3.1 DYNAMIC EFFICIENCY

In the case of climate change policy we face a fixed target – compliance with Kyoto – so our problem is cost-effectiveness, or how to achieve that target at the least cost / with the most benefit to New Zealand. Thus we will not discuss here whether the overall Kyoto targets are too loose or tight at given points in time or whether renewables policy should go beyond that required to achieve the Kyoto targets effectively.

Cost-effectiveness can be thought of in two dimensions, static cost-effectiveness and dynamic cost-effectiveness. Static cost-effectiveness requires that given current technology, the goal be achieved at least cost. This requires that information flows efficiently, that players use all the information they have and that marginal costs of abatement are equalised across all players: consumers and producers in all sectors, government and private sector.

Dynamic cost-effectiveness takes the long-term targets as fixed (here the Kyoto target from 2008 – 2012 and expected targets beyond that) and achieves those in the lowest cost / highest benefit way possible. This involves an appropriate path of abatement over time, appropriate structural changes in the economy with appropriate timing, as well as efficient innovation and diffusion of new and existing technologies. Here we focus on movement toward renewable technologies from fossil-fuel energy sources and the innovation and diffusion of new renewables technologies.

> "Schumpeter distinguished three steps or stages in the process by which a new, superior technology permeates the marketplace. *Invention* constitutes the first

[1] As outlined in section 2.1.

development of a scientifically or technically new product or process. Inventions may be patented, though many are not. Either way, most inventions never actually develop into an *innovation*, which is accomplished only when the new product or process is commercialized, that is, made available on the market. A firm can innovate without ever inventing, if it identifies a previously existing technical idea that was never commercialized, and brings a product or process based on that idea to market. The invention and innovation stages are carried out primarily in private firms through a process that is broadly characterized as "research and development" (R&D). Finally, a successful innovation gradually comes to be widely available for use in relevant applications through adoption by firms or individuals, a process labelled *diffusion*. The cumulative economic or environmental impact of new technology results from all three of these stages, which we refer to collectively as the process of technological change."[2]

Here we consider what might be required within New Zealand in each of these phases for efficient dynamic use of renewables.

3.1.1 Invention

Most technology used within New Zealand is invented elsewhere. The key question here is whether other countries have incentives to provide the technology we will need or if it is worthwhile for us to deliberately develop it ourselves. If we do develop new technologies, we will potentially benefit from the value of the new patents created. We need to weigh up the value of the technology to us (both direct and through our ability to appropriate the gains to others) against the cost of that type of R&D. We also need to consider that we have a small and probably inelastic (fixed in size at least in the short run) R&D sector so increased emphasis on one type of technology is likely to remove emphasis from other areas. For example, it may not be sensible for us to invest in research on hydrogen fuel technologies where other countries have an advantage but we might want to invest in better understanding of geothermal power where we are a significant player and already have expertise.

3.1.2 Commercial Application / Adaptation to Local Conditions

More important is probably our adaptation of existing inventions, developed in New Zealand or abroad, to new applications and conditions. This may well be relevant for many renewable technologies. Some have been successfully commercialised overseas (e.g. offshore wind power in Europe, solar in high temperature desert areas) but will have differing costs, benefits and design factors in New Zealand because of different environmental conditions.

As a society we should invest in adapting these technologies if the expected benefit outweighs the expected cost of adaptation. This is of course difficult to anticipate but we need to make sure we make our decisions using all the information available to us. How much is adaptation likely to cost? If applied successfully how profitable will the technology be at a range of likely energy costs? How widely will the technology be able to be applied in New Zealand – i.e. how far can we spread the costs of adaptation? Investment in adapting geothermal technology that might be applied in

[2] Jaffe, Newell and Stavins (2001) p. 3

one plant is very different from the development of a wind power technology that could be used in hundreds of sites.

Even if we think a given technology is promising in New Zealand, we still need to decide whether we should develop it ourselves or contract other researchers and companies to assist with the application. This could be done through contracts, joint ventures or simply direct foreign investment. This choice depends on the availability of appropriate skills within New Zealand. For both invention and adaptation / innovation, to the extent that this would most efficiently be done in New Zealand, we would need to train people in the necessary skills.

Because it is often difficult to distinguish invention from innovation or adaptation, from now on we will consider them jointly and refer to these processes as 'innovation'.

3.1.3 Diffusion / Adoption

At each point in time it is socially optimal for a firm or household to adopt a new technology (i.e. buy, install and use it) if the present discounted value of benefits / profits from the adoption exceeds the cost. Profitability will change over time with the cost of the technology, energy prices, the discount rate used, and likely utilisation rates. In addition we must consider that the cost of adoption will not fall and quality will not rise sufficiently in the future so that it is worth waiting to adopt. Even if it is a profitable investment now it might be even more profitable in the future.

Diffusion can be modelled in terms of discrete adoptions by firms / households or as a continuous process within a firm or across an industry as a whole. We will discuss discrete models first, then continuous. There are four ways of modelling the discrete process of adoption, each of which sheds some light on the nature of an efficient dynamic process: epidemic, rank, stock and order.[3]

3.1.3.a Discrete Models

Epidemic models consider adoption to be a function of knowledge about the technology, which is spread by contact with others who have adopted. In a more sophisticated model, there may be differential access to information about the innovation's profitability, which could lead to epidemic type effects. [4] Firms adopt as they receive information about the new technology or its profitability. Having rapid and effective information flows might speed the process of adoption if this is a binding constraint. Generally, among sophisticated players (large firms rather than households and small firms) information is not found to be a major constraint. It can however be a barrier for the small players who are too busy surviving with few staff and limited cash necessary to collect and assimilate information – even if readily available.

A **rank** model emphasises heterogeneity among players that affects their benefits from adopting at a given point in time. At each point in time each player weighs up the costs and benefits of investing; some will adopt and some won't. If costs and uncertainty are falling over time or benefits are rising, an increasing number of

[3] Reinganum (1989) provides an excellent review of the literature on technology diffusion.
[4] See Jensen (1982)

players will adopt over time. They will adopt in an order determined by their characteristics with respect to risk, costs and benefits.

Costs, benefits and risks are heterogeneous among potential users of each technology at each point in time; this affects their rank order. For example, the benefits of adopting wind power depend on the wind speed and availability. Costs depend on the difficulty of getting resource consents and on access. Discount rates will vary among users depending on their source of financing for investment, and the uncertainty they face. This may exacerbate the impact of differences in net benefits of adoption. Higher discount rates will tend to lead to delay in investment because costs are borne immediately while benefits are received over time. A company's rank in the adoption process partly depends on managerial willingness to take risk, and on the priority in managerial decision making that the renewables option receives. For companies that are primarily potential users of renewable energy, rather than potential suppliers, the priority to consider renewables will be greater for companies for whom energy is a key input. Because firms are different, it is not efficient for all firms to adopt at the same time. The fact that some firms are slower to adopt is not necessarily evidence of inefficiency.

The benefits, costs and risks associated with investment will vary over time also due to common factors. These factors will not affect the rank order of adoption but will affect overall adoption patterns. The benefits from investment in renewables primarily depend on the alternatives available, i.e. the price of electricity derived from gas, coal or oil. The cost of investment depends on the industry structure and the cost function of the suppliers of capital. The cost and quality of the technology will tend to change over time. If a firm expects the technology to improve or the cost to fall, they will tend to delay investment.[5] This will affect firms differently depending on their expectations and on the benefits from adoption. For most technologies, the cost of adoption and risk probably fall over time but at a decreasing rate.[6] This means that firms will not delay indefinitely even with constant benefits.

In a **stock** model, the benefits to adoption depend on the total amount of adoption in the industry as a whole. Generally the benefits of adoption fall with the number of other players who have adopted. This is because later adopters will be competing with those who already have the technology. For example, for renewable power, one wind power plant might fill a similar capacity niche in the local area to another plant. This would especially arise if they were in areas that have limited opportunities for embedding and receive correlated wind. Thus a second wind power plant may be forced to pay for distribution network reinforcement and so will be less profitable than the first.

Initially, however, total adoption may lower costs significantly. If the process of adoption within New Zealand itself lowers the cost of adoption or raises the quality of the technology (known as endogenous learning) we might want to ensure that there is some early adoption to induce the fall in price. However we might actually want a slower average rate of adoption so that later adopters take advantage of the lower costs in future. A market will probably achieve the second part of this because firms

[5] See Balcer and Lipman (1984)
[6] See Tirole (1988) p40

will automatically have an incentive to delay, but unless the first adopters can appropriate the benefits of the lower future price, it may be hard to find a first mover.

An **order** model deals with the strategic aspects of adoption. This is a major recent strand of the industrial organization literature and is most relevant to imperfectly competitive industries where firms are competing for market share in the good that the innovation allows.[7] There are costs to being an early adopter: the price tends to be higher and there is greater uncertainty. There may also be benefits. Early adopters may have a first mover advantage either in the product that the technology can create or in becoming a supplier of the technology itself through its own experience. If the future benefits from the technology are expected to be high (and others do not also recognise this opportunity) there could be significant benefits from being in a position to serve the new market.

Efficient adoption requires that potential adopters know about the costs and benefits of the technology and have access to the technology and to the skills required to adopt it. This often requires training both in the installation and operation of the new technology. It also requires a capacity to provide ongoing service for the technology. Adequate availability of finance is also necessary for efficient adoption.

3.1.3.b Continuous Adoption

Continuous models of adoption can shed light on two key issues. The first is the lead-time required within a firm to fully adopt a new technology. The second is the restrictions at the level of the industry on the aggregate rate of adoption. The discrete models discussed above assume that the suppliers of technology are able to respond at any speed but often in reality there are supply bottlenecks.

When the cost of investment depends on the speed at which it is made and investment can be done gradually, firms will tend to adopt a new technology over a period of time rather than in one step.[8] This is in addition to the rank effects above which predict gradual adoption through an industry because of falling costs of supply. The costs of acting quickly can arise at either the firm or industry level. All investment takes time to plan and implement. Increasing the speed of planning may be risky and costly. One source of high costs from rapid adoption in the industry as a whole is the possibility of supply bottlenecks due to limitations in trained personnel and construction equipment or the new plant itself. Thus we will want and expect gradual investment to avoid costly rapid technology adjustment.

Within a firm, one source of increasing costs is the cost of capital; the cost tends to increase as the size of the required investment increases relative to company size. Different firms have access to different sources of capital. Investment is frequently financed by using retained profits, which is a low cost method. Firms with more retained profits (stronger cash flow) will tend to have lower adjustment costs and will tend to invest more rapidly. Larger firms will tend also to have better access to external capital partly because they tend to have more retained profits. Also large companies are less risky to banks and other lenders because of the collateral they can

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[7] For game theoretic models of symmetric firms that choose different adoption times due to the strategic nature of the situation see Reinganum (1981), Judd (1983) and Fudenberg and Tirole (1985).
[8] See Lucas (1965 and 1967) and Treadway (1971) for seminal optimal adjustment path models.

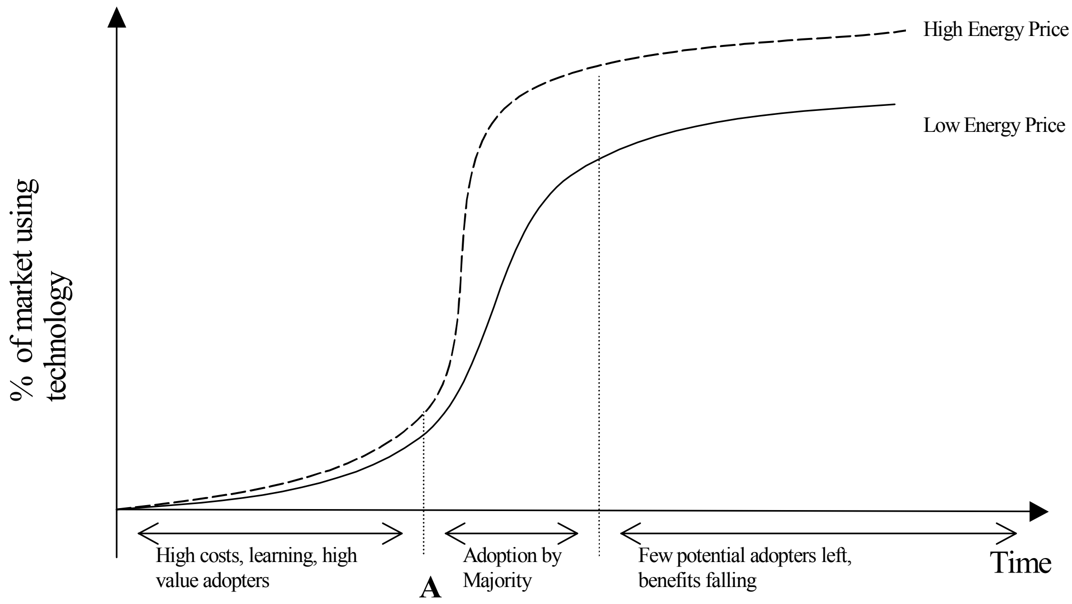
provide, the existing relationships they have with lenders, and the portfolios of projects over which they can spread risk.

Perhaps the most important source of adjustment costs comes from the natural turnover of capital. It may be much cheaper to adopt a new technology at the time when old capital is being replaced. This avoids having to scrap equipment before it is obsolete. Another source of adjustment costs comes from the physical process of investment and the supply disruption it causes. A firm that has greater flexibility in production, or that can replace its production by drawing on stockpiles or the resources of other plants in the same company or network, will face less supply disruption during investment.

Investing in new technology also requires a change in expectations, and requires managerial decisions. The process of investment involves appropriating orders, dealing with delivery delays, installing equipment and making it function, and retraining staff to operate the new equipment.[9]

Between them, all the factors that drive adoption tend to lead to a process of adoption that is 'S' shaped.

Figure 1 Cumulative Adoption Path



In the early period very few people adopt, then there is a period of rapid adoption followed by a tailing off as most profitable adoptions have been made. The time taken from beginning to end of the process depends on the specific technology among other things but can be decades rather than years.

All told, diffusion of a new technology tends to be a slow process for many reasons. The investment required to adopt will tend to be more expensive if it needs to be done fast. This makes policy certainty and signalling a long time in advance more important for achieving future goals.

[9] See Berndt (1991)

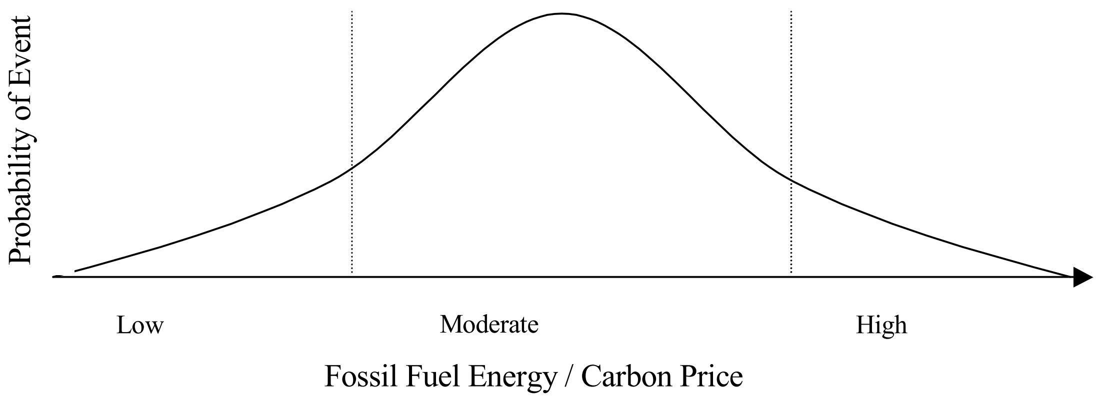
3.1.4 Optimal Innovation and Diffusion under Uncertainty

If society is risk averse, we need to maximise the expected value of investments in innovation and diffusion. For each technology, the range of returns should be calculated for different 'states of the world', i.e. different energy prices, and technology costs and qualities. Then these should be multiplied by the probability that each state would occur. In reality we rarely do this explicitly. We make judgements based on available information and rules of thumb.

For each renewable option, we need to consider payoffs under three scenarios, moderate energy prices (around our best guess), and high and low prices. If an option will have reasonable returns in a wide range of scenarios then it is robust and more attractive.

The first risk is that fossil fuel energy prices turn out to be low so the price received for renewable energy is also low and existing renewable energy investments lose value. Clearly options that are profitable at moderate energy prices will lose less if prices turn out to be low. Smaller projects make smaller absolute losses. For example, a low level of investment in biomass around Taupo, which is profitable at moderate energy prices and may offer some benefits in terms of energy security, might be a relatively low risk investment.

Figure 2 Distribution of Fossil Fuel Energy / Carbon Prices



Options with low fixed cost (and higher operating costs) are likely to be at lower risk from low energy prices because the total level of investment / effort in the project can be altered relatively easily to match the prices offered. More generally, investments that are reversible, for example if a large part of the cost is the cost of the land and it can be returned to other uses, are less risky. Projects that pay off over a shorter time frame (and maybe where the equipment becomes obsolete in a shorter period of time so is cheaper) are less vulnerable to long term uncertainty in prices. If energy prices are a small component in overall profitability or if they affect the costs and the benefits relatively symmetrically, the project will be more robust. Similarly, projects that have a lot of ancillary benefits so that a large percentage of the benefits are not affected by the energy price are likely to be worthwhile even if energy prices are low.

The second risk is that fossil-fuel energy prices turn out to be high but we are not in a position to benefit from renewables investment so are trapped with high levels of fossil fuel use. This may arise because of higher than expected carbon charges, or, in the case of gas, because of the relative allocation of capital cost between oil and gas supplies for each field (a strategic negotiated allocation). The severity of this depends heavily on how long it would take to respond to a higher price level. The present discounted value of a stream of renewables investments will be much higher if, at the time when prices rise we have already overcome the innovation and initial learning stages and developed basic supply capability for expanding investment. At that point the cost of investment has fallen to a point where a large range of projects might be profitable and possible to implement relatively quickly.

For example, in Figure 1, higher energy prices imply a higher adoption path at all points in time. If we are already at point A on the low price curve because of early investments, and energy prices rise, we will move up toward the higher curve but we will also already be close to the point where adoption begins to be rapid. Getting to point A might be an efficient social investment even if the current energy price would by itself lead to no adoption. It creates a potentially valuable option.

If we have not even begun the process of adoption, learning will likely be faster at higher energy prices. This is because there is more pressure to learn, but the speed of learning may be inherently limited however much money is put in, and adoption might still take a long time. Similar issues would arise if a period of innovation and adaptation were required before adoption can even begin. If this is relatively cheap but can create the option of more rapid adoption in a high price world it could be efficient.

The most difficult decisions relate to long-term fixed-cost investments. They could perform badly in either unexpectedly high or low scenarios. The option value on delaying these investments, if they can be delayed until some of the uncertainty is resolved, could be high.

To the extent possible, we should choose options that maximise the upside gains of new valuable technologies and an early start while minimising the downside risk of investing in ultimately useless unprofitable technologies. Even in an ideal world, errors will still be made because the uncertainty is genuine – no one can make a decision that will ex-post be best under all situations. Government cannot get rid of the underlying uncertainty. Government investment simply transfers the risk to government.

3.2 Why Dynamic Efficiency might not be Achieved Simply through Market Signals

Dynamic efficiency may not be achieved simply through market signals. The two basic reasons are: first that carbon prices might be below the international market level possibly because some sectors or companies may have partial exemptions from regulation; and second, that markets may be dynamically inefficient.

3.2.1 Carbon Prices Below the International Market Level.

The international price signal is the world permit price (a price to be determined by uncertain market forces). This is the true opportunity cost of emissions in New

Zealand. The assumed New Zealand climate change policy could create differences from this price signal in three ways.

First, a Negotiated Greenhouse Agreement (NGA) is unlikely to provide as strong a price signal as the international price or even a \$20 carbon charge. Second, if the international price is higher than \$20 per tonne of CO_2 then all New Zealand players face a relatively low price signal. Third, if revenue is recycled in such a way that it favours labour rather than capital (GST and income tax cuts rather than corporate tax cuts), or even more so if it cuts petrol taxes, this might bias even further away from renewables which tend to be capital intensive or can substitute for petrol.

3.2.1.a Fiscal Cost of Low Price Signals

The government is ultimately responsible for our compliance with Kyoto and is the residual claimant if, together with our sink revenue, New Zealand makes a net gain from Kyoto. If emissions reductions or sink revenues are lower than they could be because sectors face lower incentives, then the government will need to buy more (sell less) and will face a fiscal loss.

3.2.1.b Situations in which it could be more Dynamically Efficient for the Domestic Price to be Lower than the International Price

To the extent that these more lenient policies are justified by lower economic cost, the economy as a whole might benefit and even the government losses would be partly offset by higher tax revenues. In the case of the 'competitiveness-at-risk' firms we would only know if this had been an efficient policy when we find out what the long run path of international regulation is. In the case of avoiding adjustment costs from rapid structural adjustment we will never know but there are some cogent arguments in favour of a slightly slower transition.

3.2.1.c Costs of Differences in Marginal Costs to Optimal Renewables Uptake

The relevant thing for this paper is the extent to which the differences in price signals will lead to the inefficient uptake of renewable energy. This is not an intended consequence of any of the policies so would be a pure loss.

Essentially this depends on the nature of the sectors that receive more lenient treatment, the extent to which they have feasible renewables options and how credible the long run (post 2012) transition to full cost internalisation is.

The first situation is if the feasible option is one that creates process heat or anything else that cannot be shared with other users who face full carbon prices. In this case, if the renewable is competing with a fossil fuel source, the renewable technology is likely to be delayed by the special treatment of the sector or company.

In contrast, if the feasible renewable option is to create electricity for the grid it is more complex. The 'at risk' sector will not face higher electricity prices but other electricity users will face the full carbon price. In fact the special treatment of the 'at risk' sector will raise overall demand for electricity relative to a base under a comprehensive carbon charge so will tend to push prices up even when excluding the carbon price[10]. If the renewable option provides marginal electricity which goes to users outside the 'at risk' sector it might still benefit from its competitors facing the full price increase from the carbon price and not be delayed at all. This will be complex in New Zealand because electricity markets are segmented by geography and some 'at risk' users may be major demanders in some sectors. It also depends critically on exactly how 'at risk' sectors are exempted from the carbon content of electricity. It will be different if they are exempted from the average carbon content than if they have to specify the source of their electricity.

3.2.1.d Implications for Renewables Policies to Complement Climate Policy

The special treatment of 'at risk' sectors creates some disadvantages for renewables uptake relative to a policy that passes on the full international price in all sectors. This will lead to some slower uptake of some specific renewables options in certain places and sectors. We will endeavour to identify some of these in section 4. The special treatment could provide a justification for additional policies to take advantage of the emissions reduction (and hence international permit revenue) possibilities from renewables.

3.2.2 Dynamic Inefficiencies in Markets

This section analyses the processes of innovation and diffusion, over the investment horizon affected by policies implemented between now and 2012 (i.e. a period not limited to before 2012), with specific attention to reasons why the market might not lead to the dynamically optimal levels of these activities even if the price were equal to the international price.

This section also identifies potential arguments for additional policies to complement a price incentive rather than substitute. We basically created the list by thinking about traditional market failures and how they may apply here.

An extensive literature addresses the benefits of economic instruments relative to performance standards or technology standards.[11] Most of this work has focused on static efficiency gains arising from heterogeneity in costs among firms.[12] It is increasingly recognized that the most important implications of the form of regulation may arise from their effects on dynamic behaviour: research, innovation, and adoption of new ideas and technology. Some theoretical work has been done on the effects of the form of regulation on incentives to innovate and adopt.[13] Maloney and Brady (1988) consider the effect of constraints on the use of economic instruments on capital turnover in the electric power industry. There is some new empirical work on the effects of environmental regulation on innovation (Newell et al., 1996), choice of

[10] The overall demand for electricity will fall but it would have fallen even further if at-risk sectors were not exempt.

[11] See for example Dales (1968), Kneese and Schultze (1975), Hahn (1989) and Hahn and Stavins (1991, 1992)

[12] For an excellent discussion of many of these studies see Tietenberg (1985)

[13] For a survey see Jaffe, Newell and Stavins (2001) pp: 25 – 29. Key references include Magat (1979), Milliman and Prince (1989), Jaffe and Stavins (1994), Prince (1989), Malueg (1989), and Fischer et al (1998).

technology (Gray and Shadbegian, 1996) and rate of adoption (Kerr and Newell, 2000). There is much less literature on how economic instruments might still fall short in inducing efficient dynamic adjustment.

3.2.2.a Invention and Adaptation to Local Conditions

Exogenous technological change is very important for New Zealand. Most of our basic technology comes from abroad. The key issue is appropriate pick up and adaptation to local conditions. In this section we discuss the sources of market failure in R&D markets that may affect New Zealand innovation and adaptation of international inventions. We present possible solutions to them as well as discussing the effects of different policy instruments on incentives to innovate and diffuse technologies.[14]

Three basic problems can arise: positive externalities from invention, high risk combined with an intangible asset, and a thin labour market.

The fundamental problem with investment in any R&D activity is that it is extremely hard to appropriate all the benefits from that investment. Many of the benefits go to other firms and to consumers. This reduces the incentive to invest. Even from the point of view of New Zealand as a whole, we cannot appropriate much of the benefit from invention because our market is so small relative to the potential international market. Some people also claim that New Zealanders do not have a good track record at managing the commercialisation of their inventions so most gains go to others.

The second problem arises because research is an unusual investment. The returns from R&D tend to be very skewed with most of the potential value coming from a few very low probability but very high value outcomes. This makes R&D highly risky. In addition, the outputs of research are intangible so they cannot be sold or used as collateral and cannot even be easily measured. This makes it extremely difficult to get outside funding to finance R&D. If the companies who want to do the research are large they may have internal funds they can use but if they are small they will tend to under invest.

Finally, a problem that may be particularly acute in a small country like New Zealand is that we have a very thin labour market for skilled researchers. If engineers and researchers are to work on renewable technologies, unless they can be imported, they have to be drawn from other research in a very direct way. It might be very difficult to suddenly increase the number of people working in this area.

3.2.2.b Possible Implications of Problems with Innovation for Government Policy

In the case of GHGs, New Zealand is in an unusual situation for an environmental regulation. Because Kyoto is fixed from the point of view of New Zealand (assuming ratification) and because New Zealand will face a carbon / GHG price determined in the international market, if the international price were to be imposed on New Zealand

[14] Martin and Scott (2000) provide a survey of market failures in R&D and responses.

emitters it would completely internalise the effects of Kyoto on New Zealand.[15] If compliance is our only goal, and if the government's intention to continue to comply with Kyoto is credible, the issues with R&D will become essentially the same as those in the market for any other private good. Any anticipation of more stringent targets in the future is an issue of expecting a higher future price.[16]

Governments generally do some publicly funded research through universities or research institutes. This is largely for 'blue-skies' research – i.e. for invention rather than adaptation of existing technology. There are few successful examples of government commercialisation of a technology.[17] Governments routinely contribute also to private sector R&D either through tax breaks or direct funding. Unfortunately it is very difficult to assess the effectiveness of government investment in research. David et al. (2000) summarise the available literature but the results are not that strong. This does not suggest that public R&D funding is ineffective, simply that there are methodological and measurement problems with estimating the effect.

For New Zealand, with a small labour market and little indigenous research, our key needs might be facilitating training / retention of key skills and maintaining and building strong linkages to international research and commercial development. These would allow us to rapidly identify and adapt new technologies as they become available.

GHG Instrument Choice and Innovation

This is slightly off topic but we include it briefly because it has been a major area of research elsewhere and might still be relevant to government decisions. In the case of New Zealand's compliance with Kyoto, a tax system or a permit system will have the same basic effects on innovation and diffusion of new technologies. This is essentially because we are international price takers so our own innovation and diffusion will have no effect on prices.

Technology standards can have a perverse dynamic effect. If the government official setting them is prescient they can force technology adoption in an appropriate direction but they are much more likely to lock in or force adoption of inappropriate technologies. Similarly, a performance standard for emissions per unit output can lead to technology development but setting the standard is a complex trade-off between not being too lenient so there is no pressure for technology development and being so strict that firms are simply unable to meet the standard.

3.2.2.c Diffusion / Adoption

Diffusion of a new technology tends to be a slow process for reasons discussed in section 3.1.3.[18] The question here is: is the process inefficiently slow and what could possibly be done to address this? This is not only significant on its own account but

[15] In particular we do not need to worry about the linkages between innovation and target setting and strategic behaviour in this regard. This is a major focus of the international literature.

[16] If we are worried about other environmental effects from renewables, either positive or negative, the problem becomes more complex but we will not address that here.

[17] See Cohen and Noll (1991).

[18] Kemp (1997) also offers an overview of theoretical models of diffusion.

because inefficient diffusion also implies reduced incentives for invention and adaptation of new technologies; technological change is a closely integrated process. Adaptation is often found to be very rapid but it may be inhibited by expectations of slow market growth for the new technology.

Potential market failure in diffusion can be grouped under five headings: information availability and diffusion; increasing returns; agency problems; high private discount rates; and market power. In addition there could be regulatory barriers that need to be addressed to allow the market to operate efficiently.

Information Availability and Diffusion

To adopt efficiently, firms need to have good information on the profit potential of the technology, its costs and any problems with installation and operation. Information is a public good which can be made available at no additional cost to other potential users after it has been created. Problems can arise in both production and dissemination of information. Each player that learns about a renewable technology through research or by adopting it creates a benefit for all future adopters. Hence all players have an incentive to let others gain the information for them, i.e. to 'free ride'. This leads to underproduction of information.

In addition, it is difficult to control the flow of information so that the creator of the information can benefit by selling it. Once the information is available, it is socially efficient to disseminate it at almost no cost, but unfortunately not being able to gain by selling information reduces the incentive to package and distribute the information. A final issue relates to the credibility of the information. If the information is available only through a firm's competitors or through consultants or firms selling the technology the information may not be trusted.

If information availability is a limiting factor in adoption of new technology, that is clear evidence of a market failure. In general, empirical studies find evidence of the importance of information when they are dealing with adoption by small, unsophisticated players but not with larger firms.[19]

Increasing Returns

Another set of problems can arise if the technology exhibits increasing returns to scale, i.e. a few small investments will not be profitable but adoption on a large scale would be profitable. This can arise for three major reasons. First there could be endogenous learning so that early adoptions themselves lower the cost of future adoption.[20] This is another example where adopters create benefits for other users. It may not be profitable for them to adopt but it might be worthwhile for society as a whole.

Another reason is 'network externalities'. The more people who join a network, the more valuable the network is to all those already on the network. Increased patronage

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[19] Kemp (1997) found that an epidemic model (where information dissemination is a driving factor) fit very well in the case of adoption of thermal insulation in the Netherlands.

[20] Several authors have estimated learning curves for renewable energy: Nakicenovic (1996), Neij (1997), Grübler and Messner (1999) and Grübler et al (1999).

either directly provides benefits because old users may want to network with new users or because it allows for extension of the overall network. For example, if technology requires ongoing service, having a larger number of adopters will increase the availability of service within New Zealand. A small network may not be profitable where a large one could be.

Both endogenous learning and network externalities can create path dependence and potentially 'lock in'. If for some reason one firm does adopt, this can create a virtuous circle, which lowers cost and expands the network and thus leads to more adoption and deep penetration of the technology. In contrast if no project is initially profitable, the adoption process may never take off. In the case of lock-in, an inferior technology may become dominant and exclude other technologies simply because it was the first to be adopted.[21] It may not be worth it for any individual to swap to the better technology once the inferior one is in place; a large number would need to swap simultaneously.

The third issue would simply be that the optimal scale of adoption (even if a single case) is very large so that the costs and risks are large. This limits the firms that would be able to consider adopting this type of technology. They may need to be multinationals or at least large national companies.

Any of these three reasons mean that socially the adoption might be worthwhile on a large scale but private players may not be able to make investments on that scale because it would require either one large project or coordination among projects.

Agency Problems

A classic problem in the uptake of energy efficient technologies is that landlords generally make investment decisions while tenants pay the energy bills. This leads to lack of investments that will lower energy bills. A similar problem can arise within firms where one part of the firm receives the benefits from a new technology while another bears the costs. If they are not able to communicate and align the investment with their incentives, good opportunities may be missed. A similar problem arises where adoption of renewables requires many small applications that are most likely to be identified at low levels in the organisation. The high level managers may not want to allow such projects that involve a high level of monitoring for a small return per project.

High Discount Rates

A consistent 'paradox' in the literature is that firms and individuals implicitly use very high discount rates when assessing energy efficiency and renewable investments. In particular empirical evidence finds that adoption decisions are much more responsive to falls in the initial cost of adoption than rises in benefits (especially when those benefits come through higher future energy prices).[22] This is a particular concern for renewables, which tend to have high up front costs and benefits spread over time. This could be a rational response to the high levels of uncertainty in future benefits.

[21] Cowan and Kline (1996) explore the issue of technology lock in the case of renewable energy and fossil fuels.

[22] See Jaffe and Stavins (1995) and Hasset and Metcalf (1995).

Uncertainty can create an option value that justifies waiting if the uncertainty is likely to be resolved in the future. It can also reduce the weight investors put on future benefits and hence deter investment if the investor is risk averse. All of these are efficient responses. High discount rates could, however, also indicate a degree of myopia and short term vision or problems with capital markets so that firms cannot borrow money for these investments at reasonable rates.

Market Power

If some firms have market power this can be an advantage for technology change. Large firms are more able to capture the benefits of learning and new technology and may be more able to protect their intellectual property rights. Thus they might have stronger incentives to invent and adapt new technologies. A large literature in economics has explored whether this thesis is empirically true. The evidence is mixed. Large firms do tend to adopt earlier but they are not necessarily the source of invention.

If the large firms that dominate the energy sector have existing generation capacity that would be in competition with new renewables options, they may actually have an incentive to block or delay adaptation and adoption of the new technology. This would protect their existing generation assets. More benignly, if they are not actively developing the renewable options themselves, they may not contribute to network infrastructure that is necessary to make the renewables a success.

Regulatory Barriers

Government would be involved in optimal adoption of technologies in several ways. If they do not play their roles, the private adoption would also be inefficient. Some renewables may require investment in public infrastructure for their optimal use. For example, investment in more large-scale hydro in the South Island is likely to require enhancement of the electricity network to be efficient. This enhancement may require some government involvement.

Regulatory barriers may exist simply because no one has tried to do renewables policies before (though some renewables have been an integral part of the New Zealand energy scene for over a century). Government (local or central) may be the only body that can address these. One example may arise in the application of the Resource Management Act. If councils have not dealt with similar situations before they may need to invest in planning for how to deal effectively with renewable energy applications.

Given that government is still the major provider of tertiary education, it may need to consider the effect of its funding policies for polytechnics and universities on the skills needed for efficient uptake.

Finally, government is a major purchaser of energy services in its own right. It may need to think about places it would optimally use renewables in its own activities. Even without an explicit renewables policy, government would need to think about renewables.

3.2.2.d Possible Implications of Problems with Diffusion / Adoption for Government Policy

If there appear to be problems with the availability and dissemination of information that might be influencing adoption, this might be an area where government can help at relatively low cost. Publishing credible information, subsidising international visits and travel to maintain international research networks, and using its existing channels to disseminate information within New Zealand could all be valuable.

If the problem is that early adoption needs to be done to learn and reduce uncertainty, but this adoption is not profitable on its own, there may be a role for government-subsidised demonstration projects that deliberately build in a process for collecting and disseminating information about the technology. Government could in some instances decide to act as an early adopter within its own activities. If there are network externalities (probably not big in renewables) then some coordination could facilitate establishment of the network.

Voluntary environmental programmes promoted by government or the private sector (e.g., New Zealand Business Council for Sustainable Development) may help to address agency issues within firms simply by bringing the range of opportunities to the attention of senior managers who are able to coordinate action.

If the government does want to speed adoption above the rate the market will produce, possibly to create future options in case carbon and hence fossil-fuel energy prices rise significantly, it might be best to address the upfront costs of adoption rather than enhancing the down stream benefits. Empirical work has found that adoption responds most to falls in cost. This could be done with technology subsidies targeted at early adoptions of specific technologies that could have high payoffs with high energy prices.

Whatever policies are chosen, we should avoid technology forcing that requires heterogeneous players to adopt at similar times. This might lead to more adoption but would be likely to be very inefficient. More renewable energy use is not always good even if it is good for some firms.

Downing and White (1986) show that market-based instruments induce optimal diffusion if diffusion has no effect on the optimal tax or quantity. In the case of GHG policy for New Zealand, the targets and international prices are given from outside, so all market instruments behave in very similar ways. Thus the exact choice of price instrument does not have a large effect (tax versus permit system).

3.2.2.e Development of Markets in Response to Carbon Regulation

A final area where learning and adaptation may need to take place for efficient uptake of renewables is in the development of market instruments to finance renewable energy. If permits are used as an instrument, firms will have to become used to this extra factor in their decisions. More importantly, where the gains from a new investment are in lower energy costs, those who provide finance might want to be able to estimate those gains and maybe appropriate them directly. An example of this occurs with energy service companies (ESCOs) in the United States (Meridian

Solutions is an equivalent New Zealand company). The ESCO provides and installs the technology in exchange for the reduction in energy expenditure by the firm over the next few years. This requires no up-front investment by the firm itself. The ESCO bears all the risk. A range of contractual forms and private sector 'projects' could be used to respond optimally to higher fossil-fuel energy prices. These will need to be developed. Some innovation and adaptation of existing instruments is involved here, the rest is diffusion of information. These markets will probably develop quite rapidly when carbon prices become sufficiently high. A significant group of sophisticated players is interested in developing these markets internationally. These markets will probably not require government intervention.

4 BACKGROUND ON RENEWABLES POTENTIAL BY SECTOR

The following section outlines the major renewable energy options available in New Zealand, and how they can assist supply in the energy sectors of electricity, process heat, low-grade heat and transport. The interaction of carbon charges with cost and availability for various renewables (and their fossil fuel competitors) are considered, particularly in the areas of electricity and heat. Sectors of the economy are then considered, along with the impact of the assumed climate change policy and the potential for renewable energy substitution. Regional impacts and constraints are then outlined. The section finally draws material together for a more focussed discussion for the balance of this report.

4.1 THE MAJOR RENEWABLES OPTIONS

In October 2001, the Ministry of Economic Development commissioned East Harbour Management Services Ltd to produce a report entitled “Availability and Costs of Renewable Sources of Energy for Generating Electricity and Heat” (East Harbour Renewables Report)[23]. The report focussed on significant renewable energy options for heat and electricity that can be developed at a cost less than an equivalent of 15c/kWh by the year 2012. Considering consent and construction issues has reduced the options further. A range of renewable options are available that can satisfy the Government’s final target in the Renewables Strategy all at a price.

In addition to these significant, and largely established energy options, a number of other technologies at a very early stage of the cumulative adoption path may be considered. These new and emerging energy technologies would include wave power and technologies associated with the wider hydrogen economy.

The “renewables” debate has revolved around potential global or energy sector targets, with the four sectors of interest being electricity supply, process heat, low-grade heat and transport. Renewables options can supply all of these sectors.

[23] See East Harbour (2002a)

Table 4 Renewables Options by Energy Sector

Resource	Energy Sector				Notes
	Electricity	Process Heat	Low Grade Heat	Transport	
Hydro	Yes	No	No	No	Other uses include irrigation, recreation, municipal water supply.
Geothermal	Yes	Yes	Yes	No	Other uses include tourism, and mineral extraction.
Wind	Yes	No	No	No	Limited recreational transport.
Biomass (Woody)	Yes	Yes	Yes	Yes	Woody biomass is most flexible. Heat applications for non-woody options are limited.
Biomass (Landfill Gas)					
Biomass (Other)					
Wave	Yes	No	No	No	Technology at prototype stage.
Hydrogen	Yes	Yes	Yes	Yes	The hydrogen economy will have widespread applicability but is not expected in strength for another 50 years.
Photovoltaics	Yes	No	No	No	Price is currently high. Research continuing.
Solar Hot Water	Yes (negawatts)[24]	Yes (limited)	Yes	No	Useful load management tool.

4.1.1 Electricity

The technologies are generally well known and will not be explained here. However the following notes apply:

1. *Hydro*. Available resources have been well studied and the technology is mature, with many examples in New Zealand. Project Aqua (a project drawing on the Waitaki River in South Canterbury) does represent divergent thinking in that it is based on a long cascading canal system with minimal structures in the river rather than impoundment, with secondary irrigation benefits. As a general rule, costs are site-specific so that large size does not necessarily correspond to lower cost. Costs are not expected to fall significantly with time (unless Project Aqua lessons can be reapplied to other projects). Much of the remaining consentable hydro resource is in the lower South Island. Hydro stations are very flexible in operation, capable of rapid start-up or increased generation from part load. The generating companies with hydro operational experience include Meridian Energy, Mighty River Power, Contact Energy, Genesis Power, Trust Power, and Todd Energy interests.

[24] "Negawatts" are avoided megawatts. In the case of solar hot water, no electricity is generated but the electricity that must be supplied by the grid is reduced by the amount of energy for water heating that is absorbed by the solar panels.

2. *Geothermal*. High temperature resources, located in the central North Island and Northland, have been extensively studied with many fields tested by Crown drilling. Unknown aspects of these resources can be determined primarily by more extensive drilling and exploitation. High temperature resources can be developed by conventional steam turbines (as at Wairakei and Ohaaki) or a mixture of steam turbines and binary cycle plant (as at Rotokawa and Mokai). Lower temperature resources or hot water can use binary plant (as at Ngawha and Kawerau) for generation. Technology is well established, although research into chemical deposition is proceeding in an effort to extend the limits of operation. As a rule a 50MW project will have a lower unit cost than a 25MW project but economies beyond that are not expected. Where the Crown has already drilled wells there may be niche opportunities for smaller developments. Costs are expected to be stable. The generators with geothermal operational experience include Contact Energy, Mighty River Power and Todd Energy interests.
3. *Wind*. Resource characteristics are broadly known, with several sites receiving detailed study. Three developments have occurred in highly prospective areas (Wellington, Wairarapa and Manawatu Gorge), with major additions / expansions in these high wind speed / low development cost areas being possible. The technology is maturing rapidly such that capital costs have been dropping. There are marginal economies for larger projects. Wind allows generation in otherwise resource-scarce areas. Generators with operational experience include Meridian, Trust Power and Genesis Power.
4. *Biomass*. Biomass resource characteristics are generally less well defined as these are often based on a waste resource e.g. landfill gas, sewage plant gas, wood process residue, factory biowaste, or farm waste. Forest residues are currently too expensive because of transport costs. However, they can be a secure backup source of biofuel. Dedicated forest or agricultural crops appear too expensive in New Zealand. Landfill and digester designs are advanced (though refinements are being made). The gas conversion plant is mature. Gasification technologies (as an alternative to mature combustion technology) are being developed and will be entering commercial applications in the near future with a corresponding decrease in cost. These plants are often on a relatively small scale with electricity largely absorbed by the host, i.e. electricity generation may be embedded in a factory or local network. This can mean that the hurdle price at which the plant can be economic is higher than if connected directly to the national grid. A larger plant has a lesser capital cost but greater fuel cost due to the need to transport fuel. It also will have to compete with the wholesale electricity price. Waste resources are found near major populations or industry centres throughout the country. Generators with experience include Genesis Power, Meridian Energy and Mighty River Power.
5. *Wave*. NIWA continue general research on potential wave power sites. Technology is at a very early stage of development. There are forecasts of competitive generation costs at the 100MW size, but investor confidence is low due to the failure of several prototypes. There will be a number of consent issues associated with structures over the sea bed and risk to shipping that have not been tested by consent applications for this purpose. The resource has not been included in the East Harbour Renewables Report because of this general lack of confidence.

6. *Hydrogen*. Hydrogen may be seen as an energy storage means. It can be produced via a number of means including electrolysis of water.[25] Technologies for conversion of hydrogen to electricity include a range of fuel cells at a prototype stage. Commercial interests, including motor vehicle manufacturers are investing in stationary electricity applications to prove the fuel cell technology for wider mobile applications, and accelerate the learning curve. Limited trial use is expected in the short term, but widespread use is not expected in the next 10 or 15 years.
7. *Solar*. The solar resource is infinite; availability is more a function of uptake scenario. The resource is available everywhere with little difference between Southland and Northland. For the East Harbour Renewables Report, solar hot water uptake was seen as being applicable to a percentage of new and existing homes, while photovoltaics were modelled as being installed on an accelerating path from a small base. Either technology can be applied to an isolated location or can be used to directly offset purchase of electricity from the network. If the decision to install these units by a home or office owner is made on a purely financial basis, then the threshold price for comparison will be the variable component of the retail electricity price rather than the wholesale electricity price. Photovoltaics are a rapidly maturing technology, with price decreasing markedly in recent years, helped by accelerated uptake overseas. Solar hot water is competitive now but has an undeveloped market. The cost of solar hot water will decrease with time as factory costs are spread over a greater number of units.

All of the renewable energy options have potential for electricity generation (or in the case of solar hot water for the offsetting of generation). However some of these generation options will have a limited applicability because they cannot be relied on e.g. on calm days wave or wind power will be zero, solar options will not be available at night, and dry-year hydro limitations are well known (though less restrictive). Geothermal generation and biomass options are secure.

New Zealand's electricity network is peak / volume-constrained in several places. Several significant constraints include those of the High Voltage Direct Current (HVDC) link[26] (particularly if old equipment has to be retired, or large South Island hydro development occurs), those south of Whakamaru (located in south Waikato) (which will restrict northward transfer of generation from the south, or from the Central North Island to the high demand/growth centre of Auckland), and end-of-system constraints (e.g. on the West Coast, Northland, Gisborne etc). The cost to overcome these constraints has not been built into any calculations and is not in the public arena.

Several technologies affect a wide area and potentially can affect local communities / ecosystems in their implementation and operation. Consequently, they face opposition in the resource consent process far greater than that associated with, say a

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[25] As electricity is required, the hydrogen economy is only truly renewable when the electrolysis plant is directly powered by a dedicated renewable resource, or when the whole grid is renewable-based. Until that time, electrolysis plant would draw on electricity at the margin – a dominantly fossil-fuelled supply.

[26] The HVDC link has been installed in stages, with the earliest equipment commissioned in 1965. Nominal capacity of new and old poles and associated equipment is now around 1000MW. The older equipment may be retired in the next 10-15 years.

gas-fired combined cycle plant. As an example, Contact Energy has been involved with consenting for existing and new hydro, geothermal and gas-fired combined cycle plant. Consent applications / hearings saw far more submissions opposed to the renewable projects than the potential gas-fired plant. The much smaller geothermal plant was eventually taken to the Environment Court with associated delays and costs. Consentability has been taken account of in resource assessments. A more liberal consenting environment will greatly increase the potential available renewable resource and its cost, as will be discussed later.

Human resource capability for project development is fast disappearing because limited projects are being undertaken. In some areas, such as detailed resource assessment, design and construction there is already a lack of recent relevant experience. Many of these skills could be accessed overseas, though competition for these resources in a world where many countries are considering these same options could be restrictive. New Zealand's dam construction expertise is far less than it used to be; New Zealand has had a limited geothermal programme that could be expanded.

4.1.2 Process Heat

The principal sources of process heat include geothermal energy and biomass (especially woody biomass). Solar hot water has not made significant development steps at the commercial and industrial level, as it is principally low temperature (60^{o}C) hot water. Hydrogen sources are in the distant future.

Geothermal energy for process heat is restricted to the vicinity of high temperature geothermal fields (Central North Island and Northland). Steam may be transmitted a limited distance. Options include direct geothermal steam supply (possibly with gas problems) or generation of clean steam from geothermal heat. Steam supply can be from a greenfield (previously undeveloped) location, or arranged in parallel with a geothermal power station (effectively this is geothermal cogeneration or combined heat and power). The relative inefficiency of a geothermal power station (in terms of simple thermodynamic efficiency) means that the value of geothermal steam when used to generate electricity is about 40% to 45% of that from a fossil-fuelled plant. Thus steam can be offered from a geothermal power station at very competitive prices on a heat market (if there is room for the industry to relocate to the power station site).

The most widely spread renewable heat resource is that associated with biomass. Most attempts to use biomass waste streams for process heat purposes (e.g. using methane generated at landfills, sewage plants or other waste piles undergoing anaerobic decomposition) have failed to attract industry to co-locate.

The major opportunity for use of waste lies with the producers of the waste themselves, or for use by plant developed in a supporting role. The timber industry is the largest source of biomass waste, both in the forest and at the processing plant. This industry is a major user of heat and can (and does) readily use woody biomass as an energy source rather than view it as a disposal problem.

A very successful model of renewable heat use can be found at the wood processing and other facilities at Kawerau, dominated by the Norske Skog Tasman Pulp and Paper Mill. The site is the largest user of geothermal heat in the world. Geothermal steam at the mill is fed direct to a turbine or used to generate clean steam, with geothermal condensate supplying makeup fluid for the process system. Some geothermal steam is fed to timber drying kilns. Further geothermal steam is delivered to adjacent horticulture developments. Hog fuel (waste wood) is used as a boiler fuel. The facility also has black liquor recovery boilers for extraction of heat. Waste geothermal hot water supplies energy for electricity generation.

Technologies for the production of process heat are mature with no significant price changes expected with time. The cost of a geothermal cogeneration steam supply could be independent of size, while the cost of a wood boiler is a stronger function of size.

4.1.3 Low Grade Heat

Discussion of low grade heat, primarily for domestic water heating has focussed on solar hot water heating. As mentioned in section 4.1.1, this can be justified on economic grounds because users can avoid purchasing retail electricity.

Other options for low-grade heat include geothermal heating and biomass (wood-fired heaters). Geothermal options will include use of both low temperature resources (e.g. as at Waiwera, Tauranga, Rotorua, Maruia and Hanmer) and ground-source heat pumps. The former technology relies on wells and heat exchangers, possibly with some neighbourhood networking. The latter technology can be applied at any location in the country and involves pumping heat between air or water in a residence and the soil outside. Both low temperature geothermal resources and heat pumps need further research in New Zealand's context.

Wood burners, possibly with wetbacks, have been part of the New Zealand domestic scene for a long time. Modern burners are cleaner burning and more efficient than earlier versions.

4.1.4 Transport

In the future there should be a substantial move towards a sustainable hydrogen-based economy. Iceland is a country making significant moves in this direction now. That shift is largely beyond the scope of this report. However, research is suggesting that in the intervening decades there could be a transition in technologies and resources through the use of renewable (biomass) resources, and through use of electric vehicles to form a bridge.

The types of alternative fuels include:[27]

- Methanol from cellulosic (woody) biomass,
- Ethanol from starch-rich or sugar-rich crops, from whey or from woody biomass,
- Biodiesel, esterified oil from crops containing vegetable oil or from tallow,
- Hydrogen by electrolysis of water or reforming of a variety of fuels, and
- Synthetic fuels using a Fischer-Tropsch process (for example).

[27] See IEA (2001)

These alternatives (with the exception of hydrogen) can be blended with existing fuels (up to 15-20%) to allow use with largely unmodified engines and to avoid the need for a refuelling infrastructure. Advantages include potential for reduced CO_2 emissions and for displacement of oil.

Currently, New Zealand (Anchor Ethanol) produces 12 million litres of ethanol from whey per year. This ethanol is used in the production of spirits although if all the whey were used for making ethanol, there would be enough whey to produce 40 to 50 million litres of ethanol.[28] This equates to 1PJ of a total transport consumer energy demand exceeding 220PJ per year.

The Liquid Fuels Trust Board has previously researched the production of biodiesel from tallow. Tallow production by the New Zealand meat industry was around 100,000t/y and (after conversion to esters) could have been used to supplement 10% of the national transport diesel demand.[29] Tallow has competing market uses in soaps, lubricants, polymers, etc. There is a proposal by the Bioenergy Association to revisit the costs and opportunity.

Major biofuels uptake (say to allow the 10-20% blends that might be acceptable to vehicle engines) would require development of energy crops. This would require substantial, possibly unrealistic changes to agriculture systems, especially for New Zealand's agriculture-dependent economy. In addition, fuel conversion technologies are largely experimental in nature for biofuels. Finally, there are cost and performance penalties in switching to biofuels.

4.2 Renewables Adoption in the Event of a Carbon Charge

If introduced, a carbon charge would generally alter the economics of the energy balance in favour of renewables uptake by making energy from fossil fuel competitors more expensive. Carbon charges would have a minor direct impact on the price of potential geothermal developments.

[28] See PA Consultants (2001).
[29] See EECA/CAE (1996)

4.2.1 Renewables Adoption for Electricity

The following table shows likely emissions from a range of technologies for electricity generation.

Table 5 Impacts of Carbon Charge on Fossil and Geothermal Electricity Generation

Technology	CO_2 g/kWh	Low Level ($5/t) Charge Impact c/kWh	High Level ($20/t) Charge Impact c/kWh	High Level ($30/t) Charge Impact c/kWh	High Level ($40/t) Charge Impact c/kWh
Coal Best Practice[30]	955	0.48	1.91	2.87	3.83
Oil Best Practice	818	0.41	1.63	2.45	3.27
CCGT	430	0.22	0.86	1.29	1.72
New Zealand Geothermal[31]	100	0.05	0.20	0.30	0.40
Ngawha	597	0.30	1.19	1.79	2.39
Ohaaki	249	0.12	0.50	0.75	1.00
Kawerau	226	0.11	0.45	0.68	0.91
Rotokawa	105	0.05	0.21	0.32	0.43
Mokai	66	0.03	0.13	0.20	0.27
Wairakei	33	0.02	0.07	0.10	0.13

The fossil fuel figures in this table are based on international best practice. Contact Energy has argued that they may be able to achieve emissions levels slightly less than indicated for a combined cycle plant. The emissions quoted for the geothermal developments are based on the emissions from the stations, and make no adjustment for background emissions levels prior to development.

Table 5 ignores lifecycle emissions associated with other renewable technology. The impact of a high level charge on technologies like hydro, wind and biomass is typically less than a 0.05c/kWh (largely based on construction emissions). From the table above, the major negative impact of a carbon charge would be on geothermal developments at Ngawha and Ohaaki. No further development of Ohaaki has been envisaged. Ngawha development costs would be high such that further development could be significantly delayed, if they are still considered.

The East Harbour Renewables Report has analysed the availability and costs of renewable energy options in tight bands of 2c/kWh. The impact of application of a carbon charge on renewables is insufficient to alter these bands in the area of interest for this report.

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[30] See “Benign Energy? The Environmental Implications of Renewables” International Energy Agency report, October 1998. http://www.iea.org/pubs/studies/files/benign/full/06-bene.html.

[31] All New Zealand geothermal developments include a measure of fluid reinjection. Until now, most gas has been vented to atmosphere with dispersion frequently assisted by cooling towers or stacks. Gas reinjection has been undertaken in rare cases overseas so could be considered in New Zealand. Gas reinjection would add further operational difficulties and uncertainties to geothermal developments, while yielding only a marginal benefit in terms of reduced emissions.

MED has commissioned a report on the cost and performance of thermal generation.[32] Despite the recent moves in exchange rate, it is expected that a Combined Cycle Gas Turbine with a fuel price of between $3/GJ and $3.50/GJ at 10% Weighted Average Cost of Capital (WACC) would have a unit cost of between 4.5c/kWh and 5.0c/kWh by 2012. Adding a 1.3c/kWh carbon tax (based on the intermediate high level charge in the table above) will bring the hurdle price for renewables (all other considerations being equal) to between 5.8c/kWh and 6.3c/kWh.

Available natural gas resources are limited. The country has relied on Maui and Kapuni gas reserves until recently. Further reserves have been identified, and an active exploration programme will likely lead to the discovery of additional resources. Connection of these resources to the existing or new gas transmission systems will be an economic decision, partly dependent on the relative allocation of costs between gas and condensate recovery. The table in Appendix 2 indicates recently published information (though the database continues to expand) on these resources.

Coal is a resource commonly used as a power station fuel internationally. The Huntly coal / gas-fired power station (south of Auckland) is New Zealand's largest power station. There are very large reserves of coal of a range of qualities in both the North and South Islands. If gas for electricity generation was limited, then the long run marginal cost of coal plant using either local or imported coal could ultimately set the benchmark cost for electricity generation.

For a coal plant with a fuel price of between $2/GJ and $2.50/GJ at 10% WACC, the unit cost would be between 8.8c/kWh and 9.3c/kWh. This cost assumes full emissions cleanup. (If special emissions abatement technology is not required then the unit cost could be reduced to the 7.6-8.1c/kWh range). Adding a 2.9c/kWh carbon tax (based on the table above) will bring the hurdle price to between 11.7c/kWh and 12.2c/kWh.

Cost supply curves for electricity supply were developed in the East Harbour Renewables Report. Inputs to these curves are given in Appendix 3. A synthesis of information from the East Harbour Renewables and Thermal Reports, along with the impact of carbon charges, is shown in Figures 3 and 4 below.

Figure 3 and Figure 4 show costs in 2012, based on a 10% WACC for high and medium confidence resource assessments. 'High confidence' resources are well proven resources, with a high level of certainty that they can be permitted and developed with an achievable development rate taken into account (assuming an early start). The 'medium confidence' resources include high-confidence resources plus additional resources that could be accessed with improved perceptions about and management of the local environmental impacts. A third 'low confidence' category was included in the East Harbour Renewables Report, but was based on a more optimistic assessment of available resources and a more liberal consenting regime so is not considered further in this report.

[32] See East Harbour (2002b)

Figure 3 **High Confidence Electricity Cost Supply Curve (including effect of $30/t CO_2 Carbon Charge)**

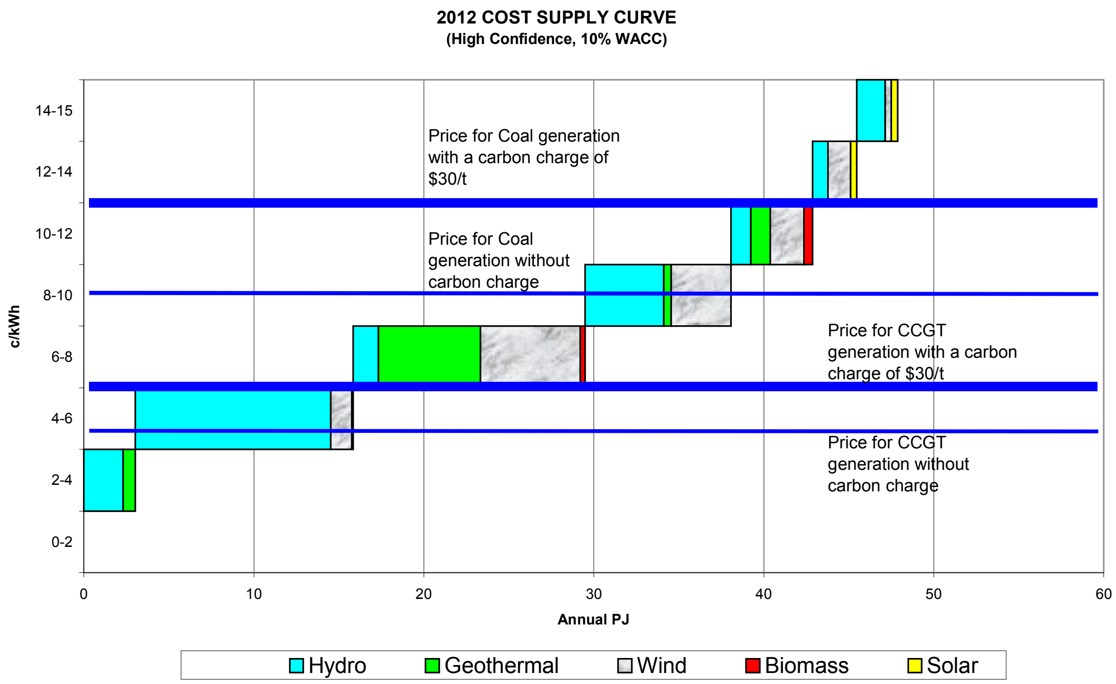
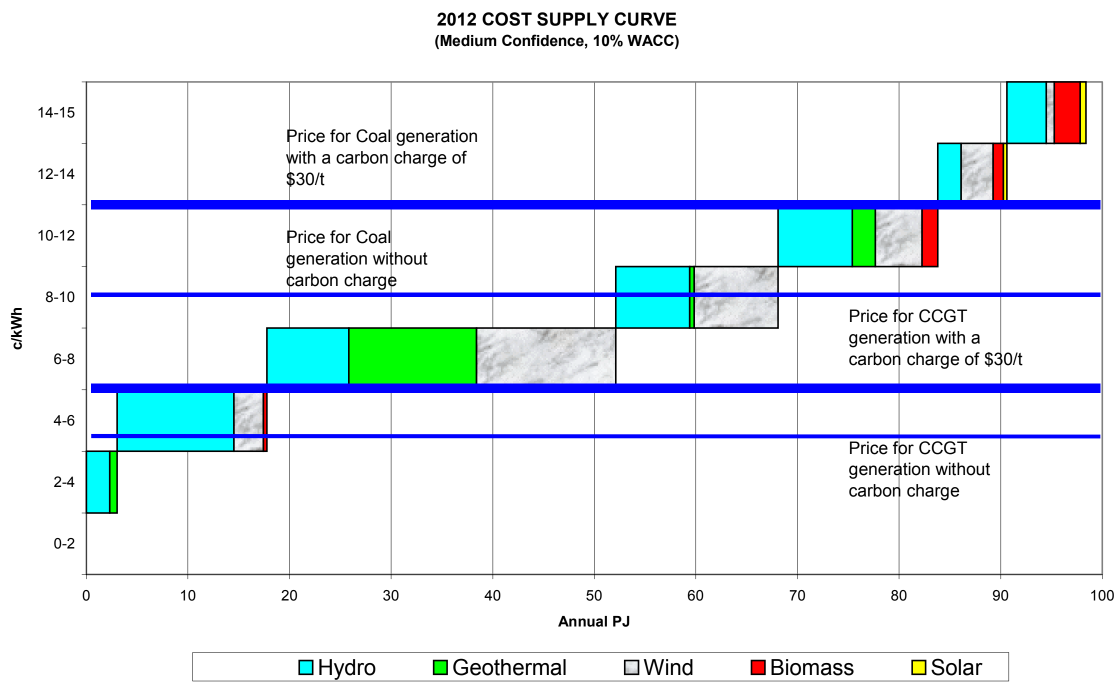


Figure 4 **Medium Confidence Electricity Cost Supply Curve (including effect of $30/t CO2 Carbon Charge)**



Referring to these cost supply curves, we will initially discuss the projects under the line representing the CCGT unit cost without a carbon charge. The lowest price hydro represents the Meridian Energy Manapouri Tailrace project which has been successfully commissioned since the initial drafts of this report. It will increase South

Island generation by about 175MW/640GWh/y. As the South Island is a net exporter of electricity, this additional generation less growth in South Island demand represents additional load on the HVDC link.

A second project shown at low cost is a geothermal project at Wairakei. This Contact Energy project would involve reconsenting the Poihipi Road Geothermal Station for full output base load operation (50MW) based on an alternative steam supply from the Te Mihi area. Currently the plant's consents only allow reduced operation in a peaking mode. A prerequisite for this would be the successful reconsenting of the existing Wairakei Station.

Landfill gas projects are attractive while only making a small contribution. Two new units were recently commissioned at Whitford and others will follow. These units are typically of a 1MW size.

A technology experiencing rapid development with associated cost reductions is that of wind power. Some generic wind projects in the Wellington and Manawatu Gorge area are anticipated by 2012 – possibly 195MW/805GWh/y.

The last project possible in a "Business as Usual" scenario is Meridian Energy's Project Aqua. The project includes a number of hydro stations located on a canalled off-take from the Waitaki River that, in total can generate 570MW (3200GWh/y or 11.4PJ/y), and has the ability to be staged. The project is thought to be valued at under 5c/kWh so could be encouraged by a lesser carbon charge. However, a heavily loaded HVDC link means there is reduced dispatch certainty over all South Island generation. It is likely that the complete project will happen only if there is significant load growth in the South Island and / or there is major HVDC link reinforcement along with further transmission reinforcement as far north as Auckland.

There are no other significant projects under 6c/kWh. Thus, based on the gas price assumed in this report, if a high level carbon charge in the order of \$30/t CO_2 was to be introduced it could assist the development of Project Aqua and the potential wind farms.

In the event of restricted gas supply to the electricity industry (say to allow greater margins for gas players through retail sales) so that CCGT plant could be considered primarily as replacements for existing gas use at other thermal power stations, then the new standard for thermal generation could eventually become that of the higher priced coal generation at 12c/kWh (including the high level carbon charge). Uptake of renewables would continue across a range of projects up to this 12c/kWh limit.

The next bracket of projects, with unit costs in the 6-8c/kWh range, comprise a number of wind, geothermal and hydro projects, along with the balance of landfill gas projects. In this range, the hydro and wind projects represent a continuum of prices starting at around 6c/kWh (and lower for wind), while the geothermal projects are likely to be tightly grouped around the 7c/kWh mark (lifted marginally by the effects of a carbon charge). Wind projects at this price would be located in the Wellington / Manawatu regions (but possibly drawing in projects in the Wairarapa, Coromandel and the South East coast of the South Island) while the geothermal projects at this price would all be located in the Taupo / Rotorua area (southern Waikato/Bay of

Plenty regions). Given the continuum of prices for wind, and to a lesser extent for hydro in each unit cost range, we can conclude that there are no significant discontinuities in the cost supply curves to bring in the first projects above 6c/kWh.

Renewable electricity can be supplied from hydro, wind and geothermal as major suppliers, and landfill gas as a minor source. There is likely to be further minor uptake of PV, with this uptake likely to accelerate in rural areas late in or after the first commitment period due to uncertainties created by provisions in the Electricity Act 1992. Some minor electricity supplies are also likely from woody biomass cogeneration plant embedded in factories displacing retail electricity.

4.2.2 Renewables Adoption for Industrial Process Heat

Table 6 outlines the impact of carbon charges for heat applications.

Table 6 Impacts of Carbon Charge on Fossil and Geothermal Industrial Process Heat

Technology	CO_2 t/TJ	Low Level ($5/t) Charge Impact $/GJ	High Level ($20/t) Charge Impact $/GJ	High Level ($30/t) Charge Impact $/GJ	High Level ($40/t) Charge Impact $/GJ
Coal	114	0.57	2.27	3.41	4.55
Gas	67	0.33	1.33	2.00	2.67
New Zealand Geothermal	5.8	0.03	0.11	0.17	0.23
Ngawha	13.1	0.07	0.26	0.39	0.52
Ohaaki	10.3	0.05	0.21	0.31	0.41
Kawerau	10.1	0.05	0.20	0.30	0.40
Rotokawa	7.2	0.04	0.15	0.22	0.29
Mokai	4.7	0.02	0.09	0.14	0.19
Wairakei	2.0	0.01	0.04	0.06	0.08

Note: CO_2 emissions for geothermal fields have been calculated using known gas concentrations in the steam then using a steam enthalpy of 2780kJ/kg. In the case of Ngawha, gas concentrations were known in terms of total fluid, so emission calculations were based on a fluid enthalpy of 1010kJ/kg.

The East Harbour Renewables Report does not contain cost supply curves for heat, due to unknowns associated with the size of heat plant across all industries. However a relationship between renewable energy sources and fossil fuels was developed. This is shown in Figure 5.

The renewable options shown in the figure include:

- Geothermal Cogeneration: Steam is diverted from a geothermal power station at a price yielding a similar return to that obtained by passing the steam through electricity generation plant.
- Greenfield Geothermal: This shows costs for a previously undrilled geothermal field with a dedicated direct geothermal steam supply (assuming typical production characteristics). Costs for a clean steam supply via a heat exchanger are marginally (up to $2/GJ) greater.
- Biomass Heat Plant with Process Residue Fuel: This is the cost of simple combustion plant using process residue from a forestry mill with that fuel valued at $0.25/GJ i.e. valued as waste.

- Biomass Heat Plant with Forest Landing Material as Fuel: This is the cost of simple combustion heat plant using landing material valued at $2.70/GJ (includes some transportation costs).

Figure 5 shows the costs of heat delivered to the plant in the form of steam or hot water including fuel and conversion plant capital and operating costs. The graph shows several renewable technology options to be competitive now.

Figure 5 Cost Relationship Between Renewables and Thermal Plant for a Range of Sizes (2012, 10% WACC, 85% Load Factor, No Carbon Charge)

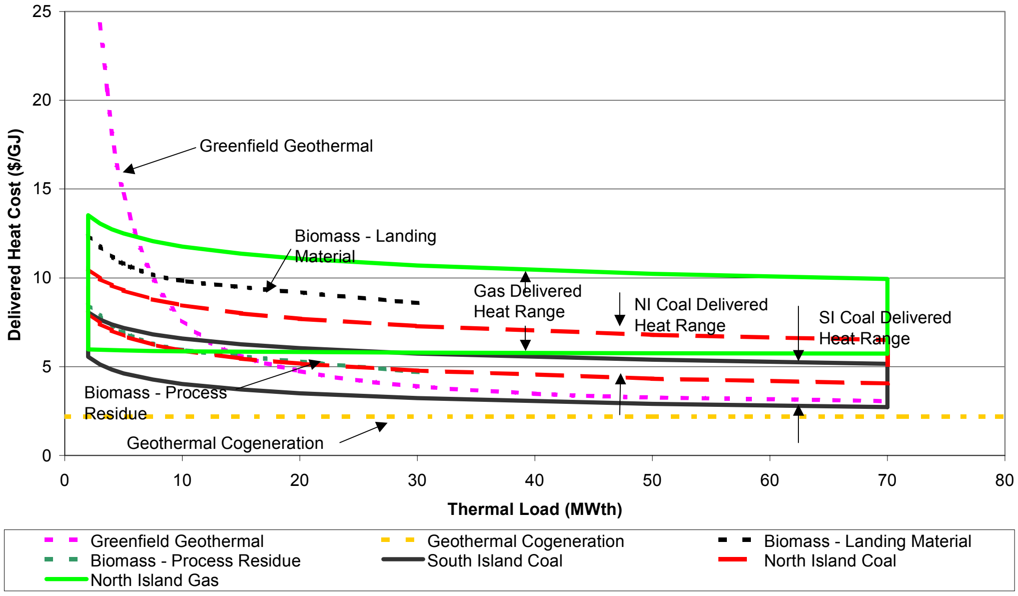
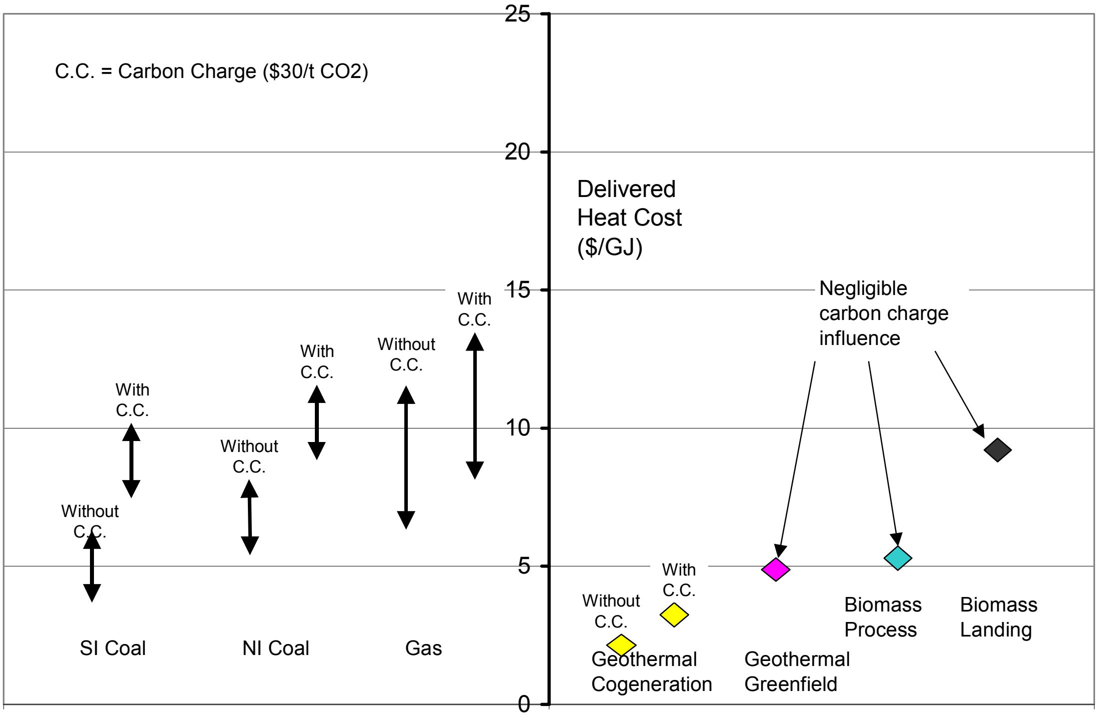


Figure 6 shows the effect of carbon charges for a 20MW thermal load.

Figure 6: Effect of Carbon Charge on 20MWth Heat Plant (Various Fuels) (including effect of \$30/t CO_2 Carbon Charge)



The impact of the low level charge appears to be minor and has not been shown in Figure 6. The high level charge will have a particularly significant impact on coal, raising the South Island coal heat price by about 70%. The effective gas heating price will be raised by between 10 and 30%.

Note that the carbon charge will impact on the geothermal cogeneration cost because the average price received for electricity sold on the market will be raised from around 4c/kWh now to the cost of CCGT plant with carbon charge of 6c/kWh. This will lift the minimum price of this heat from \$2.20/GJ to \$3.30/GJ.

Some firms in the North Island are using gas in preference to coal now even though it may be more expensive. This may have relevance for the uptake of renewables. Reasons why people may be prepared to pay this gas premium include:

- Lower initial capital investment for gas;
- Investors are working with higher discount rates/shorter paybacks than allowed for in the graphs;
- Convenience and security of gas with respect to supply and handling;
- Less land is required for stores, fuel handling and for heat plant itself;
- Clean nature of gas supply; and
- Perceived environmental benefits of gas over coal in terms of triple bottom line reporting (especially on the international scene).

From Figure 6 and the discussion above, we draw the following conclusions:

- Woody biomass, because of its nature (inconvenient to handle and store, dirty) is a more direct competitor to coal rather than gas.

- Biomass heat plant using process residues should be competitive with North Island coal in almost any location. It would be difficult to compete with South Island coal in a business-as-usual (BAU) scenario. The high-level carbon charge will mean that process residues can compete with coal at almost any South Island location.
- Biomass heat plant reliant solely on forest material (if not supplemented by process residue) will be marginal or not competitive under a BAU scenario. A high-level carbon charge will make biomass stations fired by landing material competitive with coal in some locations. This will significantly increase the resource that can be economically developed. The more predictable this fuel can be made in terms of quality and quantity, the easier it will be to market it to industry.
- Where suitably located, greenfield geothermal energy may be able to displace coal and a baseload portion of gas if delivered in a hassle-free manner to the consumer. Neither low nor high carbon charges will significantly alter the geothermal greenfield price.
- Geothermal developments would be further helped by availability of existing wells.
- A process industry attracted to co-locate by a geothermal power station could secure a very attractive heat price.
- Any increase in the effective gas or coal price (whether due to the need for alternative sources or due to special charges) will raise the price range for heat and could begin to draw in a wider range of renewable heat alternatives.
- The difference in the effect of a carbon charge on coal vs. gas is such that gas will tend to displace coal to a greater extent than currently.
- Opportunities for bioenergy / geothermal local area heating schemes in concentrated manufacturing areas may provide opportunities for ESCO's to provide heat (or electricity) from central heat generating plant under contract.

4.2.3 Low Grade Heat

Low-grade heat will be highly dependent on uptake of solar hot water heating, or the expansion of the use of firewood. There will be further opportunities in limited areas for use of geothermal energy. The effect of a carbon charge would be to raise both the cost of retail and wholesale electricity. This would result in these options appearing more attractive, accelerating uptake over the rate currently envisaged in a "Business as Usual" scenario.

The solar hot water unit cost would be around 14c/kWh (if the household's discount rate is 10%) a cost that is roughly equal to the current retail price of electricity.[33] If the wholesale price were to rise by 2c/kWh under the influence of a carbon charge and the cost of CCGT plant, then this price increase would be passed through to the retail customer. The unit cost would then be significantly less than the retail tariffs. The East Harbour Renewables Report had an uptake scenario based around half of

[33] If the household's discount rate is only 0-5% the cost would only be 8c/kWh. See East Harbour (2002a)

new homes utilising solar hot water heating. However, given that solar hot water could allow significant savings to the consumer then uptake could be wider than this, drawing in retrofits of existing homes, offices and other heat users such as on-farm milking sheds.

4.2.4 Transport

Transport fuels blend opportunities will be limited in the short term. Some weak bioethanol blends could be used if appropriate contracts can be established with the dairy companies. Biodiesel from tallow could be mixed with other diesel supplies.

The attractiveness of biofuel blends will depend on the tax applied to the fossil fuel portion of any transport fuel blends. If all transport fuels including the biofuel are taxed there will be no increase in attractiveness.

4.3 SPECIFIC OPTIONS IN SECTORS AFFECTED BY KYOTO

Several attempts have been made to quantitatively analyse the potential impacts of carbon charges on the various sectors of the New Zealand economy, most notably reports by ABARE and NZIER in November 2001.[34]
While each analysis is based on a different model, different sectors and different assumptions, they both predict negative impacts across a similar range of sectors for similar scenarios. A comparison is made in Appendix 4. As a result, there can be some measure of confidence in using the analysis to at least give a qualitative assessment of heavily impacted sectors, where scenarios are similar to those assumed by the Ministry for the Environment (e.g. methane not regulated).

In addition, MED has identified a number of major CO_2 emitters. These are listed in Table A4.2 in Appendix 4, followed by details on each sector.

Combining the assessments of ABARE, NZIER and MED, sectors which could be heavily affected by carbon charges are as shown in Table 7

[34] See ABARE (2001) and NZIER (2001). The NZIER report has been subject to some serious criticism including in a review by Arthur Grimes. Despite the limitations of the NZIER analysis, which leads to estimates of the overall effect of Kyoto that are very different from the ABARE analysis, the relative effects across sectors are consistent in a qualitative sense. We consider that this is an indication of the robustness of ABARE's identification of affected sectors. Analysts might argue about the overall impact of Kyoto on New Zealand but there is broad agreement on which sectors will be affected, which is the relevant issue for this report.

Table 7 Sectors Likely to Face Large Impacts from Carbon Charges

Sector	Comment
Transport	This includes road, rail, air and marine. Biomass substitution opportunities will be limited.
Coal Industry	This is likely to be significantly impacted by carbon charges, losing market share to both gas and renewables.
Iron and Steel	Coal is a chemical requirement for the iron sand reduction process. The Glenbrook steel mill is now a highly integrated operation significantly more energy efficient than 10 years ago due to installation of an enlarged cogeneration plant using waste heat and coal gas. Of note is the presence of a private power operator (Duke Energy) on site.
Aluminium	There are emissions associated with the production and degradation of carbon electrodes. Renewables substitution is not thought viable. There may be opportunity for some embedded renewable electricity generation into the plant (to supplement the close relationship with Manapouri Hydro Station).
Cement/Lime	Emissions result from calcination of limestone and fuel usage. There may be renewable substitution opportunity for fuels.
Electricity	Emissions come from fossil fuel (>5Mt of CO_2/year) and geothermal stations (<0.4Mt of CO_2/year). There are a number of renewables substitution opportunities.
Gas Extraction	This could be affected by downturn in the economy, but could be helped through substitution for coal. Renewables may displace some gas.
Petroleum Refining	Major emissions are from burning refinery gas.
Petrochemicals	Natural gas (CO_2-enriched) is an integral part of the process.
Fishing	Fishing industry will be impacted because of the high transport component. Renewable opportunities are limited
Dairy Industry	Energy is a significant component of the product cost. There may be renewable substitution opportunities on farm e.g. solar hot water or photovoltaics, and could be opportunity for biomass usage in factories.
Meat Processing	Opportunities for renewables substitution are less than in the dairy industry. Waste to energy opportunities.
Forest Processing	This is a major energy user that has been, and will continue to be a significant user of renewable energy.
Government / Local Government / Health	As a group, this is a significant emitter, but opportunities for renewables use or substitution are limited.

4.4 KEY REGIONALLY-FEASIBLE APPLICATIONS OF RENEWABLE ENERGY IN NEW ZEALAND

New Zealand does not have a perfectly integrated electricity network and many process heat fuels have high transport costs, others are immobile (geothermal). This makes the location of renewables opportunities relative to demand for the relevant energy output critical in assessing the feasibility of options.

Regional opportunities are outlined in Appendix 5. Table 8 summarises these by region.

Table 8 Regional Opportunities and Constraints

Region	Comment
Northland	Expanding forest resource with biomass opportunities in this sector. Geothermal energy for electricity may be possible but is associated with high gas concentration and a high development cost. Wind resource will be expensive. Portland Cement may have an opportunity to use biomass fuel. Energy supply (both gas and electricity) is constrained.
Auckland	High growth area with large and expanding energy demand. This is a focus for national energy demand. Resources in the area are limited, with the region subject to constrained energy supply.
Waikato	This area is a net energy exporter, both of fossil fuel and fossil and renewable electricity (hydro and geothermal). There are further excellent geothermal energy options. There are forests in the south with processing in the vicinity of Taupo. Dairy herds and associated factories are significant. There are electricity constraints in the vicinity of Whakamaru that may restrict export through and from this region.
Bay of Plenty	There are some major forestry developments in this area that already use biomass and geothermal cogeneration. Further development of these resources is possible. There are significant geothermal opportunities and some minor hydro opportunities.
Gisborne / Hawkes Bay	There is major expansion of the forestry industry in the area. This could provide a renewable fuel in an otherwise renewable-starved area. Both electricity and gas supplies to the area are constrained such that premium prices are being paid.
Taranaki	Some existing small hydro developments have further opportunities at small scale. Wind resource is likely to be expensive to develop because of transmission costs. There is no forestry resource of significance.
Wanganui / Manawatu	While the region contains major rivers these are of a nature that prevents development. Forestry is expanding in the area. The area near the Manawatu Gorge is a prime wind resource, already with one wind farm and with potential for significant expansion.
Wellington	There are expanding forests in the Wairarapa. There are some limited further hydro possibilities. However the region has two prime wind sites that can be significantly expanded over the current first stage developments.
Nelson / Tasman / Marlborough	This is a growth area dominated by fishing, forestry and horticulture. There are some reasonable wind resources. Significant hydro resources have already been developed. The major resource is likely to be woody biomass. There are possibly some import constraints on electricity, though these may be relieved if transmission from the West Coast is reinforced for possible hydro developments there.
West Coast	This area of stagnant economic and population growth is based on extractive industries. Coal mining is one of these major export earners. Native timber logging has been stopped and will eventually be replaced with a small plantation forest industry. The dairy industry is a significant contributor to the local economy. There are some significant low cost hydro opportunities but the region is highly constrained in terms of electricity transmission. Relief would be needed either to the Nelson area or to Canterbury to allow export, or to account for natural growth in demand.
Canterbury	This significant region is currently a major source of hydro generation including the lowest cost hydro opportunity (Project Aqua). A problem may exist in the export of this due to transmission constraints.
Otago	This region is a source of hydro generation. There are limited sources of coal. There are further hydro opportunities. Forestry has been significant with some growth expected (though not as great as some regions).
Southland	Southland is also a major source of hydro generation with further opportunities. Manapouri generation and Comalco Aluminium smelter demand dominate the local energy scene. There is some further wind opportunity. Meat processing is a significant local industry.

4.5 CONCLUSIONS

Table 9 summarises the key options we believe would be feasible if the market operated efficiently and all sectors were exposed to the international carbon price at the high carbon charge level. We have included only those options that provide significant energy supply either at the level of a single project or overall. We also outline some of the locational and product limitations in their application.

Table 9 Major Renewables Options that would Probably be Efficient with a Carbon Charge Throughout the Economy

Energy Form	Renewable Source	Sector and Location
Electricity	Hydro	• Mostly available in South Island
	Geothermal	• Predominantly Waikato and Bay of Plenty
	Wind	• Predominantly Wellington, Wairarapa, Manawatu
Process Heat	Biomass	• Forest Processing, Dairy Processing, Meat Processing, Industrial Estates, Cement in Northland
	Geothermal	• Forest Processing
Low Grade Heat	Solar water heating (displaces electricity)	• Feasible at current prices • Possible in range of locations
	Geothermal	• Current applications could be expanded • More fields available for low grade heat than for supply of process heat but basic research is needed
Upcoming Technologies (Long Term)	Hydrogen (from renewables)	• Research needed
	Wave / Marine current	• Research needed
	High-temperature Solar (electricity and process heat) and Photovoltaics	• Research needed
	Biofuel for transport	• Whey available immediately (limited scale) • Biodiesel from tallow – research needs to be recalibrated

From here on the report will focus on these options. We will identify reasons why these options may not be taken up without additional policy above the government's climate policy. We will discuss the 'Upcoming Technologies' as a group.

5 POTENTIAL JUSTIFICATIONS FOR ADDITIONAL POLICIES TO PROMOTE RENEWABLES ABOVE CLIMATE POLICY IN THE SPECIFICALLY NEW ZEALAND SITUATION

This section combines the theoretical results in section 3 with the information and conclusions in section 4 to assess the importance of regulatory limitations and market failures for dynamic efficiency in the New Zealand context. It will match renewables options (sources/ sectors and locations) and 'failures' to find areas of potentially useful intervention. It will also roughly assess the likely magnitude of these problems.

The information and examples given in the following section would apply only if there was an incentive or a requirement for the at-risk sectors to move to an (increased) uptake of renewable energy resources. The reason that these renewable opportunities are currently available is that, assuming an efficient market, because of more economic alternatives they are not sufficiently valued by the market or markets they are available to.

As discussed elsewhere in this report, even a low-level carbon charge will not alter this situation.

Hence this section provides possible options should there be an incentive for the at-risk sector industries to meet some of their energy demand from renewable resources. As further identified in the section, while there may be some interest in focussing on local renewable resources in the first instance, the commercial drivers would almost certainly result in companies looking throughout New Zealand for the most economic source of renewable energy to meet their specific needs.

5.1 'AT RISK' SECTORS

The first key reason why the renewable options may not be taken up in some sectors is that those sectors may not be exposed to the full carbon price. If they face instead a Negotiated Greenhouse Agreement they may have significantly less incentive to explore renewables options. The sectors that are mostly likely to be treated preferentially are those who face a combination of strong foreign competition from non-Kyoto countries and high levels of energy use. For the purposes of this paper we identify 'competitiveness-at-risk' sectors that might not be exposed to the full carbon price as the following sectors.

- Aluminium
- Cement
- Forest Processing
- Dairy Processing
- Iron and Steel
- Petroleum Refining
- Methanol Production

We cannot identify significant specific renewables opportunities on-site for Iron & Steel, Petroleum Refining, Aluminium, or Methanol Production, so do not address those further.[35]

In Table 10 we identify where our remaining 'at risk' sectors would have significant renewables opportunities.

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[35] If renewable-offset projects would have been done in 'at-risk' sectors for their intangible benefits (e.g.: public relations value) combined with the carbon charge these opportunities may be missed (though another company may take up the option).

Table 10 Renewables Potential in 'Competitiveness-at-risk' Sectors

		Cement	Forest Processing	Dairy Processing
Electricity	Biomass	On site heat or cogeneration	On site heat or cogeneration	On site heat or cogeneration.
Process Heat	Biomass	Portland Cement: Northland	Significant Opportunities	Some opportunities
	Geothermal		Significant Opportunities	

Biomass: Cement

There are two cement producing facilities at Westport and Portland (near Whangarei). With its proximity to forestry activities, Golden Bay Cement's Portland plant has made progress towards fuel substitution with renewable energy sources, specifically the use of biomass (wood waste) as a potential fuel source.[36] Biomass could also be explored as an option for the Westport plant.

Biomass: Dairy Processing

Some dairy processing sites are near forestry operations, e.g. Kauri in Northland, Anchor at Edgecumbe, Reporoa near Rotorua, Edendale in Southland. While these sites may theoretically have an opportunity to use biomass (wood waste) as a renewable energy source, issues relating to fuel handling and other characteristics of the biomass including the resulting air discharge may limit the feasibility of this opportunity. The dairy industry has been reluctant to take up biomass opportunities as a general rule, although examples have existed in the recent past.

Fonterra has co-generation plants on a number of its sites. Most of these are gas-fuelled gas turbine plants which are, for all practical purposes, unable to be converted to biomass fuelling. Edendale has coal-fired co-generation plant on site. This, through fuel substitution to biomass theoretically provides a renewable opportunity for electricity generation.

Biomass: Forest Processing

A significant level of biomass fuelled energy supply already occurs in the forest processing sector. The uptake of biomass in the forestry sector is likely to be greater than in dairy because:

- the technology is mature for forestry applications;
- operating units are in service at a number of localities;
- the scale of energy from biomass is significant;
- energy from biomass is within the business scope rather than being an add-on;
- part of the increased uptake can be from incremental growth;
- it can be a "continuous" resource in the forestry sector because they control supply, i.e. high level of certainty of resource availability; and

[36] See Golden Bay Cement, 2001.

- increasing cost of landfill prompts use of biomass wood waste as an energy source.

Geothermal: Forest Processing

Some locations have an opportunity to use geothermal-sourced energy for forest processing. This currently takes place at Kawerau, Norske Skog Tasman Plant. It is possible that the use of geothermal could be expanded for forest processing in the Taupo area, along with expanded use at Kawerau.

Where fields like Wairakei are being used for generation of electricity, the value obtained for diverting steam to process heat use can be greater than allowing conversion to electricity.

5.2 MARKET FAILURES

The second set of reasons why efficient renewables options may not be taken up is that some market or regulatory barriers inefficiently limit their potential. Table 11 lists the key areas of potential failure discussed in section 3.

Table 11 Sources of Market Failure and Regulatory Barriers

Invention and Adaptation	• Inability to Capture Benefits • High risks / intangible assets • Thin Skilled-Labour Market
Diffusion	• Information Availability and Diffusion • Increasing Returns / Learning Externalities • Agency problems • High Discount Rates • Market Power • Regulatory Barriers

The following sections combine our knowledge of the renewables options with the ideas about potential reasons why they might fail (even though they are efficient) as summarised in Table 11. In Table 12 we identify the key problems associated with each key option. Some are discussed in more depth below or in the Appendices.

Table 12 Market Failures or Governance Issues that could Block Efficient Use of Renewables Options

Energy Form	Renewable Source	Potential Problems
Electricity	Hydro	• Transmission constraint issues – link to North Island, minimal storage possibilities – e.g. storage in lakes measured in weeks rather than months or years (some of this is explained further in Appendix A1.1), and the fact that the new opportunities are mainly run-of-river mean that hydro provides an uncertain supply and needs to be carefully integrated with the grid and complemented by thermal generation. If the institutional structures for managing the grid are not well designed, useful projects may be unable to succeed. This is discussed further in Section 5.2.2.e. • Market interconnection barriers • Distorted information on costs and benefits • Supply bottlenecks for new projects • Consents - information issues
	Geothermal	• Transmission constraint issues in the Whakamaru area • Electricity market interconnection – rigidities in contracts between retailers and distributors is a problem for small embedded generators • Access to land and resources – uncertainty over ownership of Crown wells and resources (due to Waitangi claims) could lead to delay. • Consents - information issues
	Wind	• Transmission constraint issues – bottlenecks and link to South Island • Reliability – hour to hour fluctuations - creates similar problems to the uncertainty of hydro supply leading to dispatch/governance issues . • Electricity market interconnection – rigidities in contracts between retailers and distributors is a problem for small embedded generators • Information availability and diffusion – lack of information to affected parties • Supply bottlenecks for new projects • Consents - information issues
Process Heat	Biomass	• Biomass seen as waste rather than heat source • Contractual issues around uncertainty in future fuel supply. Some of this is explained further in Appendix A1.4. • Fuel quality. Some of this is explained further in appendix A1.4. • Little knowledge on models • Learning externalities - providers fragmented
	Geothermal	• Electricity market interconnection • Consenting issues • Access to land and resources – uncertainty over ownership of Crown wells and resources (due to Waitangi claims) could lead to delay • Little knowledge on models
Low Grade Heat	Solar water heating (displaces electricity)	• Poorly informed households and builders • Undeveloped market • Poor quality control

		• Lack of service provision network
	Geothermal	• Poorly informed households and builders • Lack of information on low temperature resources • Undeveloped market – previously hurt by caution and uncertainty as a result of government intervention (forced bore closure) in Rotorua area • Poor quality control • Lack of service provision network
Upcoming Technologies	Wave / Marine current High-temperature Solar (electricity and process heat) Photovoltaics Biofuel for transport	• Inability to capture benefits • High risks / intangible assets

5.2.1 Invention and Adaptation

5.2.1.a Inability to Capture Benefits

New Zealand cannot internationally commercialise inventions easily. This is primarily an issue of scale / market size. Any New Zealand invention in the renewable technology field being commercialised in New Zealand is likely to have to compete with alternative products that are, or will be available on world markets. As an example of the focus that New Zealand has in the renewables area, New Zealand consultants are internationally recognised as having very high levels of expertise in the geothermal technology area, we have not however retained control of the intellectual property we have created. The many inventions, both in terms of hardware and geoscience, have been published and freely made available to the international community. Patenting has been the exception. Commercial research has been undertaken on a confidential basis, but for various reasons, few of the leads have been followed through to product commercialisation.

It is worth noting that the Foundation for Research Science and Technology has recognised this weakness in New Zealand research, and is now putting increased emphasis on appropriate capture of Intellectual Property benefits.

5.2.1.b High Risks / Intangible Assets

The renewable energy industry is characterised by the large number of small and medium sized companies that are significant players but do not have sufficient access to finance to undertake research or even to seek out information that would provide knowledge to their staff and thus encourage adaptation of existing knowledge. These companies often do not have the finance to adequately invest in R & D. They are currently grouping to pool resources by forming industry associations to jointly undertake research, promotion and advocacy. Their collective financial base is still too small compared to the market transformation and development that is necessary to put the industry on a firm footing.

Government's funding emphasis has been on pure research rather than applied research. There has been a shift to more applied research. Research that has been funded by government has usually been captured by researchers; output from research programmes does not flow to users other than through the researcher. The Foundation for Research, Science and Technology research programmes produce few research outcomes or reports that are made available to the renewables market players because it is considered to be the intellectual property of the researchers. This means that valuable research results that could have wider application are not made available to those most able to make use of it, i.e. the investors and main market players.

5.2.1.c Thin Skilled-Labour Market

The scarcity of people with skills specific to renewables means that even if renewables became more profitable the industry could not rapidly expand to take advantage of new opportunities. It is also difficult for the industry to grow rapidly for other reasons but they may be addressed with adequate financial incentive.

While opinions may differ on the availability and flexibility of manufacturing and installation resources we might expect national and international supply bottlenecks (therefore much higher costs in the short term) if we try to do a lot of projects quickly. This problem would be exacerbated if New Zealand were undertaking these projects using a technology that is being taken up worldwide. Wind is an example of a technology that has an increasing international demand and is a significant contributor to renewables technology in a large number of countries. It is likely to be the technology most affected by skill shortages and international capacity constraints.

While New Zealand has some experience in hydro, that expertise is rapidly falling away or moving offshore. This leads to a reduced capability to build a significant amount of new hydro, a technology characterised by long lead times, in a tight timeframe. The local skill base also lacks depth at the resource and project assessment stage of projects.

The cost of growth to smaller industry players, such as for solar water heating manufacturers and installers, can limit growth if they want to maintain quality standards. Training of new staff can be limited by the availability of supervisory staff.

The standards for performance in the solar hot water industry are currently uncertain; accreditation procedures are needed to give customers the necessary assurance. We need skilled and qualified installers so that customers can be assured that the systems purchased will perform to standard. Few current education providers can bring renewable market players up to appropriate standards. The solar industry is still too fragmented to organise this themselves.

5.2.2 Diffusion / Adoption

5.2.2.a Information Availability and Diffusion

Except for hydro and geothermal, the renewables market is relatively undeveloped and faces all the issues of any startup industry. The historically fragmented players in solar, wind and biomass have only recently formed industry associations to organise their group requirements and to build economies of scale for undertaking research and collect information for themselves and their potential customers.

Quality information is not available to all industry players. As a result, barriers and constraints arise when the parties interact. For example when wind farm developers seek resource consents the potentially affected neighbouring communities might react adversely because they lack full information on potential effects. The developer acting alone may not have the financial resources to obtain and disseminate the information to relevant parties. Miscommunication can result.

Public perceptions of renewable projects are formed from limited experience because there are few role model projects and limited case studies. For the developers there are few good-practice guides.

Little new information on renewable resources and the technologies has been introduced into the public arena since the early 1980's when Government departments were the primary energy developers. Since then New Zealand has largely been living on the knowledge bank created in that period. This has resulted in the data aging and in some cases now being well out of date. Some large private companies or State Owned Enterprises have continued to undertake research but this is not readily available to the wider energy market.

The cost of information can be a major barrier to small and medium market players as previous government agencies no longer have libraries from which information can be borrowed and the cost of periodicals, technical information, conference papers mean that consultants, investors and other industry players no longer have access to the up-to-date information from overseas that could encourage adoption of the best of knowledge. There are few avenues for funding small information dissemination projects, case studies or good practice projects that would speed the adoption of existing knowledge.

5.2.2.b Increasing Returns

Learning Externalities

In an area where technology is relatively immature or the technology has not been applied in New Zealand before there will be high costs and risks associated with the first project using that technology. If the project is done by a company that plans to create many more of the same project they can absorb these initial costs as part of their long-term investment. If however, in the short run there is only the opportunity for one or a small number of these projects or the company that is interested in doing it is only able to finance one, the project may not go ahead even if it would bring social advantages through the learning it generates.

In some areas traditional ways of thinking still dominate, as there has been little new blood into the industry. While technologies such as hydro are very mature, new ways of adapting the technology might not be looked for. A counter-example to this is the Meridian Energy Aqua project, which introduces modular design, shared use of the water resource with irrigation, and extracts only the economic quantity of water from the river, rather than attempting to maximise output or utilisation of the resource. This is a new way of looking at an old technology.

Renewables comprise some "mainstreamed" technologies e.g. hydro, wind, geothermal, and others including high energy solar, photovoltaics, and biomass. The disparate and fragmented nature of the proponents and organisations involved in these technologies makes renewable technologies learning an issue. Because of this, the adoption process may start very slowly or not at all as a result of perceptions (in some cases the reality) of low returns on early projects. While some of the "learning" will be evident to those in the industry, New Zealand's competitive electricity generation market will probably result in a reduced transfer of learning from the ideal. Strong intra- and inter- technology associations should assist in increasing the learning.

5.2.2.c Agency Problems

Effective adoption of renewables may require that business establish or re-define relationships between parts of their business that are usually unrelated. Sometimes renewable projects are very small projects that may not get the management attention necessary to provide a focus for successful implementation. An example where these agency issues were overcome, leading to a very successful outcome using renewable biomass, was at Norske Skog Tasman where the Tasman mill halved the amount of fuel oil used in one of its boilers and substituted more bark and wood waste.[37]

Bioenergy often has significant problems within a firm where heat users (kiln operators) may communicate with fuel suppliers (sawmill or processing plant operators), and the bioenergy plant operators. Thermal plant operates most efficiency on homogenous fuel and at steady operating states. Variations and fluctuations in these can stress the plant or make it difficult for the plant to meet heat load requirements.

Bioenergy facilities based on fuel from wood processing plant also suffer from insecurity of fuel supply. Plant will be designed and built on specific assumptions of fuel quantities and qualities. Over a 20-30 year economic life, the processing plant providing fuel will have significant changes in the mix of wood waste available for fuel. For example, several years ago bark was a problem waste but on many sites today it is sold for non-energy uses and values and is no longer available as a biomass fuel. The uncertainties of biomass fuel supply provide significant business risk to bioenergy facility investors. These problems can be easily resolved if the supplier and user are in the same company but are much more difficult to resolve between companies.

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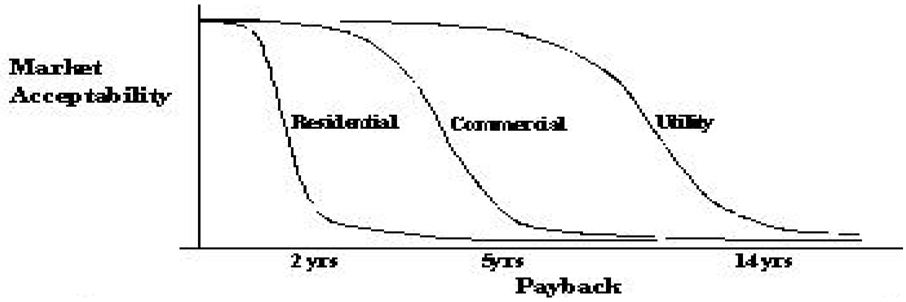
[37] Energy Wise News - Issue 71, June 2001, EECA. The barriers were the lack of awareness of the needs of the boiler department for dry fuel, and the wood processing department's need to remove the wood waste. Once these mutual needs were recognised, the value of the operation could be enhanced by woodwaste stockpile management.

5.2.2.d High Discount Rates

The market players have a range of expectations about financial returns from investments; they evaluate opportunities with different discount rates. This is demonstrated by the required payback periods for potential investors and is highlighted in the following graph.



Residential investors normally require a payback of two years or less to consider an investment in an energy product. Commercial investors with a greenfield opportunity look for about a five-year payback. For retrofitted energy products, commercial investors often require a payback very similar to the residential requirement of two years. Utilities have longer horizons as they usually have a wider portfolio of investments many of which have long economic lives and are backed by potentially long term contracts.

The large players who could get into the renewables market are focused on cost of supply considerations and growing new business areas is not their core business. The renewables industry is still principally driven by enthusiasts who have lower financial return targets and lower risk profiles.

Small companies are often innovative fast followers because they are able to make decisions without significant consultation with other parties within the company, and directors may have a more direct handle on the pulse of the business. On the other hand the larger companies should be in a position where they can manage their risk portfolio much easier and better than a small company. The smaller companies often do not do such rigorous analysis of potential projects and may be driven by other objectives, particularly if they have owner managers with specific personal interests. The lack of sound information on the lifecycle costs, risks and benefits of renewable projects does not encourage rigorous analysis or informed decision making.

The size, scale and focus of renewable project promoters and their projects can vary quite significantly. This leads to a spread of discount rates with, typically, a higher discount rate applied to small organisations. In general the larger, longer term investors for whom energy / electricity assets are the bulk of the business will have discount rates / payback periods that reflect the long-term stability of the business. Where an investment is made by an organisation that has, overall, a much shorter payback period or higher rate of return requirement than an energy / electricity business, investment in an energy opportunity might not occur. In some of these situations an energy company may enter into commercial arrangements with the "host" and pick up the project as it can meet the energy company's financial criteria.

The process of informing the public about energy issues may have the further effect of pushing out the required payback periods for the different categories above.

5.2.2.e Market Power

As with most industries, the focus of any rules, while not necessarily disregarding the small participants, is generally to meet the needs of those who have the larger share of the market. The smaller companies may face inappropriate and inefficient rules if large companies set them. Market power may hinder resolution of the electricity network issues discussed above.

Electricity Market Structure and Interconnections

There are and will be many small scale renewable generation projects. The contract set-up and transaction costs, as well as a lack of market power mean that the value of this energy is discounted, in some case significantly so, leading to higher hurdles for potential investments that are technically efficient projects. There are additional factors where this generation is exported and sold beyond a Transpower grid exit point (GXP) as the (network) Use of System agreements are not necessarily set up to deal efficiently with two-way flows, especially when they are small.

The process that a small renewables developer must follow in order to find a buyer for the facility output is unclear. The role of incumbent energy suppliers is uncertain and in many cases even finding an energy company that is prepared to negotiate a sale contract can be time-consuming and frustrating.

Small players have a place in the market but they sometimes lack flexibility, diversity, or other features that provide the service the market expects and is attuned to. One example is where a company has one run-of-river hydro power station. This company will be able to guarantee generation equivalent to the output when the river is at its lowest flow, but for most of the time will have an uncertain quantity of ‘surplus’ generation; it has to find a customer who is willing to take this ‘surplus’ as it comes, but not rely on it. This is likely to be another generating company, or perhaps a retail company. Either of these is likely to discount the value of the energy because of the need to generate any shortfall or purchase it from another generating company.

For photovoltaics there is the question of net metering vs. the need to install a separate meter for export from the site. The cost of an additional meter can be prohibitive and can make installation of photovoltaic equipment uneconomic.

If the renewable generator is able to enter into a contract for sale of electricity another problem is that there is no clear mechanism for dispatch where uncertain export generation features. The facility may be embedded with only a small amount of electricity exported to the electricity network from time to time (say 1MW) but the Network Operator will consider them to be a generator operating at their full capacity (e.g. 39MW in the case of Kinleith cogeneration plant) in which case they need to bid in their generation two hours ahead. This may be a significant impost for a facility owner and a barrier to efficient operation.

Safety issues may arise with embedded generation and these require additional resources to manage so that a safe working environment is assured. This is also a major issue for photovoltaics as a dwelling owner may inject electricity into the street lines and cause a safety problem for lines maintenance staff who may be under the impression that they have isolated a line from electricity flow to undertake the maintenance.

The interconnection standards that are necessary may vary throughout the country and it may be difficult when dealing with a local lines company to establish a contract for connection.

Electricity Governance Policy

A Government Policy Statement for the electricity industry was issued in December 2000 following consideration of the recommendations of The Ministerial Inquiry into the Electricity Industry. It supplanted previous statements of government policy on electricity. Attachments to the statement deal with objectives and principles for the provision of transmission services, and management of electricity supply risk ("dry-year risk"). In February 2002 the Government revised the Policy Statement following a review of the way the electricity system functioned over the winter of 2001.

In the Government policy, the Electricity Governance Board (EGB) is to ensure that rules are developed to "ensure that the use of new electricity technologies and renewables, and distributed generation, is facilitated and that the generators using these approaches do not face barriers". The Governance Board has established a Transport Working Group to work on the terms and conditions of distributed generation including that of renewable energy.

While the Government has a clearly stated policy that the EGB is responsible for resolving these issues and establishing procedures that assist renewable energy projects, there has been little evidence of action to date. The EGB does not even include a target date for resolution of this issue.

Transmission Constraint Issues

The large renewable energy companies are actively involved with the new governance arrangements and should be in a position where they can influence the resolution of transmission constraint issues with a flow on to all renewable investors. No representatives of small renewable energy developers are involved with the Transport Working Group. The composition of the Working Group is dominated by representatives of large generators or the lines companies. To date the outcomes of the Working Group have indicated a bias toward large companies with large renewable projects. The EGB has not consulted the broader renewables industry very much on the barriers and issues, and in particular on the interconnection rules and standards.

5.2.2.f Regulatory Barriers

Issues relating to the requirements associated with the connection and operation of grid connected electricity generating plant, while not aimed at any particular technology or group of technologies, may affect plant that is using renewable resources. The current electricity market and connection rules, set by industry bodies, are difficult to understand and appear to impose significant transaction barriers to new parties connecting small electricity generating plant to the electricity supply network. This may be in terms of sale of electricity, parties to deal with, interconnection requirements, dispatch requirements and reporting requirements.

The government intends the electricity industry to be self-regulating to a large extent. The industry is in the process of setting operating rules for the Electricity Governance Board that meet government policy statements. A draft has been submitted to the Commerce Commission who will call for further submissions, arrange an industry conference and eventually make a final determination (possibly in July 2002). The Commerce Commission has been slow in dealing with this documentation because of the extent of its other commitments.

With the potential for dwelling owners and others to install photovoltaics and other electricity generating equipment there are now a number of safety issues that will need to be addressed. The current transmission line management procedures were not designed for injection of electricity from a number of individual sources and lines maintenance staff are at risk of such injection if uncontrolled.

The rules on metering of electricity supply from dwellings does not allow for the situation whereby a photovoltaic owner exports electricity from their site into the network. This raises issues with regard to net metering.

The resolution of these issues will be difficult if the Electricity Governance Board is controlled by the large corporates and the renewables industry is unable to influence the rules being established.

At least one regulatory provision is specifically focussed on renewable energy resources. It is a section in the Electricity Industry Reform Act 1998 as amended in 2001 and authorises the electricity "lines" companies (previously restricted in involvement in generating activities) to invest in "new renewable" distributed electricity generation facilities. This allows line companies to invest in renewables along similar lines as other investors. As there are significant benefits to lines companies from investing in distributed electricity generation to improve the quality and quantity of supply, and to relieve their own distribution constraints, these are potentially large investors in renewable projects. The lines companies are likely to provide a kick-start to the renewables industry if they can be encouraged to use renewables to solve transmission/distribution issues. Early role models and case studies will assist this process. In addition, if the lines companies are also involved in renewables projects they will think about the transmission needs of renewable energy when they plan new investments in lines. This is an example of regulatory success.

Access to land and resources

Renewables are invariably location-specific. For access to hydro, wind and geothermal resources the developer needs to come to an arrangement with the landowner. The landowner effectively controls access to the site or sites where the resource is located. A hydro project will usually involve a multiplicity of landowners.

Any arrangements with landowners will be of a commercial nature i.e. both landowner and developer are willing parties to any agreement. This may result in an "ideal" renewable resource not being utilised. Optimal development will not necessarily take place, but this is just a feature of the market. Developers will invariably seek out the most economically efficient resource, with denial of that resource leading to a less economic resource as the remaining "best" choice. Other than an educational involvement, however, it is difficult to envisage any role that Government might take to facilitate or enhance access to renewable resources in a market environment.

For the geothermal resource, a developer also needs to obtain permission from the Crown (who owns the resource) to access the geothermal resource. A number of Treaty of Waitangi claims are associated with resources, especially the geothermal resource, or the surrounding land. The Crown also has an involvement in the hydro area as the edge and bed of a water body is usually under Crown ownership. In some cases the local tangata whenua are the owner of (or at least have strong kaitiakitanga interests in) these areas. Thus they must authorise any changes in ownership or activities associated with these areas.

Generally access to land and resources are simple 'free market' issues where government interference may result in different or greater economic inefficiencies. There are occasions, however, where government may hold residual assets (e.g. Crown geothermal wells) or where government can accelerate resolution of ownership issues (e.g. where there are claims before the Waitangi Tribunal). In these cases, resolution of issues is within Crown control and can be accelerated to allow the market to function with clarity of position.

Consenting Issues

The Resource Management Act controls activities on land, and that involve water and / or discharges to air. These requirements are specified in the New Zealand Coastal Policy Statement, Regional Policy Statements, Regional and District Plans.

The rules in the relevant District and Regional Plans effectively determine whether the activity will be a permitted, controlled, discretionary, non-complying or prohibited use, with the likelihood of consent being granted ranging from "already in place" for a permitted use to "no consent possible" for a prohibited use.

Because of the effects-based philosophy of the Resource Management legislation, an activity would not usually be described as either a 'renewable' or 'energy' activity. This may not be the situation for geothermal as the following extracts (with some qualifiers) from the Waikato Regional Plan's Geothermal Module[38] identify:

> *"Take or use of geothermal water, or heat or energy from geothermal water or the material surrounding any geothermal water, within a Protected 1 Geothermal System, or*

[38] Proposed Waikato Regional Plan as Amended by Decisions (February 2002)

Discharge of water and associated naturally occurring contaminants into water, or onto or into land, arising from the taking of geothermal water from within a Protected 1 Geothermal System;
that is undertaken for the purpose of scientific investigation or enhancement of the Protected 1 Geothermal System or associated surface features is a ***non-complying activity*** *(requiring resource consents)" (Environment Waikato emphasis)*

and that the:

"Take of geothermal water, or heat or energy from geothermal water or the material surrounding any geothermal water, within a Protected 1 Geothermal System, or
Discharge of water and associated contaminants into water, or onto or into land, arising from the taking of geothermal water from within a Protected 1 Geothermal System;
that was not lawfully established or authorised prior to the date of notification of this Plan is a ***prohibited activity*** *for which no resource consent shall be granted" (Environment Waikato emphasis)*

More often, the rules address the effects of the activity e.g. limits on noise levels, visual aspects, limits on discharges to water or air of contaminants, taking of water reducing the life-supporting capability or some other value associated with a river.

Renewable energy projects often have a potentially high effect on neighbouring communities. The project developers have a more significant interaction with the requirements of the Resource Management Act than for many other industrial investments. Because of this high profile there is greater risk that having done all the investigations, established contracts for resources and outputs, prepared conceptual designs, provide information on the potential effects, and liased with the neighbouring community, the project will fail at the end of the process.

Renewable energy opportunities use resources that are likely to have other values, or require technology that means a new facility is built in the area. Along with the scientific parameters of any renewable energy activity, what is important are the perceptions of the public, particularly those who are affected. For those opportunities that require a resource consent to be notified, consultation with the public, including those who are affected, can become a significant, costly and emotive part of the process of gaining resource consents with suitable conditions. Good information is a strong determinant of the effectiveness of the consultation process. This is costly and time consuming to prepare.

Renewable projects such as wind, and hydro also must meet extensive information requirements to obtain resource consents. These invariably involve extensive and costly investigations both of the resource and of the potential effects. This means that only large companies, with substantial funds to commit to projects, can consider renewable projects that have no certainty of ever proceeding. A small investor cannot contemplate such projects.

The community issues can be distorted when outsiders bring other agendas to the resource consent process. Wind farms, geothermal, and hydro projects have suffered extensively when opposition to a project is captured by a few individuals who are adept at using the media to influence the potentially affected community.

Some renewable projects are “small”. For example, a hydro-electricity project may be 20 MW in comparison with Benmore at 540 MW. If the same consenting information is required for both, this can be a very significant cost impost on a small project. While there is a scale difference between the projects the issues of effects are the same and have to be investigated and addressed.

Fixed costs associated with obtaining consents can act as a barrier or deterrent to investment in renewable energy opportunities. Some of these “fixed” costs arise out of the need to produce information that in all likelihood is largely reinventing a wheel. Another developer may well have already carried out analysis on a different, but similar, opportunity. Credible information on common issues (e.g. a New Zealand Standard for noise levels from wind turbines now exists) would lower some of the fixed costs of applications, as well as reducing the uncertainty of gaining acceptable resource consent. Inconsistency in and the variable quality of information available to public and interested parties is a problem.

The term of a resource consent and the ability for review of the consent conditions can be a barrier to projects. While it is appropriate that projects should meet community expectations of the time, this is a major risk that investors take into account. If the term of a consent is less than the economic life of the project, investors will expect higher returns for the risk they are taking. They might manage that risk by entering into only those projects with pay back periods within the consent term.

A review of a consent will impose substantial direct costs on a facility owner and any changes in the consent conditions arising from a review have to be allowed for. Because these are unknown when the investment decision is being made the investor will face more risk than if they had certainty of outcome for the period of their investment.

In summary, the inefficiencies in investment stemming from regulatory barriers in all their forms often arise because of unnecessary uncertainties in the investment climate. Investment does not proceed as a result of the risk assessment. With a more certain investment climate, investments are more likely to proceed.

6 POTENTIAL GOVERNMENT INTERVENTIONS

This section takes the conclusions from section 5 and, where there are areas with significant shortcomings in dynamic efficiency, we outline possible policy responses that could be considered to address these. We want to stress that we see this as a purely qualitative exercise. The work is not designed to give full analysis of any specific policy, renewables source or sectoral application. We address three major areas, the effects of the form of revenue recycling, policies to supplement NGAs in 'at-risk' sectors and policies to address ‘market failures’ in all sectors. Finally, we look at the effects of early action.

6.1 FORM OF REVENUE RECYCLING

The recycling of carbon charge revenue through tax cuts would have an effect on the renewables sector (as in all other sectors). Revenue recycling aims to reduce distortionary taxes to increase the overall efficiency of the tax system. In this section we are only concerned with tax cuts that would improve the efficiency of the tax system and the incidental effects they might have on the renewables sector. In section 6.3.5.a we discuss the possibility of using tax cuts directed at the renewables industry with the intention of actively promoting renewables.

Taxes that potentially could be cut to improve the efficiency of the tax system include company tax, personal income tax, GST, and petrol taxes. If the aim of revenue recycling is efficiency of the tax system, the effects on renewables should not affect the decision of how to recycle.

Tax cuts have both absolute benefits to a sector and can also provide them with a larger benefit relative to their competitors. For our purposes we are primarily interested in benefits relative to those received by fossil-fuel energy investors because we are interested in the impact on renewables investment. Renewables will benefit most from cuts that reduce up-front costs of investment or lower costs of capital. Renewables tend to involve high capital costs and low running costs.

Companies generally prefer a cut in company tax (accompanied by a cut in the top personal tax rate so that shareholders benefit). This will however affect all energy companies and may provide more benefit to the larger firms involved in energy production from fossil fuel than to renewable producers. Income tax cuts and GST cuts mostly benefit labour and hence labour-intensive industries. Because renewables are capital-intensive these tax cuts are probably less valuable to them. A petrol tax cut would not provide any obvious benefit. Transport costs are not a major component of the costs of renewables. It could bias against the efficient use of bio-fuels if the tax cut was on refined petroleum rather than fuel at the pump.

An optimal tax system allows actual depreciation as an expense. Increasing provision for accelerated depreciation above the level of actual depreciation would create a subsidy for capital investment relative to other corporate activities and thus would not be a candidate for efficiency-enhancing revenue recycling. Unless we believe that capital investment is overtaxed relative to other things, this would increase distortions.

Similarly tax cuts targeted at the renewables sector (e.g. Green GST) would probably increase the distortions in the tax system because it would increase the tax burden on other activities by effectively narrowing the tax base. These would need to be justified as externality correcting taxes. In the context of climate policy, assuming that there is a carbon charge, this charge already corrects the externality. While we know that the optimal tax system would not tax all goods equally, we do not have any evidence that renewable energy is the product that would optimally be taxed at a lower rate.[39] A different role for differential taxes, where they aim to compensate for 'market failures', is considered below.

Overall, at a first cut it is not clear that the form of revenue recycling will significantly affect choices between renewable and fossil-fuel energy. A corporate tax cut would probably benefit renewable companies most out of the possibilities but it would benefit their competitors at the same time.

6.2 OPPORTUNITIES IN COMPETITIVENESS-AT-RISK SECTORS

6.2.1 Build Renewables into Negotiated Greenhouse Agreements

Deliberate renewables policy could be built into NGAs in at least four ways. The aim would be to induce 'at-risk' sectors to consider socially efficient renewables options even though they may not face the carbon price.

The first, lowest intervention approach would be to require that firms subject to NGAs explore renewables options, especially in those sectors where likely opportunities have been identified. Some renewable energy opportunities may be economically feasible at current fossil fuel energy prices but would not happen unless prices were higher because of non-price barriers. If the NGAs can lower these non-price barriers, equivalent levels of uptake might be achieved.

A second approach, which we would not recommend, would be to require, as part of the NGA, that firms invest in renewables if studies suggest that the hurdle rate would have been high enough with the carbon charge. This is risky because it would depend on the accuracy of outside studies, which generally are indicative but not totally accurate assessments of the feasibility of opportunities. They may miss company-specific issues that make investments in renewables more or less attractive. This policy is likely to force companies to make investments that are not in fact efficient. It will also tend to miss efficient options because firms will not have an incentive to reveal the existence of opportunities analysts do not spot. The arguments against this are very similar to those against rigid technology standards for emissions control.

The third approach would use the type of information that would have been used in the second approach but is less prescriptive. Government negotiators would set targets for CO_2 efficiency within the NGA taking into account the renewable possibilities identified by outside studies. They would not however require renewables or any specific project. It would simply be another way of deciding whether extra pressure could be put on a sector to lower their CO_2 emissions.

A fourth approach, discussed further below, is to allow firms that enter into NGAs to bid in to the projects mechanism.

[39] Goods would optimally be taxed at different rates because they have different demand elasticities and cross elasticities as well as different distributional effects. We normally tax all at the same rate because it is extremely complex to estimate optimal rates.

6.2.2 Projects

Projects are part of the assumed climate policy described in section 2.1. For the purposes of this report we have assumed that firms entering into NGAs would be able to access the projects mechanism. These assumptions may or may not be consistent with the Government's final decisions on climate change policy.

Here we seek to clarify what projects might be most useful for encouraging efficient renewables uptake that might not otherwise occur. We will discuss the design of 'hard projects'. These involve investments that lead to identifiable CO_2 reductions either through changes in plant and equipment that reduce emissions directly or through investments in renewable energy generation. 'Soft projects' are discussed in Section 6.3.

The main issue in designing projects is specifying the 'baseline' or the level against which emission reductions are rewarded. The reason some sectors may face NGAs rather than the full carbon price is that the Government is concerned about reductions in output and employment in these sectors. Thus projects need to be designed to be consistent with this aim. This suggests that projects should not affect the marginal cost of production but should be focused on reducing emissions rates per unit of output.[40]

If the NGA defines a level of expected CO_2 emissions per unit of output as well as clearly defining how that output would be measured, a project could be rewarded for reductions below this level. The reward could either be in the form of credits that can be sold (they could be AAUs which are internationally tradeable), or as cash directly from government in the form of a reverse carbon charge. The level of the reverse carbon charge could be the same as the carbon charge elsewhere in the economy or set independently.

An alternative, that could be used where the NGA defines targets only loosely, would be to assume that all renewable energy directly offsets fossil-fuel energy and calculate the carbon reductions in that way.

Suppose a firm is processing dairy products and currently uses coal-based energy. Its NGA could define total dairy output as some weighted basket of different dairy products produced. Then a target could be set for CO_2 emissions per unit of dairy output. For example suppose output is 1,000 and target emissions per unit output are 10. The firm could respond to this target by reducing energy use per unit of dairy output or by substituting renewable energy for coal-based energy. The target might be set below their current rate of emissions but any gains beyond the target could be rewarded. If current emissions per unit are 12 the firm needs to make internal changes with no reward to meet the target. If it can go beyond this by changing part of its energy source to electricity from wind energy so that emissions fall to 5 per unit output the firm saves 5,000 units of emissions and could receive 5,000 emissions

[40] This is not generally an efficient form of regulation because it over emphasises reductions though technology rather than allowing efficient emission reductions through output reductions also. In this case it might be justified either because of temporary competitive disadvantage or because of socially excessive short-term adjustment costs.

credits. These would be worth $20 each at the low-level carbon charge, or $100,000. This would be the reward for the project.

We would not want to design projects where gains are measured against a fixed baseline of total emissions. This would make the opportunity cost of output, and hence the marginal cost of production, the same as it would have been if the sector had not been treated as 'at risk'. This policy would generate the negative output and employment effects the government aims to avoid.

Having projects where the company is rewarded for lower emissions rates through use of renewable energy would not alter their output decisions. Neither would it bias their demand for renewable energy unduly as long as the reward per unit of renewable energy was the same as the carbon charge (or higher energy cost) a not 'at risk' firm would avoid by using renewable energy. The projects would simply level the playing field for renewable energy so that in the choice of energy source 'at risk' firms would behave as though they faced the carbon price.

If the dairy factory discussed above faced the carbon charge, it could reduce its use of fossil-fuel energy by moving to wind power and reduce emissions by 5 per unit of output. This would save them $100 in carbon charge per unit of output or $100,000 if their output were unchanged by the carbon charge. Thus their decision about a renewable investment is essentially the same however they are classified under climate policy.

These projects can be seen as an alternative way to meet the targets the government sets in the NGA (for example they could replace use of best-available-technology) or a way to create incentives for additional reductions beyond the NGA. Their role is simply a matter of degree and how difficult the NGA targets are to achieve.

6.2.2.a Funding of Projects Through $5 per Tonne Carbon Charge

In a perfect world where projects were easy to organise, emissions could be easily monitored and NGAs defined clear baselines, a project-based system would be equivalent to an emissions trading system where companies with NGAs are sellers. If the amount of funds available for projects is fixed, two problems could arise. First, if there were too few funds, not all worthwhile projects could be done and some type of rationing system would be required. It would be hard to pick the most efficient projects so an average mix of projects would probably be approved and some good projects would miss out. Second, if there were too many funds, if projects are well designed there will be insufficient investment in projects. Without increasing the subsidy beyond the carbon charge level applied elsewhere in the economy, the funds will not be spent.

In the real world, projects are difficult to organise, emissions are hard to monitor at a plant or company level and NGAs are likely to be defined at least partly in qualitative terms which are hard to translate into quantitative emissions-per-unit-output terms. This means that many projects will not be done because the hassle of doing them will exceed the potential gains. It also means that projects will tend to be under or over rewarded relative to the carbon charge. With a fixed pool of funds it will be tempting to spend all the funds (and difficult to tell if you should not). If there are insufficient projects that would be efficient at the level of the carbon charge (or international price), inefficient ones will tend to be funded. With a low level of funds the process will become highly discretionary.

If the at-risk industries are those we define in section 5 and only major emitters are exempt from the carbon charge, then currently roughly 10 M tonnes of CO_2 come from companies in at-risk sectors relative to 35 M tonnes of total emissions.[41] Simply using these numbers as an illustration, a $5 per tonne carbon charge would raise $125m. If projects are able to reduce emissions in 'at risk' sectors by 10%, then if all these funds were used to reward those reductions (1 M tonnes) they would be paid $125 per tonne of reduction. This is clearly a case of having too high a level of project funds given that total carbon charges are expected to be between $20 and $40 per tonne. The funds come from all emissions in not-at-risk sectors but are used to fund only changes in emissions in 'at-risk' sectors.

An alternative form of project is a 'soft project' where the results are not directly measured as emissions reductions. These are not a direct price instrument but are primarily aimed at non-price barriers to energy efficiency and renewables uptake. We discuss their possible roles below.

6.3 POLICIES TO ADDRESS 'MARKET FAILURES'

Some justifications for government action could arise even in sectors where all players are facing the world price. These actions would be designed to complement government's climate policy rather than substitute for it (as the 'hard projects' were above).

Several market failure issues come out of section 5. These suggest possible roles for government action. Here we discuss five areas, which deserve further scrutiny. We also discuss some general policies to promote renewables including tax breaks that are understandably popular among renewables advocates but that we do not feel are justified purely on grounds of enhancing dynamic efficiency in response to climate policy.

6.3.1 Adaptation / Early Adoption Assistance

Policies here should be designed to address three problems:

- First, difficulties in adaptation research that arise because it is difficult to capture all the benefits from research or because it is difficult for the active players in the renewables market to obtain financing for this research.
- Second, a thin labour market with limited skill base that makes any research and pilot projects difficult and particularly would hinder rapid uptake of renewables technology in the case of a rapid rise in carbon prices.
- Third, problems with information dissemination that primarily arise because the industry is fragmented and because the information needs to be disseminated to a very wide range of players in different sectors.

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[41] These numbers are taken from Table A4.2 (in Appendices) and an assumption of 20% growth in CO_2 emissions since 1990 from a base of 29m tonnes.

The policies should aim to increase our ability to respond quickly if we need to expand renewables capacity and to speed the overall adoption process where it is inefficiently slow in its early stages.

Given these goals, options to assist adaptation/early adoption would include:

- Creating a contestable fund;
- Use of industry associations;
- Use of renewable energy within government;
- Government information provision; and
- Facilitation of training.

6.3.1.a Contestable Fund

A contestable fund could be established to provide access to finance for applied projects that do not fit the criteria of the FoRST programme.

The funds would be available only for projects with the following characteristics:

- They create significant New Zealand-specific knowledge; and / or
- They provide for effective dissemination of knowledge; and /or
- They build local skills and / or utilise international skills during a period where they are not in such intensive demand; and
- They must focus on renewables options that have the potential for significant utilisation within New Zealand in the foreseeable future (for example those we have identified).

Some of the projects might be focussed on long-term opportunities such as hydrogen and wind. These will tend to concentrate on knowledge creation and dissemination.

The projects should be co-financed with the private sector as much as possible. This will be more possible for demonstration projects and much less so for more research focussed projects. The private financing should not compromise the dissemination of information about the project although we recognise that intellectual property issues will arise. Demonstration projects should be unique rather than repetition of projects already done elsewhere. This should not be seen as a fund for promoting renewables in general but only for addressing these very specific concerns.

6.3.1.b Use of Industry Associations

Another approach, which could be part of the administration of the contestable fund, would be to provide financial support through industry associations. These groups would help to make decisions on how best to use the funds. Various associations are becoming active in the industry now (solar, photovoltaics, wind, geothermal...). The degree of association responsibility could range from the associations acting as advisors to a government agency through to government completely devolving management of the funds to the associations.

The level of funding to the associations could be dependent on assessment of the stage of maturity of the relevant technologies and the industry. As the industry becomes well established, the financial support could be removed and they could levy their own members to fund research, create certification programs and disseminate information.

If we use industry associations as a mechanism to direct funding to address market failures in the renewable energy industry we would receive the following benefits:

- The industry as a whole would be engaged in the transformation;
- Costs of learning, information dissemination etc. could be spread across the sector as the industry evolves;
- The appropriate work programme would be identified through grass roots participation;
- Researcher capture would be avoided;
- Research priorities would be driven by industry needs;
- Expenditures would be prioritised;
- Communication from leaders to followers would be enhanced;
- Small players would be able to access information at low cost; and
- Initial government assistance could fade out but leave industry able to continue the work.

6.3.1.c Use of Renewable Energy within Government

Government is a major player in the economy. If all branches of government search for appropriate uses of renewable energy within their own operations this could help to provide the critical mass the industry needs in some areas. Where the initial adoptions of technologies by government would not be cost saving, they would need to have access to funds (from existing budgets or supplementary funds) to cover these costs. Encouraging effective use of renewables within government would require information dissemination and would face many of the same issues such as agency problems as in the private sector. It would be important that these projects are made on either sound commercial grounds or explicitly to achieve the goals listed for the contestable fund above. Renewables investments should not be simply made because they are fashionable. Government is at greater risk than private companies of over-investment or poor investment because of the different financial incentives they face.

6.3.1.d Government Information Provision

Another direct role for government could be in information provision. Government may be able to provide information that will be seen as credible by the public, industry and local authorities and to provide the infrastructure for collating and disseminating information. The provision of information would need to be concentrated in areas where renewable energy opportunities are significant and where the industry does not currently have the capacity to provide this information efficiently. This could be a transitional arrangement with industry gradually taking over this role.

6.3.1.e Training

If we are concerned about the ability of the renewable energy industry to grow rapidly in response to rapid changes in carbon charges, we might want to actively build core capacity so that there are critical people in place and a core of skilled people who are able to train others and rapidly expand the industry. This could be done with formal training through universities and polytechnics if that is needed, e.g. having components on renewable energy use in engineering schools, architecture schools and building qualifications. It could involve training junior people through apprenticeships of some description.

At a more senior level, closer interaction with the international renewable energy community could be valuable. Either having visitors to New Zealand from key international companies or facilitating extended 'sabbaticals' for key New Zealand staff to work in international energy companies or laboratories could be an effective way to transfer skills and build networks that we can draw on later. Implementing this type of policy would require clear identification of the key skills needed to effectively invest in major renewables options.

6.3.2 Electricity Market Structure and Interconnections

The Government has explicitly recognised that a number of interconnection and regulatory rules currently affect the sale and delivery of generation from small-distributed generators, many of which are likely to be from renewable energy. To date little evidence suggests that the renewables industry has been involved in the development of the standards and rules that will govern the interactions between renewable energy generators and other market players – both for sale and delivery. To ensure that the new rules are addressed expeditiously and effectively it is important that the EGB or Commerce Commission invite representatives of small renewable energy parties to be involved in the process of development of the rules. Funding would also have to be provided. It is unlikely that representatives would be able to contribute the extensive time necessary to review and comment on the draft rules being produced unless there is financial support. Of concern is the fact that the development of Standards and Rules are already well advanced without this input.

6.3.3 Resource Consent Issues

Renewable energy projects have potential to create real local environmental impacts. These are regulated under the Resource Management Act and require that projects receive consent from local or regional councils. Getting a resource consent is often one of the major stumbling blocks for renewables projects, particularly for local hydro, geothermal and wind projects. This will be a big issue for wave / marine current projects. It would not be efficient to bypass these consent processes. They were created to produce decisions that reflect local interests and environmental impacts. If, however, the process is unduly costly or long, or decisions are made with poor information there could be reasons to improve the process.

The renewables sector is made up of a number of small players and a few larger ones. It is to a large extent a new sector and very fragmented. A wide range of technologies are involved. This makes information generation and transfer difficult to fund and coordinate.

One area where consenting costs could be reduced would be in the provision of common information on environmental impacts. For example the noise impacts from wind power are very similar across projects. If credible information were available, each applicant would not need to repeat these noise studies – they would simply apply the information to local conditions if they were unusual. The fragmentation of the sector makes it difficult to create this information and disseminate it in a credible form. One possible way to provide this information would be through national environmental standards.

A second area could be in education of local councils and local interest groups in the true effects of renewables. Because there are relatively few renewables projects, people are not accustomed to them and may have unreasonable fears about their impacts. If the impacts of demonstration projects and other early projects can be carefully and credibly documented and then disseminated in accessible form to those involved in consent negotiations the quality of decision making may improve. Again the sector may be too fragmented to coordinate this alone.

A small amount of assistance through EECA or another group might provide considerable benefit in dealing with both of these issues.

Finally, an unusual feature of renewable energy projects is that they are extremely location-specific. Currently most projects are developed for a specific site and then consent is sought. If there are environmental impact problems with this site the project might founder and the effort might be wasted. If, in contrast, the renewables industry could work with local councils and landowners to find land that would not raise major consent issues but would provide the resource then projects might only be developed in detail when the probability of receiving a consent is high. This could be achieved partly through dissemination of information on the types of sites where renewables projects would be feasible and on the areas where environmental impacts would be significant. It would require some coordination within the renewables industry and longer term planning jointly with councils.

6.3.4 Reduction in Government-Controlled Uncertainty

Much uncertainty is driven by scientific uncertainty or uncertainty about the international agreements and international carbon market. Government cannot reduce this uncertainty, all it can do would be to take it upon itself. This would not necessarily be efficiency improving.

In a few situations, however, the uncertainty is under government's control. The first is simply making government policy as clear as possible. If decisions can be taken early they should be. If final decisions cannot be made because the appropriate decision is contingent on future international developments, the broad outlines of the future decisions (e.g.: NZ will use a carbon charge but cannot currently specify the exact level) and the process by which the details would be completed should be clarified and committed to as early as possible. Current administrations cannot commit future ones but by using a careful process to develop legislation and regulations, and making good decisions that receive broad support, they can reduce the chance of future policy reversals.

A second specific area where government could reduce uncertainty would be where Treaty of Waitangi claims are relevant to the use and development of renewable resources. If these claims can be settled the projects may be able to go ahead. This is particularly an issue for geothermal resources. Another area where government needs to clarify property rights relates to the allocation of geothermal wells. As long as this is not resolved, projects cannot be developed and implemented.

6.3.5 General Incentives to Encourage Renewables

Government has published its National Energy Efficiency and Conservation Strategy (EECA 2001a). A key feature of this Strategy is the promotion of new renewable energy resources. This government policy for the first time elevates new renewable energy to be a serious contributor to total energy supply. This report is concerned only with the linkages between renewable energy and climate policy. We do not aim to promote renewables per se for other reasons (e.g. energy security). We are looking specifically for instruments that can address the market failures in the renewable energy market. If these are generalised across many options and difficult to address directly, then one option would be to simply intensify the price signal in favour of renewables by subsidising them. This would not correct the failures but might counteract their impacts on market uptake. If the 'market failures' are an issue of economies of scale and increasing returns, simply increasing the demand for renewables could solve the problem, albeit not necessarily in the most efficient way.

In section 4 we considered the efficient response of renewables uptake to the international carbon price (assuming no competitiveness issues or adjustment costs). If we extend this analysis to look at prices beyond $30 per tonne of CO_2, we find that a 2c/kWh premium paid for renewable energy opportunities would allow 10 to 30 PJ of additional renewable electricity generation. There would also be some advantages for use of renewable energy to generate industrial process heat. A stronger price signal might lead some of these extra projects to be developed. Alternatively, it might lead to more complete uptake of options that should be feasible at $40 per tonne.

If the price intensification approach were taken, the question would be how to increase the intensity of the price signal beyond the world price / domestic carbon charge. Two options are commonly discussed: targeted tax breaks and a tradeable renewables portfolio standard. 'Projects' could also be used to reward renewables beyond Kyoto levels but this would be cumbersome.

6.3.5.a Targeted Tax Breaks

These are understandably popular in the renewable energy community. They are subsidies that tilt the economic playing field toward renewables making more projects attractive. The most valuable tax break for renewables would probably be accelerated depreciation. Renewable energy projects tend to have high up-front costs and low running costs. Empirical studies have found that reducing the up-front cost of technology adoption elicits the greatest response.[42] Thus if the goal is to speed uptake of renewables, accelerated depreciation might also be an effective and relatively efficient policy.

A similar tax break could be used to encourage adaptation research for new and upcoming technologies. If tax breaks were given for research and development in the renewables area, this could help companies develop technologies through the early

[42] See Section 3.2.2 of this report under 'high discount rates'.

experimental phases to the point of adoption. The tax breaks would not directly address the intellectual property issues or the difficulties in financing research and development but they may ameliorate them. This idea would come close to the idea of a contestable fund but the government would have less discretion over which projects received funding.

An alternative instrument that might be worth exploring, if the government does aim for generally increased uptake, would be a simple subsidy on energy produced from renewables. The total production of renewable energy from each source would be monitored and periodic payments would be made on that basis. This could be refined to focus more on specific renewables options that are considered particularly socially favourable. As a tool to address market failures, this could simply be applied to new developments during their start up phase. Given that the problems these sectors face are primarily non-price barriers however, this is unlikely to be an effective policy.

One problem with targeted tax breaks is that they are indiscriminate. Much of the subsidy would not go to projects where there are positive externalities (e.g. where early learning-by-doing is key) or even to sub-sectors that are too fragmented to do these projects themselves. To a significant extent the tax breaks would simply subsidise unprofitable projects. Another general problem with the use of tax breaks to create differential advantages for one sector is that they are a non-transparent form of subsidy. This can create political economy problems. The New Zealand tax system general avoids use of 'tax expenditures' both for this reason and to limit the complexity of the tax code.

An advantage of using targeted tax breaks relative to the contestable fund discussed above is that it avoids the discretionary and discrete nature of funds. Under a fund a few projects will be likely to receive generous funding while many will be unsuccessful or will find that the transactions costs of applying to the fund make it too expensive. On the downside government would have less control over the funds; on the up side the funds would be less likely to be captured by a few special interests or effective lobbyists.

6.3.5.b Tradeable Renewables Portfolio Standard

A tradeable renewables portfolio standard (or something similar) is another popular option. This would guarantee a certain level of renewable energy use. If insufficient projects would have been profitable without the regulation, the standard will force investment in additional projects. If the aim is simply to increase renewables uptake this will be effective.

It may however be a very costly policy. The benefits from increased renewables uptake are probably not very sensitive to the exact level of uptake (unlike something like toxic waste emissions) and we do not face any internationally binding target. Thus the cost of not quite meeting a target might be quite low. In contrast, the cost of renewable energy might increase very rapidly after a threshold so the risk that the renewables standard requires very expensive and inefficient projects is real. In this situation a 'price' instrument is probably preferred to a 'quantity' instrument.

6.4 EARLY ACTION

The final question relates to the optimal timing of policies.

6.4.1 Benefits of Early Action

In general early action (i.e. any policy before 2008) aims to increase the credibility of the longer-term policy, address myopia that investors may have, and reward any positive externalities created through learning-by-doing. Creating the infrastructure for price signals through carbon charges and projects in 'at risk' sectors would improve credibility and encourage investors to think about longer-term renewables investments.

Early action will provide more ‘model projects’ and case studies, which will allow better definition of costs and returns pre 2008 in both 'at-risk' and other sectors. This will allow more informed choice for NGAs or for uptake of renewables in order to mitigate or avoid carbon charges or any other mechanisms introduced.

Early price signals will create an increased awareness of the specific opportunities that may be taken up. It will lead to dissemination of the costs of these projects and the effect of these both on the environment. The renewables industry has principally been an interest of the ‘hippy’ era and until recently was still referred to as ‘alternative’. Hydro was also until recently not included within the renewables camp as it was perceived as being ‘big and nasty and driven by the state’. Also until recently renewables were focused on electricity production and heat energy was rarely considered. Even today there is little information available on New Zealand’s heat use.

Many of the renewable industries are in early stage of maturity and do not have appropriate quality standards, performance control systems and training capabilities. These will take some time to evolve and early action will allow their implementation to occur at a rate commensurate with the growth in maturity of the individual technologies within the industry.

Within the process heat industry, leaders outside the forestry sector are needed to allow the use of wood process residue to really take off. Within the electricity sector significant barriers prevent small renewable projects gaining access to the electricity network. These market and interconnection issues will take some time to resolve particularly as the large energy companies who may not have the incentives to obtain a quick resolution dominate the market.

Finally, relatively few renewables investment decisions are made each year as the investment decision is frequently coupled with a much wider and greater investment decision e.g. heat plant at a new wood processing facility. Few renewables investment decisions (e.g. electricity projects) are stand-alone. This makes it important for investors to be altering these larger projects to include renewables early.

6.4.1.a Sale of Early Credits to International Markets

Some countries and regions (including The Netherlands, the United Kingdom and potentially the European Union) have created or are creating emissions trading systems that will be active before 2008. They may be willing to accept emission reductions in other countries as part of those systems. If so, New Zealand may have opportunities to sell emission reductions before 2008.

The key issue here is whether New Zealand will have access to these markets and on what terms. This will ultimately be at the discretion of the countries concerned so here I will only speculate on the issues they will probably consider.

Other countries face similar decisions to New Zealand in regard to early action. They want to encourage learning about carbon markets, and facilitate investment decisions in both research and physical plant and infrastructure that will lead to an efficient transition to a lower carbon economy. Some systems, such as the Dutch one, explicitly include international trading. Here they may wish to facilitate the development of mechanisms such as Joint Implementation and the Clean Development Mechanism so that these are functional post 2008 when they are seriously needed. Legally (since 2000), reductions certified under the Clean Development Mechanism can be used to meet post 2008 commitments. This is an additional incentive to start developing CDM projects and buying credits early.

As part of this learning process, some countries might be willing to experiment with New Zealand credits. However they are unlikely to offer complete access before 2008 because the gains to them are limited. It is hard to see why, beyond a few experiments, other countries would be willing to pay New Zealand to reduce emissions below current levels before 2008. If New Zealand had an early action system of equivalent stringency to the others, the transfers of funds and credits would be two-way and this might be more acceptable. This would not be achieved at a $5 per tonne of CO_2 carbon charge.

Stranger things have happened however. It would be worth it for private players to explore the potential to sell discrete amounts of credits into these other systems. I have heard, for example, that there may be potential for selling some sink credits into the United Kingdom system. As long as these were only reductions pre 2008, there would be no negative implications for New Zealand. Ownership of pre 2008 reductions is not defined. This would not provide any exemption from domestic regulation.

If the government wished to become more actively involved in European markets, it would need to directly negotiate with them so that our system could be directly linked to theirs. We would need to address the problem of translating a carbon charge into credits that can be internationally traded. Full linkage would provide the most learning but may also require a higher domestic carbon price as well as extensive negotiations.

A secondary issue is the prices that will prevail in these markets. Some carbon credits are already traded at a wide range of prices. The market is extremely idiosyncratic and illiquid. In the recent United Kingdom reverse auction (where government was paying firms to reduce emissions), an indicative price was US$17.70 per metric ton of carbon equivalent.

The key problem is finding a buyer not the price. Without significant development of bilateral agreements, any early action related to international markets is likely to be project specific and idiosyncratic. Thus New Zealand firms, at-risk and not-at-risk, will be unlikely to be seriously exposed.

6.4.2 Costs of Early Action

Early action offers some benefits. On the downside, unless New Zealand has access to early international markets, early action imposes costs on the economy that are not offset by increased revenue flows from the net sale of credits internationally (as opposed to carbon charges imposed after 2008). If the policies accurately address market failures, the benefits from early action will exceed the costs because the policies are by definition efficient. They are likely, however, to be poorly targetted in some cases. Some firms and consumers will simply face higher prices and will be unable to respond in useful ways. For example, if a firm's only feasible response to higher costs is to close down, early action will lead them to close, with the consequent loss of profit and jobs, earlier than is necessary. This could have economic and social implications. Given the level of proposed early action charge, these impacts are likely to be minimal.

6.4.3 Appropriate Form, Timing and Intensity of Early Action

The levels of payoff from any early action are impossible to assess quantitatively. Thus it is hard to say what the appropriate level of carbon charge and project incentive would be. The appropriate level would however be less than the expected price in the first commitment period. A positive level of price pressure as well as information dissemination and clear policies are certainly valuable pre 2008 – what is unclear is how much action is desirable. Some price signal to provide credibility to the Government's policy and work out the administrative details will probably be valuable. Providing as much clarity about future policy as possible as early as possible will be valuable. For example, clarifying which firms will be treated as 'at-risk' and which will not, and clarifying exactly how at-risk firms will be treated (will they be exempt carbon charges on electricity use and how; what exactly will be involved in an NGA) would remove a lot of uncertainty.

Complementing this with specific actions targeted at parts of the energy sector where responses are likely to take time and are not likely to respond simply to a price signal, for example institutional change in electricity sector or training and adaptation of new technologies in fragmented sectors, might make the later transition smoother and more efficient.

7 CONCLUSIONS

In general renewable energy technologies are either well established and mature (hydro, wind, geothermal, bioenergy, solar water heating), or upcoming (photovoltaics, wave). The opportunities based on the mature technologies have been thoroughly investigated over the years and generally are not currently proceeding to investment because there are other more economic ways of obtaining the consumer energy. Because of this there has been a lack of incentive for further investigation and development, particularly as New Zealand is living on the legacy of knowledge last funded during the 1970s-1980s period. Renewable projects such as hydro suffer from the fact that no recent investigations have been undertaken and the data, concepts, and designs are now very dated.

Increased uptake of renewables will depend on the funding of new smart thinking, and a relative change in the cost of energy from all services. Essentially we are dealing with a sector that is characterised by having a large number of small/medium players who do not have the cashflow to individually fund work that collectively needs to be undertaken. This puts the industry into the category that most justifies government intervention from a macro efficiency perspective, albeit for co-ordination and initial stimulation.

The analysis shows that unless very significant, climate change initiatives will affect the uptake of renewables only at the margin. The efficiency improvements that result from addressing market failures and regulatory barriers will have micro rather than macro affects.

Preferential treatment of some sectors (possibly for good reasons) could hinder uptake of renewable energy if at-risk sectors do not face the full carbon price. Potential losses of opportunity are primarily for process heat from either biomass or geothermal energy. Good options exist in the cement, forest processing and dairy processing industries. Government could encourage efficient uptake for at-risk sectors by building renewable options into negotiated greenhouse agreement targets. For example, at-risk sectors where renewables use seems feasible could have more stringent carbon per unit output targets. Renewables uptake also could be encouraged through the use of 'projects' that reward reductions in carbon usage per unit output beyond an agreed baseline.

The other reasons that even feasible and economically efficient renewable energy investments might not be made relate to market failures. We identify four main areas for potential policy attention, along with general incentives for renewables:

- adaptation / early adoption assistance,
- electricity market structure and interconnections,
- resource consent issues and
- government-controlled uncertainty.

For adaptation / early adoption we outline potential solutions to assist those sectors of the renewables industry which are fragmented and too small to fund their own research and information dissemination. This includes a contestable fund focused on specific technologies and options where learning and development of role models is important. This fund could potentially be run with the involvement of the relevant industry associations with responsibility for running the programme gradually passed to them as the sector matures. Additional policies would involve actively seeking good renewable role model opportunities within government's own activities, direct information provision by government, and facilitation and possibly funding of training. All of these policies would aim to speed up the early stages of the adoption process so that the industry overcomes start-up hurdles to reach critical mass and/or is well placed for more rapid adoption in the event of unexpectedly high carbon prices or changes in the relativity of energy costs.

For the electricity market issues we simply point to the need for greater representation of the small companies that have renewable interests when making decisions on the market regulatory and interconnection rules.

The solutions to any consent issues are primarily based around the provision of credible information on common problems (e.g. noise from wind farm) to all parties, and encouraging long-term planning on the part of councils to help identify good locations for renewable energy projects.

Government has the ability to reduce the significant uncertainties affecting the sector. Given the importance of climate policy in the economic feasibility of renewable projects, any increase in the certainty and credibility of government climate change policies would help. Government also has the ability to clarify property rights in the case of areas where Treaty claims are critical, or property rights are simply not defined.

We consider the impacts of broader policies on renewable energy. We conclude that the form of revenue recycling, when aimed at improving the efficiency of the tax system, is unlikely to be important for the renewable energy sector. In contrast up-front subsidies to renewables either through cash grants or accelerated depreciation might significantly enhance renewables uptake; they may not, however, be well targeted to areas with genuine inefficiency so may simply end up subsidising unprofitable projects.

Finally, resolution of uncertainty about government policy, even if only the form and sectors affected can be decided, should be done as early as is feasible. This requires not only that government makes robust decisions that are unlikely to be reversed but that they create credible signals that make the policy clear to market players. Other early action should focus on overcoming the barriers that make adoption of new technologies very slow in its early stages and facilitating the regulatory processes that can resolve electricity market and property rights issues.

Early action may also allow advantage to be obtained from other countries prepared to accept emission reduction in New Zealand as part of an international market of emissions credits.

Overall we identify some roles for policy to supplement and complement the proposed climate policies. These are very focused roles however. Any renewables policies related to climate policy should address clearly identified problems with respect to a narrow range of renewable options.

The analysis done for this report has largely been qualitative rather than quantitative. All the proposed options need considerably more analysis before firm recommendations can be made.

7.1 Policies that Merit Further Consideration

1. More stringent NGA targets for firms with good renewables options;

2. Use of renewable projects to complement NGAs and reward reductions in carbon per unit output;
3. Establishment of a contestable fund for 'soft projects' to address adaptation research, information diffusion, and demonstration projects for renewable options that show significant potential, but where the current industry is fragmented and in early stages of development;
4. Government use of renewable energy in its own activities where efficient;
5. Use of Industry Associations to provide a critical mass for activities related to barriers to uptake;
6. Government provision of common information to speed adoption of new technologies;
7. Government facilitation of specific training needs for nascent renewables options;
8. Effective representation of smaller renewable interests in the Electricity Governance Board;
9. Government provision of common information to enhance consent processes;
10. Policies compatible with other governments interested in sale of early emissions credits; and
11. Reduction of government controlled uncertainty: climate change policy, Treaty claims and geothermal well ownership.

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9 APPENDIX 1: DESCRIPTION OF RENEWABLE RESOURCES

A1.1 Hydro

New Zealand has already developed 5000MW of hydro capacity in both the North and South Islands. There are still significant resources available in both islands, though the largest high confidence resources are located in Canterbury (919MW out of 1103MW of high confidence resource). Extending the assessment to medium confidence resources, a further 737MW could be installed in Otago and the West Coast out of a medium confidence band of 1096MW. At a WACC of 10%, there are no hydro resources in Auckland or Northland less than 15c/kWh.

New Zealand hydro developments are characterised by having little storage. Some radical rethinking of development concepts has been demonstrated by Meridian Energy's Project Aqua to be located in the Waitaki River area – these have lead to significant reductions in the environmental impact and capital cost of this scheme, on an already managed river to compete directly with CCGT plant i.e. with a unit cost under 5c/kWh.

Given that Auckland is the major electricity load centre, and the South Island is already a major exporter of electricity, any further SI hydro development will require a significant increase in the capacity of the DC link, further transmission strengthening through Whakamaru, and probably major transmission work through the West Coast. Without this transmission reinforcement, hydro development would be limited to a range of minor projects that would serve the local South Island market.

For many years, New Zealand maintained a hydro construction capability through a government policy of ongoing hydro and irrigation scheme construction. This has not been maintained in the 1990's so there will be a greater need for offshore input into design and construction.

A1.2 Geothermal

Geothermal energy can and has been used for both heat and electricity. Wairakei and more recent power stations such as that at Mokai and Ngawha (in Northland) are examples of electricity production. The Norske Skog Tasman mill at Kawerau is the largest user of geothermal energy for process heat in the world. Lower temperature geothermal resources have been developed both in the Taupo Volcanic Zone and elsewhere for domestic and commercial heating purposes. Nationally there is the option to use geothermal heat pumps to reduce electricity requirements for home/water heating/cooling.

There are many geothermal fields that could be developed for electricity generation, but all of these high temperature fields are located in the Taupo/Rotorua/Kawerau area or at Ngawha in Northland. Installed capacity is currently around 430MW generating about 2270GWh per year. Typical generation unit costs for new electricity stations are close to 7c/kWh for conventional (or hybrid steam-binary cycle) plant on the highest temperature resources, and about 10c/kWh for lower temperature fields reliant on binary cycle plant. Taking high and medium confidence resources, there is opportunity for additional generation of between 290MW (2310GWh/y) and 560MW

(4450GWh/y), predominantly from already developed fields. The potential could be expanded further if the Waikato Regional Council remove a "Protected 2" category from their Proposed Waikato Regional Plan.

This latter resource category indicates a common attitude of seeking to protect resources from development. This reflects an often held public view that adverse impacts created by geothermal development can affect nearby towns, tourism value or scientific research value. The default position, where there are perceived risks has often been one of protection. This will deflect those development applications that could manage possible impacts.

The greatest potential development prospects are on existing development fields. At Wairakei, for instance, optimistic resource assessments indicate the potential for a further 430MW of development while conservative estimates would place it at its development limit now. If Contact Energy can have confidence that they will be the "Single Tapper" of the field, then they can invest in deep exploration drilling to prove additional capacity and further development might be possible.

Generation from most of the fields would naturally be fed into the National Grid south of transmission constraints at Whakamaru, again requiring constraint relief to supply the Auckland load. Generation at Ngawha (a 10c/kWh development) is one of the few generation opportunities north of Auckland and is unlikely to require grid strengthening for the level of generation envisaged.

By the end of 1999 there was over 7PJ of direct geothermal heat use in New Zealand. There are more opportunities for process heat supply. There is good co-location of geothermal resources and major Central North Island forests suggesting possible supply of process heat to new processing plants as at Kawerau. Steam diverted from a geothermal power station could be available at a steam price less than half that from dedicated gas-fired boilers. In the past there has been a difficulty in encouraging industry to relocate to a geothermal field. Fields located next to existing industrial areas such as Tauhara field beside Taupo or the Rotorua field have drawn local opposition because of possible environmental impacts. In this respect, while the potential for geothermal supply of process heat exists, its uptake is likely to be limited.

There are widespread low temperature geothermal areas that could be used for domestic or commercial heating. A large number of these resources are remote from housing and commerce so will not find applications. There has been limited application in places such as Hanmer, Maruia, Tokaanu, Taupo, Rotorua, Kawerau, Tauranga, Helensville and Waiwera. With the exception of the two resources north of Auckland, there is opportunity to expand usage, but field characteristics and capacities are poorly understood, and are only now starting to draw significant research funding in New Zealand.

In Europe and the United States, ground source heat pumps are counted as part of the geothermal resource. They help to meet domestic heating/cooling needs and supplement hot water heating. Studies have been undertaken in New Zealand based on a limited application but these pumps did not appear to be economic. The situation could change if hot water preheating is included and as requirements change for both further heating and cooling to international standards, however uptake is expected to be minimal. Hybrid applications of heat pumps and elevated ground water temperatures may be possible in a number of places including those listed above, plus Banks Peninsula, Oamaru and Hamilton (there is a large existing example of a ground source heat pump here) among other locations.

Deep geothermal drilling capability has been maintained at a low level by ongoing Crown work at Kawerau, limited drilling for Contact Energy at Wairakei and Ohaaki, and recent drilling for the new developers at Ngawha, Mokai and Rotokawa.

New Zealand maintains a world-respected core of engineers capable of field design and plant specification.

A1.3 Wind

Currently there is 36MW of wind generation installed in New Zealand with an output of 150GWh per year. This is all within the Wellington and Wanganui-Manawatu regions. In terms of potential, there are wind opportunities throughout New Zealand and near most major coastal cities. The best prospects are around Wellington hills and coast, the Manawatu gorge, followed by Wairarapa hills and coast, Coromandel/Kaimai ranges and the "Foveaux Strait" area between Invercargill and Dunedin. Attention will be focussed on the highest wind speed sites (a 10m/s site will yield a unit cost of around 6c/kWh).

Consenting has proven difficult near major centres due to concerns about possible noise and visual pollution effects.

These projects are of a size that facilitates distributed generation with input into local networks. The analysis done for the East Harbour Renewable Report was based on algorithms that took into account total resource area and a range of wind speeds, rather than on a project-specific basis. Future projects are likely to be of a 30 to 40 MW size.

A1.4 Biomass (Woody)

Woody biomass is one of the most versatile forms of renewable energy, and is widely dispersed. Current usage is assessed as about 30PJ/y.

A review of energy costs shows that the primary source will be wood processing industry residues, followed by a collection of forest landing material (a currently unused biomass source). In addition, there could be other wood sources via recovery operations at landfills. As with many fuel sources, transport can add significantly to delivered fuel cost. Major wood processing centres and of forest concentrations are wide spread.

This fuel is currently used to a limited extent by the forestry industry. A further 5PJ or so of scavenged or plantation wood is consumed domestically. However, wider marketing as a general form of fuel for industry will require a programme including some measure of fuel standardisation/upgrading coupled with long term supply contracts. A company (CHH Biogrid) has now commenced work in this area of wood fuel marketing.

Expected price for dedicated electricity plant (at 11-12c/kWh and greater), even based on advanced technologies is still a little above that of other renewables, though will become more competitive say 20 years from now. Despite this, some electricity generation is expected in a cogeneration situation where surplus steam is directed to a small steam turbine. Assessed total generation via this method is unclear but may make a small contribution to displacing electricity at the retail end of the market.

The major contribution is expected to be to providing a process heat source for the timber process industry, particularly for timber kiln drying. While plantation forest harvesting is expected to increase significantly in the near future (the industry talks about a “wall of wood”) it still has to be seen how much of this wood will be processed on-shore and how much will be exported as logs. Biomass fuel resource and biomass usage will be a strong function of the amount of local processing of wood flows. To an extent, the use of wood process residue as a fuel is a means of waste disposal for a constructive purpose. If valued accordingly, a biomass fuel is very competitive with other fuel sources.

An expanding contribution could be made to domestic heat supply, with wetbacks helping to offset the high winter electricity demand.

A1.5 Biomass (Landfill)

While reliance on landfills is declining through greater recycling and improved waste management practices, it is likely that landfills will continue in some form for the foreseeable future. There is now a move to establish a few well-managed centralised landfills in preference to the use of the many small plants owned by local councils. The anaerobic decay of material within the fill leads to evolution of methane, which is useful as a fuel for a range of applications including heat, electricity and transport. Combustion of methane both serves a useful energy purpose and coverts a damaging greenhouse gas into a gas with a lesser effect. Transportation of methane gas is expensive due to its low calorific value so uses on site are preferable.

It is very difficult to attract heat plant to a landfill, though there have been some attempts in New Zealand to reticulate the gas (or supplement other reticulated gas) from landfill gas sources. Gas reticulation projects at Green Island in Dunedin and at Porirua have subsequently ceased operation. The predominant use is for electricity generation, with 4 operating generation plants in Wellington and Auckland (5 including the newly commissioned Whitford plant). There is expected to be further opportunity for generation with an additional 100GWh per year expected from landfill gas generation in main centres for the foreseeable future over and above the current 74GWh.

This generation is available at prices less than most other renewables at around 6c/kWh. If gas collection and flaring is a compulsory feature of landfill operation (to minimise methane discharge) then the unit cost drops to around 4.5c/kWh making it cheaper than almost any other source including combined cycle generation, while being of a size to displace electricity at the retail level.

It would be possible to clean the gas and then process it for use as a transport fuel. However, quantities would be small.

A1.6 Biomass (Other)

Other biomass sources exist e.g. biogas sources on farms, but the resources are limited and implementation may well be driven by waste disposal criteria rather than decisions on optimal electricity or heat sources. Uptake of these on-farm options is likely to accelerate beyond 2012 as farmers lose the security of their electricity supply, but costs are currently prohibitive.

Biomass can be used to supplement transport fuel. Anchor Ethanol undertakes commercial production of bioethanol, through conversion of whey. Anchor Ethanol have supported the concept of ethanol blends for New Zealand petroleum, though available quantities, even with expansion of production facilities would lead to quantities sufficient for a 0.5% blend at most.

In the past, studies have been undertaken on production of biodiesel from meat works tallow. The costs from these studies are currently being updated, but previously had appeared attractive.

A1.7 Photovoltaics

Photovoltaics have a unit cost outside the focus level for the East Harbour Renewable Report. Nevertheless, photovoltaics are making inroads into remote diesel generation as reliable low maintenance generators. Uptake will be very limited, but is likely to directly offset fossil fuel combustion in internal combustion engines. Capital costs are dropping rapidly such that some grid-connected PV systems are likely in the medium term, and are a feature in many countries now.

A1.8 Solar Hot Water

Depending on investment criteria used, solar hot water heating is commercially attractive now i.e. at a unit cost similar to the retail price of electricity. It is able to directly offset the purchase of electricity or gas at both the domestic and commercial level for water heating. Installation requires the investor to take a long-term view to recognise the benefits. Water heating, along with space heating is a major source of energy consumption in homes.

The solar heating effect is similar across the country, though marginally better in the north than the south. Any installation will directly relieve existing electricity or gas transmission constraints.

10 APPENDIX 2: NEW ZEALAND GAS RESERVES

Table 2.1: Available Gas Reserves[43],[44]

Field	Ultimate Recoverable Reserves (PJ)		Gross Production 2000 (PJ)	Notes
	Gross Production	Net Production (as at 1 January 2001)		
Kaimiro	22	12	1	Onshore oil and gas
Kapuni	1,011	237	28	Has high CO_2 content requiring local use, especially for petrochemical industry. Onshore predominantly gas field.
Kauhauroa	100-300??	100-300??	-	East Coast Basin discovery by Westech-Orion.
Kupe	309	301	-	Offshore predominantly gas field
Maui[45]	4,130	1,324	179	Rapidly depleting offshore predominantly gas field of world scale.
McKee	138	53	10	Onshore oil and gas
Mangahewa	129	119	-	Reserves may be less. Gas field located in impermeable rock and sand adjacent to McKee
Ngatoro	10	4	1	Oil and gas on NE flank of Mt Taranaki
Piakau	7	0	-	-
Pohokura	150-350??	150-350??	-	Offshore north of Mangahewa
Rimu	150-400??	150-400??	-	Based on recent wildcat onshore drilling near Hawera by Swift
Tariki/Ahuroa/ Waihapa/Ngaere	149	89	11	Predominantly gas fields to east of Mt Taranaki
Totals	**6,300-7,000**	**2,500-3,200**	**230**	

[43] See MED 2001a
[44] See SKM/CAE 2000
[45] Assessment of Maui reserves has subsequently been revised down.

11 APPENDIX 3: INPUTS INTO THE COST SUPPLY CURVES FOR ELECTRICITY

The following values have been input into the cost supply curves for the various renewables options. These figures were obtained from the East Harbour Renewable Report.[46]

Table A3.1: Inputs into the Cost Supply Curves for Electricity (2012, 10% WACC)

Price Band (c/kWh)	High Confidence Resource Assessment (PJ)					
	Cumulative Total	Hydro	Geothermal	Wind	Biomass[1]	Solar
2-4	3.02	2.30[2]	0.72	-	-	-
4-6	15.83	11.51	-	1.24	0.06	-
6-8	29.48	1.49	6.01	5.86	0.29	-
8-10	38.06	4.62	0.43	3.53	-	-
10-12	42.85	1.15	1.15	1.98	0.51	-
12-14	45.46	0.92	-	1.33	-	0.36
14-15	47.87	1.67	-	0.34	-	0.40
Price Band (c/kWh)	**Medium Confidence Resource Assessment (PJ)**					
	Cumulative Total	**Hydro**	**Geothermal**	**Wind**	**Biomass[1]**	**Solar**
2-4	3.02	2.30[2]	0.72	-	-	-
4-6	17.79	11.51	-	2.90	0.36	-
6-8	52.11	8.04	12.59	13.69	-	-
8-10	68.08	7.30	0.43	8.24	-	-
10-12	83.80	7.32	2.27	4.60	1.53	-
12-14	90.63	2.32	-	3.13	1.02	0.36
14-15	99.06	3.87	-	1.44	2.54	0.58
Notes: 1. Biomass figure includes landfill gas, woody biomass and other biomass options 2. This figure represents the nearly completed Manapouri tailrace tunnel upgrade.						

[46] See East Harbour (2002a)

12 APPENDIX 4: SECTORAL CONSIDERATIONS

In November 2001, ABARE produced a report for the Ministry of Agriculture and Forestry looking at the potential economic impacts on New Zealand of implementing the Kyoto Protocol.[47] This covered a range of sectors, necessarily with a greater focus on agricultural and forestry interests.

A second report was produced in November 2001 by NZIER for the Greenhouse Policy Coalition and the Petroleum Exploration Association of NZ.[48] This report has been subject to extensive criticism. Reviewers found the model and results difficult or even impossible to follow as a result of poor documentation. It is likely to be more negative than is realistic. It can however contribute some information about which sectors are likely to be most affected even if the overall impact on GDP is overstated. One exception to this might be the result on the forestry sector (growing trees rather than wood processing) which is unintuitive.

While each analysis is based on a different model, different sectors and different assumptions, they both predict negative impacts across a similar range of sectors for similar scenarios. This is demonstrated in the first two columns of Table A4.1. NZIER scenario 1b and ABARE Scenario 3 were chosen for comparison.

The scenarios suggested by MfE for this study (applying to CO_2 only and therefore excluding agricultural methane emissions) are closest to ABARE's Scenario 3. NZIER scenario 1b also uses this narrow regime. ABARE worked on a US$30/t CO_2 equivalent charge, while NZIER Scenario 1b has no trade in emission credits. In this scenario the government collects the amount of taxes sufficient to meet emissions target and then recycles this in the form of lower taxes. In both of these scenarios, the United States is assumed to be out of the Kyoto agreement and Australia in.

[47] See ABARE (2001)
[48] See NZIER (2001)

Table A4.1: Direction of Change in Sector Outputs in New Zealand at 2010, Relative to the Reference Case

Sector		**NZIER Impact Scenario 1b**	**ABARE Impact Scenario 3**	**Percent of GDP**
Agriculture	Sheep and Beef Farming	-	-	**6**
	Dairy Farming	--	-	
	Mixed Livestock and Cropping	+++		
	Horticulture	+++	+	
	Other Ag, Hunting, Fishing, Mining	---		
Forestry and Logging	Forestry	--	+	**1.6**
	Logging	-		**1.6**
Food Manufacturing	Dairy Manufacturing	---	-	
	Meat Manufacturing	--	-	
	Other Food Manufacturing	---	+	**4.5**
Other Animal Products			+	**1.1**
Wool			0	
Wood and Wood Products Manufacturing	Wood and Wood Products	--		**1.4**
	Pulp and Paper Products	---		**2.7**
Refined Petroleum and Rubber Products Manuf.		---		**2.7**
Cement		---		**0.7**
Steel and Aluminium	Steel	---	---	**0.8**
	Aluminium/Nonferrous		---	
Light Manufacturing			-	**4.4**
Machinery and Equipment Manuf.		--		
Transport		---	0	**5.4**
Services	Services	+	+	**35.0**
	Wholesale and Retail Trade	--		**19.5**
Energy	Coal	---	---	
	Oil Extraction and Exploration	---	-	**2.9**
	Gas Extraction and Exploration	---	--	
	Gas Treatment and Distribution	---		
	Electricity	---	--	

Legend: --- = negative change worse than 10%, -- = negative change between 5% and 10%, - = negative change between 1% and 5%, + = positive change between 1% and 5%, ++ = positive change greater than 5%, +++ = positive change greater than 10%

In addition to the broad sectors indicated above, MED have identified a number of major CO_2 emitters. These are listed in Table A4.2. followed by details on each sector.

Table A4.2: Major Emitters (Year 2000 Data)[49]

Sector	Company	Sector Emissions			Notes
		kt CO_2	t CH_4	t N_2O	
Road Transport	Various	10,995	7,010	490	
	New Zealand Army				
Thermal Electricity Generation	Contact Energy Ltd	5,051	227	23.2	Includes New Plymouth (gas), Otahuhu B (gas).
	Genesis Power Ltd				Includes Huntly (coal and gas), Kinleith cogeneration (data is for coal and gas firing – not biomass) (Includes 877kt CO_2 from coal firing at Huntly.
	Mighty River Power Ltd				MRP supply data on Auckland landfill gas plants of minor size for which CO_2 emissions are discounted
	Natural Gas Corporation				Includes Taranaki (gas), Southdown cogeneration (gas) NGC also supply data on Silverstream landfill gas plant of minor size for which CO_2 emissions are discounted
Other Manufacturing	Various	4,233	548	132	Note that 60-70% of methane and N_2O emissions is from biomass combustion by the forestry sector. Co-generation plants are included in this category where electricity is secondary to the main industry activity.
	Dairy Processing: Fonterra Cooperative Group Forest Processing				
Methanol	Methanex New Zealand Ltd	1,990	-[1]	-[1]	Synthetic petrol production was halted in 1997/98. Plant receives a CO_2-rich gas supply (Kapuni CO_2 may otherwise be vented). Produced at Motunui and Waitara Valley plants (linked by pipeline) and distilled to chemical ('AA grade') methanol.
International Aviation	Various	1,790	39	28	
	Air New Zealand				

[49] Data has been taken from MED Energy Greenhouse Gas Emissions 1990-2000 (2001b)

Iron and Steel	BHP New Zealand Steel Ltd	1,493	-	-	Virtually all coal is used in a direct reduction process to remove oxygen from iron sand and not specifically as a fuel. Other emissions are from calcining of limestone, electrode degradation and coke usage and a small amount of natural gas used as a coolant. The iron sand mines at Waikato North Head are subject to a 100 year exclusive lease.
	Fletcher Challenge Steel Ltd				Emits a small amount from electric arc furnaces during the production of steel from scrap metal.
Agriculture and Forestry	Various	1,225	269	45.7	Data is predominantly on-farm liquid fuels use.
Commercial and Institutional	Various	866	49.9	19.4	
	Government and Local Government				
	Health Sector				
Aviation	Various	848	18.5	13.6	
	Air New Zealand				
	Royal New Zealand Air Force				
Petroleum Refining	New Zealand Refining Company Ltd	839	21.2 +251 (transport)	1.8	Majority of emissions are from burning refinery gas.
International Marine	Various	753	73	21	
Residential	Various	553	2,372	28.1	
Oil and Gas Extraction and Processing	Various	286 +241 (flaring)	6.7 +684 (flaring)	15.5	
	Shell Todd Oil Services Ltd				
	Natural Gas Corporation				Includes gas to power compressors and fuel used at the Kapuni Gas Treatment Plant
Aluminium	Comalco Aluminium Ltd	521	-	-	This data reflects anode oxidation. Another 11% is from fuel combustion and is included under "Other Manufacturing".
Cement	Golden Bay Cement Company Ltd	520	-	-	Emissions represent emissions from calcination of limestone only. Fuel usage will double this number and is included under "Other Manufacturing".

	Milburn New Zealand Ltd				
Coal Mining and Post Mining	Various	-	24,152	-	The process of mining leads to release of methane, especially as a result of underground mining (accounting for 25% of NZ coal).
Geothermal Heat and Electricity Generation	Crown	393	2,545	-	Plant includes Kawerau geothermal supply to TG1 and TG2 power plants and to Norske Skog Tasman.
	Contact Energy Ltd				Plant includes Wairakei, Ohaaki, Poihipi Road, Ngawha
	Mighty River Power Ltd				Has interests in Rotokawa and Mokai
Marine	Various	382	72.5	9.3	
	Royal New Zealand Navy				
Gas Transmission and Distribution	Various	1.2	14,178	-	This primarily includes losses by distribution companies including Unaccounted-For Gas
Rail	Tranz Rail Ltd	237	44.9	10.4	
Hydrogen	New Zealand Refining Company	179	-	-	Hydrogen is produced from the Hydrogen Manufacturing Unit from methane and steam with CO_2 as a vented by-product of this reaction. The hydrogen is a feedstock.
	Degussa Peroxide Ltd				Some hydrogen is produced and converted into hydrogen peroxide.
Ammonia/Urea	Ballance Agri Nutrients (Kapuni) Ltd	165	-[1]	-[1]	This plant (like the methanol plant) uses CO_2-rich gas as a feedstock. Heated gas is reacted with steam, then resulting gases are blended with air eventually forming the required products. Maui gas is used as a fuel.
Lime	McDonald's Lime Limited	110	-	-	This company is owned by Milburn New Zealand Ltd. Carbon dioxide is emitted when limestone ($CaCO_3$) is converted to lime (CaO)
Notes 1. Data has been merged into "Other Manufacturing"					

The following discussion focuses on the negatively impacted industries.

A4.1 Dairy Industry

The dairy industry is a primary source of export earnings (accounting for 20% of the New Zealand total). Fonterra is the major company within this industry (owned by 98% of New Zealand dairy farmers) and is the largest global cross border trader in a number of commodities (dominating the world export trade in dairy products).[50]

The industry could be hit by both the emissions from its animals on farms and from its intense energy usage in milk production and downstream processing. It is estimated that approximately 10% of the CO_2-equivalent national emissions currently is from dairy animals, largely as methane. MfE assumptions for the purpose of this report are that methane emissions will not be subject to an emissions charge.

The dairy industry was one of the primary drivers for rural electrification, and is still a source of increasing electricity demand on farms. Nationally, but especially in the South Island, there has been a move to upgrade land use through energy and capital intensive irrigation schemes, followed by conversion to dairy farming to achieve the financial rewards necessary to justify the irrigation investment. Thus the dairy industry has increased in energy intensity due to irrigation.

It is worth noting that beyond the first commitment period under the Kyoto Protocol, this major industry will see an increasing reliance on fossil-fuel generation. There will no longer be an obligation on electricity distributors to maintain rural networks beyond 2013. At this time there may be a move to greater use of diesel for own generation, supported by photovoltaics (this should be competitive with diesel in the long term), solar hot water and biogas usage. Small wind turbines and local micro-networks may also evolve.

The dairy factories are major energy users. Energy costs represent approximately 8% of the cost of production of exported dairy products. The factories are major electricity consumers so should continue to be able to justify connection to the grid and local networks beyond 2013. As major consumers of heat and electricity, dairy factories have been the sites for several cogeneration plants fired by gas or coal depending on location. These have been highly capital-intensive energy efficiency measures. Gas pipeline routes have been designed to run close to these major consumers. Dairy factories have their own coal mines e.g. the sites at Kopuku, Smith/Ruston and Pirongia developed by Glencoal Energy. Glencoal also supplies Huntly Power Station and McDonald's Lime. It is understood that biomass fuel suppliers are now looking at the possibilities of supplying woody biomass fuels to dairy factories, but this is likely to require a significant capital investment coupled with long term fuel supply agreements, with the industry sounding dubious about the option. Capital could be redirected from other utility investors prepared to operate on a dairy host site. Sites focussed on cheese production do not require process temperatures above 100°C (Zoellner, 1991), which could readily be supplied by wood-fired boilers. Smaller factories have used wood fuel in the past. Some co-firing of wood and coal may be possible in some boilers depending on feed arrangements. Marketing of biomass to dairy factories has been attempted without success to date.

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[50] Information is largely taken from Submission on the Draft National Energy Efficiency and Conservation Strategy by the New Zealand Dairy Group of Companies

A factory at Reporoa has an option to use geothermal energy. However, the Reporoa geothermal field has received an interim “Protected 2” status under the Draft Waikato Regional Plan. This new designation has been objected to, but the potential use of this resource has only been given a “low confidence” rating in the East Harbour Renewable Report as a result. Bay Milk near Whakatane could conceivably receive a heat supply from the Kawerau geothermal field, though consents from Environment Bay of Plenty would be nearly impossible, a pipeline easement could be difficult, and the pipeline would be of record length. If new dairy factory sites were being identified then co-location beside a geothermal power station would see the availability of large quantities of low cost heat with the further option of dedicated electricity supply contracts.

The dairy industry is the primary source of bioethanol if a program of fuel blending is envisaged for the transport sector. Anchor Ethanol made a submission on the NEEC Strategy strongly in favour of the use of bioethanol in New Zealand. A significant reduction in output will necessarily limit the production of whey from which bioethanol is derived. A downturn in the industry is also likely to tie up capital, such that investment in the bioethanol plant will have to be by other parties.

The dairy industry is a major transport user. Pro-rating Anchor Products transport diesel usage to total industry usage implies a total diesel use of 35 million litres per year. Efficiency measures have included rationalising collection following industry mergers, installation of larger holding vats on farms to allow alternate day collection when milk volumes are low, computerised tanker scheduling, fleet upgrades, faster pumping to tankers on farms to reduce engine hours per load, active support of roading improvement projects.

A4.2 Sheep, Beef and Other Livestock

The narrow emissions regime assumed in the NZIER study could result in a neutral or slightly positive benefit to this sector (resulting from exchange rate falls). New Zealand currently accounts for around 50% of world export trade in sheep meat and 10% of world export trade in beef. This industry is not like dairy in that it is not as energy intensive. The main emissions are methane from the herds. This industry, and to a lessor extent dairy, would not be impacted if a narrower definition of emissions were taken to exclude livestock/methane.

Within this industry, meat processing factories use electricity and low grade heat. While this may have an increasing renewable component, these factories may be able to be direct investors in renewable energy forms. Mini-hydro schemes depending on location may be options, as may be biomass cogeneration schemes.

Factory heat is currently supplied by coal (especially in the South Island) and to an increasing extent by natural gas (in the North Island).[51] Over half of the heat is directed to the rendering process (cooking and drying of waste material to produce meal and tallow).[52] Other significant loads include blood drying, wool drying (and other fellmongery tasks), and water/space heating. Hot water is used for sterilisation purposes. Heat usage is high during killing operations. Large meatworks tend to operate with 2 or 3 shifts, thus evening out the heat load through the day. Electric load is fairly constant, reflecting the high proportion of chilling load in the total electric demand. Nevertheless, these factories have been slow to take up cogeneration as an option.

[51] See Hennessy (1997)
[52] See Zoellner 1991

As for dairy farms, and perhaps more so because of their lower energy use, these farms will commence a transfer to increased fossil-fuel use as electricity supplies are no longer maintained beyond 2013. Whereas dairy farmers may have an option of collecting biogas for heat or electricity from the waste ponds from the milking sheds, this biogas option will not be generally available to other livestock farmers (with the exception of piggeries and poultry farms).

A4.3 Fishing

The fishing industry is a heavy user of diesel fuel for fishing boats. The fishing industry is export dependent, with 95% of the catch being exported (equivalent to 2% of the world catch).[53] Although New Zealand exports to Annex 1 countries, our principal competitors are non-Annex 1 countries located in Asia and South America. New Zealand fishers probably cannot pass much of the increased production cost on to their consumers but they may not change their output level much. Currently the major commercial fisheries are highly profitable as is reflected in the value of the quota. The main impact in many fisheries may be a fall in quota value.

There is strong Maori involvement in the seafood industry. 33% of quota is allocated specifically to Maori interests (through Sealord and Moana Fisheries) as part of a Waitangi Treaty settlement, with additional interests held by iwi. 22% of the industry participants are Maori.

In most situations, there is only minor potential for biomass substitution/extension of the fuel. In the past, there has been some interest in a return to wind for propulsion, which may have a very limited appeal. Expertise developed in the recreational and sports sailing markets may find special niche applications in the fishing sector, but has not been considered to date.

A4.4 Forestry and Forest Products

New Zealand has been characterised by rapidly developing forestry resources. Currently about a third of the plantation forests will count as Kyoto forests. Current forests may become permanent forests if the international carbon charge is high enough. The forestry area may also expand.

Renewable energy studies have been based on the assumption that forestry activities will accelerate in proportion to the developing forests, with a similar percentage of wood processing within New Zealand. As charges and their effects become clearer, this assumption will have to be revisited. All assumptions of a high availability of surplus woody biomass as a fuel resource will require active national processing of the wood resource rather than leaving trees standing, or exporting as logs.

The forest processing industry is energy intensive. Energy usage in sawmilling has increased as greater emphasis has been placed on controlled quality through kiln drying of timber. Laminate and panel plants are more energy intensive with high electricity and heat requirements – similarly for the pulp and paper industry. However, all of these industries have been leaders in the use of wood processing waste, and also of geothermal energy, in meeting their energy needs.

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[53] SeaFIC Submission to the New Zealand Climate Change Programme on Ratification of the Kyoto Protocol, 20 December 2001

A large portion of timber processing facilities is located in the Central North Island and Northland. Currently 63% of wood supply comes from these areas, though the percentage will decrease to 50% by 2012 despite increased production, because of the even larger increased production elsewhere. Thus a high proportion of the resource may have proximity to geothermal heat.[54]

While this sector is generally rated as being neutrally impacted, there are opportunities for increased use of renewable resources. The major Central North Island forestry resources are located near geothermal fields, and some processing plant has been located to potentially take advantage of this opportunity e.g. plant located at Kawerau and Taupo. There may also be an opportunity at Kinleith (although the Mangakino geothermal field has an interim "Protected 2" status). There is further opportunity to use waste wood product e.g. in 1998 approximately 45% of kiln drying used wood or bark as a fuel.

The Norske Skog Tasman site and adjacent Carter Holt Harvey facilities represent an example of a highly integrated geothermal and waste wood usage, and the opportunity for further expansion of these resources. The Tasman site is the largest user of geothermal process heat in the world. Hog fuel has also been a large part of its cogeneration facilities over its 40 year plus life. Recent sale of plant by Fletchers to Norske Skog has been followed by a more symbiotic approach between Norske Skog and CHH, the result of which could see addition heat and electricity generation to benefit the CHH site currently fired by gas. Plant is located on the Kawerau geothermal field, with field facilities capable of major expansion.

A4.5 Oil and Gas Refining

This sector is forecast to be negatively impacted by a carbon charge. The process is energy intensive utilising waste (or low value) products from the process as fuel. Opportunities for energy reduction will be limited. Nevertheless, the refinery may be able to assist with the blending of biofuels (bioethanol and biodiesel) for national consumption. This may be an "at risk" industry.

A4.6 Cement

The New Zealand cement industry comprises Golden Bay Cement (part of Fletcher Building Ltd, employing 120 people in Northland and 62 others elsewhere, with a plant capacity of 600,000t/year), and Milburn Cement (part of the Holcim Ltd group, employing 662 people with their 500,000t/year cement plant located in Westport). Both companies include downstream marketing of construction related products, including major use of shipping and road transport.

NZIER predict total failure of the industry in the event of significant carbon taxes unless it is exempt as under Scenario 3. ABARE do not clearly separate out this sector. This may be an "at risk" industry.

Cement is an energy intensive business with energy costs accounting for 40% of production costs. The industry has already installed major technology upgrades at both sites. It has done some fuel switching to waste oil and has looked at the possibility of using wood waste. There is little profit margin so a small increase in cost may render the product uncompetitive with cement products from manufacturers not subject to a carbon tax.

[54] See East Harbour (2002a)

Both companies report some further potential for fuel switching, the possibility of further efficiency upgrades and emissions reduction opportunities from marketing blended cements. As an example, Golden Bay has recently started a sales campaign for a microsilica product. Both companies had voluntary agreements for emissions reduction. Golden Bay achieved an 8% emissions reduction per tonne of cement between 1990 and 2000 (assisted by 15% reduction in electricity use, change to bituminous coal, and use of product extenders), while Milburn achieved a 12.45% reduction per tonne. Milburn has been assisted by significant energy savings of 19% over 1990 levels.

Milburn has helped to set up Geocycle Ltd as a supplier of waste products as fuel sources to its operations. In 2000, Milburn shipped in 11,000 tonnes of used oil into Westport from around New Zealand to substitute for coal in its kilns. Use would have been greater, but there was a shortage of supply, such that Milburn has been actively searching for alternative waste fuels.

Golden Bay has made significant progress towards use of waste wood as a fuel source but implementation requires establishing a sufficiently secure source of supply to justify an investment. Golden Bay will then look for a partnership with industry to implement the project[55] .

In 1916, Golden Bay's predecessor (the Dominion Portland Cement Co. Ltd) commissioned the 2MW Wairua Falls hydro station in Northland. This was subsequently expanded to 3MW, and for a considerable period of its operating life exported electricity into the local Northland network.

The Milburn cement supply (and waste oil import) is one of the major users of the Westport port.

Local supply of cement has value as a price setter.

A4.7 Iron and Steel

BHP New Zealand Steel is rated as the company most susceptible to failure in the event of a carbon charge i.e. this seems likely to be an "at risk" industry. ABARE predicts a very negative impact. This is because of its reliance on large quantities of Huntly sub-bituminous coal in the reduction process for iron manufacture, and for calcining limestone. The plant is reported as being marginally profitable. A small carbon tax would reduce competitiveness as an exporter, and would lead to further divergence with the already cheaper steel imports.

The process of converting iron sand into pig iron was pioneered in New Zealand at this plant, which was subsequently sold to, and upgraded by BHP.

Coal is reacted with local titanomagnetite iron sand in a reduction process. Both coal and iron sand are passed through Multiple Hearth Furnaces for drying, coal devolatisation and concentrate preheating. The energy for the furnaces is from partial combustion of evolved coal volatiles. Hot exhaust gases together with Melter off-gas are combusted in after-burners and passed through heat recovery boilers that feed steam to the steam turbine. Hot char and concentrate from the furnaces pass through rotary kilns for the reduction process. Air is combusted with some of the CO gas and char to supply the energy requirements. The

[55] See Golden Bay Cement (2001).

product is then fed to the Electric Melting Furnaces supplied with energy via Soderberg electrodes. Correction materials (lime for slag basicity control and concentrate for oxygen potential control) can be charged in these furnaces. The ability to carry out reduction in the Melters as well as in the kilns allows a trade-off between coal and electricity for the supply of reduction energy.[56]

The company has implemented major efficiency gains, including New Zealand's largest cogeneration project utilising a bottoming cycle steam turbine rated at 74MW commissioned in 1997 (this plant is now owned/operated by Duke Energy). CO_2 emissions level are similar to BHP's other steel mills in Australia. There are probably few efficiency gains remaining.

The process appears to be a carefully managed process, and it is not clear that, say woody biomass could substitute for coal. Substitution would impact on the performance of the cogeneration plant owned by a third party.

A severe impact on the viability of the BHP New Zealand Steel operation would impact negatively on the cogeneration plant. This is Duke Energy's only New Zealand private power investment. General support for private power investors is required because of the large number of renewable projects that must be implemented to achieve renewable goals suggested by government.

In an environment where heavy investment in renewable energy infrastructure is about to be made, there would appear to be some value in local steel manufacture helping to set a minimum price for steel.

A4.8 Aluminium

While the New Zealand Aluminium Smelter (NZAS) plant at Tiwai Point is recognised as the largest consumer of electricity in New Zealand, it also has significant carbon emissions associated with the production and then deterioration of the carbon anodes in the pot lines. NZIER sees the plant as likely to be exempted (this would be an "at risk" industry) or protected by its long term electricity contracts. The ABARE study indicates that the "nonferrous metals" sector will experience a major reduction in output if not exempt.

The Tiwai Point smelter is the largest single electricity consumer in New Zealand. The plant uses electricity to convert alumina to aluminium via an electrolytic reduction process. It is jointly owned by Comalco (79.36%) and Sumitomo (20.64%). The plant includes a carbon plant (for production of carbon anodes), four reduction lines (with a total capacity of 330,000 tonnes of aluminium per annum) and a metal casting facility and employs 900 staff. More than 90% of the product is exported, mainly to Asia. The product is an international commodity with the Tiwai Point smelter having to compete with 140 other smelters world-wide. Aluminium is New Zealand's largest export earner ($1.1billion in 2000), although associated with imports of alumina for processing. The company undertook a $464million upgrade in the mid-90's that is New Zealand's largest industrial investment in recent years.

The predominant energy source is electricity for the smelter operation. It has a steady demand due to its continuous operation equivalent to around 5,000GWh/year (about 12-15% of the national electricity demand). The plant receives a preferential electricity price under a long-term contract. While there is a nominal link between Manapouri hydro station and the

[56] See Burrow et al (1991)

smelter (the commitment to the smelter justified the governments investment in the Manapouri project), the smelter is clearly connected to the national grid. If the plant were allowed to fail, then a significant problem would develop with the 750MW of Manapouri generation. There would be transmission constraints out of Southland, followed by severe restrictions from the HVDC link forcing large amounts of South Island hydro spill.

In addition, coal and heavy fuel oil are used in the production of the carbon anodes, which are manufactured on site. These anodes degrade in the potlines with resulting CO_2 emissions.

NZAS has participated in a voluntary emissions reduction agreement, which has seen GHG emissions reduced 36% below the 1990 level and CO_2/tonne of product reduced by 14% below the 1990 level. At the same time, energy efficiency/tonne has improved by 9.8% on 1990 levels.

The plant is located in the wind region known as "Foveaux Strait and SE Hills" from which electricity can be generated at around 8c/kWh.

A4.9 Ammonia/Urea

MED's database on "Energy Greenhouse Gas Emissions" highlights the Ammonia/Urea plant as a single point source major emitter of CO_2.[57]

The plant, for which natural gas is both feedstock and fuel, includes a 2.5MW cogeneration plant, partly to ensure reliability of electricity generation.[58] There are no major forests or wood processing plants in the vicinity so a biomass fuel solution is unlikely. Gas is fired in a gas turbine linked to a heat recovery boiler with supplementary firing of gas. About 7t/h of steam is from the turbine exhaust, while the rest (about 20t/h of steam) is from direct gas firing. High pressure steam is fed to the ammonia plant. A portion is let down in pressure via a steam turbine to the urea plant. The steam turbine is used to provide a direct drive to a carbon dioxide compressor.

Ballance Agri Nutrients Ltd have expressed an intention to continue operation indefinitely and certainly beyond 2005.[59]

A4.10 Coal

The coal industry will be severely impacted by carbon charges, as the country starts a move away from fossil fuels. A portion of mined coal is exported, and supply in this area may continue despite widespread reductions in coal supply.

The coal industry is proactive in promoting voluntary emissions reductions. The major research group, CRL Energy has diversified interests to include research into woody biomass applications.

A4.11 Electricity

Both ABARE and NZIER predict a decrease in electricity consumption. Any decrease will be at the expense of plant with high fuel and operating costs. This will naturally reduce the emissions from fossil-fuelled plant, with coal and less efficient gas plant experiencing the greatest reduction in dispatch. Any further commissioning of renewable (low emission)

[57] See MED (2001b)
[58] See Zoellner (1991)
[59] From Bay of Plenty Fertiliser Submission on the Draft National Energy Efficiency and Conservation Strategy

generation will make further inroads into fossil-fuelled generation (provided transmission constraints are removed between South Island generation options and the Auckland demand centre).

The current long term contracts (both take-or-pay contracts for gas, and contracts-for-difference for electricity) are such that new gas-fired generation plant including the Southdown and TCC plants have been base-loaded even through the low demand summer period. The two types of contracts have allowed the projects to be "project financed" with guaranteed returns, even when the plant is offered to the market at zero price. As such, despite the apparent costs of fuel, it is possible for these gas-fired plants to be dispatched ahead of other renewables.

Promotion of renewable generation options is discussed in detail in an earlier section.

A4.12 Gas

The gas industry will also be negatively impacted according to both analyses. If electricity consumption drops then this will impact on gas sales. There will conceivably be areas of growth in gas sales despite charges, as emphasis grows on energy efficiency through use of cogeneration or combined cycle plant. There could be domestic and commercial sales increase as emphasis is put on quality of electricity generation.

At a distribution level, there is opportunity to use minor quantities of landfill or sewage gas, but this would be highly dependent on the proximity of sources and pipelines. Such developments would be helped by a tax including methane discharges.

The product gas from biomass gasification (mainly CO) could also displace or dilute some distributed supplies. However, such action will require a respecification of receiving equipment for the lower calorific value.

13 APPENDIX 5: REGIONAL CONSIDERATIONS

Region	Economy and Population[60]	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.1 Northland	GDP (1998) = $3.3 billion GDP growth (1993-1998) = 4.8%/a Population = 140k Population growth (1991-1996) = 1.7%/a Maori = 32% of population Employment (1998) = 46k FTEs 52% are urban (most strongly rural region in New Zealand)	***Carbon Sinks*** Forestry ***High Emitters*** Petroleum Refining (12.2% GDP, 0.8% FTEs) Dairy (5% GDP, 8% FTEs) (9% of national stock) Cement Reduction ***Medium Emitters*** Forest Processing and Logging (3.1% GDP, 1.4% FTEs, output will increase by factor of 3.5 by 2012) Fishing Industry (0.7% GDP, 1% FTEs) Port (28% of national volume) Meat Processing ***Low Emitters*** Wholesale and Retail Trade (9.9% GDP, 15% FTEs) Construction (3.5% GDP, 7% FTEs) Tourism (>1.7% GDP) Engineering (boat building) Fertiliser works Horticulture	***Local Renewables*** Hydro (small) Biomass (LVL plant) Cogen (small) Geothermal ***Imported*** Electricity Gas Coal ***Local (other)*** Refinery Gas Coal	***Local Renewables*** Wind Biomass (LVL plant) Cogen (small) Geothermal ***Imported*** Electricity Gas Coal ***Local (other)*** Coal	***Geothermal*** Resource –focussed at Ngawha – of limited size, high gas content and relatively expensive to develop ***Hydro*** too costly ***Wind*** cost greater than 10 c/kWh ***Biomass*** increased quantity of process residue is expected ***Electricity*** very high AC Loss Factor reliant on import via Auckland and south ***Gas*** prices are high, reliant on import via Auckland and south ***Coal*** little used local resource majority imported to region (cement manufacture)

[60] See McDermott Fairgray Group (2000)

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	**Future**	
13.2 Auckland	GDP (1998) = $31.7 billion GDP growth (1993-1998) = 5.6%/a Population = 1,100k Population growth (1991-1996) = 2.5%/a Most densely populated area in New Zealand Employment (1998) = 481k FTEs	***High Emitters*** Chemical plant Dairy Iron & steel processing International airport Electricity generation (thermal) ***Medium Emitters*** Meat processing Other manufacturing (40% of national) Construction Forest Processing (expanding) Port Defence Fishing Industry (0.2% GDP, 0.2% FTEs) – a processing centre ***Low Emitters*** Wholesale and Retail Trade (15% GDP, 21% FTEs) Services including Communications (11.7% GDP, 13% FTEs) Commerce (11.8% GDP, 3.6% FTEs) Tourism Horticulture (40% of national)	***Local Renewables*** Hydro (small) Biomass Geothermal (heat only) ***Imported*** Electricity Gas Coal ***Local (other)*** Cogen (small) Electricity generation (thermal)	***Local Renewables*** Wind Biomass Geothermal (heat only) ***Imported*** Electricity Gas Coal ***Local (other)*** Cogen Electricity generation (thermal)	***Geothermal*** Resource - small, low temperature not suitable for electricity generation ***Hydro*** too costly ***Wind*** cost greater than 10 c/kWh ***Electricity*** high AC Loss Factor largely reliant on import from South ***Gas*** reliant on import from South ***Coal*** imported to region (iron/steel manufacture)

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.3 Waikato	GDP (1998) = $8.8 billion GDP growth (1993-1998) = 3.2%/a Population = 350k Population growth (1991-1996) = 1.1%/a Maori = 21.3% of population Employment (1998) = 139k FTEs Strongly agricultural region	***Carbon Sinks*** Forestry (expanding) ***High Emitters*** Dairy (7.4% GDP, 4% FTEs) (36% of national herd) Electricity Generation and Distribution (thermal is high emitter, hydro and geothermal are low emitters) (3.2% GDP, 0.3% FTEs) Chemical plant Coal Mining ***Medium Emitters*** Meat processing Other manufacturing Gold mining Iron sand mining Fishing Industry (0.2% GDP, 0.1% FTEs) ***Low Emitters*** Wholesale and Retail Trade (10.5% GDP, 5.5% FTEs) Services (11% GDP, 6% FTEs) Tourism Commerce Timber Processing (expanding) Horticulture	***Local Renewables*** Hydro (electricity)) Geothermal (electricity) Biomass Geothermal (heat only) ***Imported*** Gas Electricity ***Local (other)*** Cogen (electricity) Electricity generation (thermal) Coal	***Local Renewables*** Wind Hydro (electricity) Geothermal (electricity) Biomass Geothermal (heat only) ***Imported*** Gas Electricity ***Local (other)*** Cogen (electricity) Electricity generation (thermal) Coal	***Geothermal (electricity)*** major concentration of high temperature resources about 7c/kWh ***Hydro*** very limited resource at reasonable cost ***Wind*** cost greater than 8.25 c/kWh ***Electricity*** constraint on supply from South net export from Waikato ***Gas*** reliant on import from South ***Coal*** significant local resource ***Biomass*** significant local resource

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.4 Bay of Plenty	GDP (1998) = $5.6 billion GDP growth (1993-1998) = 4.6%/a Population = 230k Population growth (1991-1996) = 1.9%/a Region attracts retirees. Maori = high percentage of population Employment (1998) = 84k FTEs	***Carbon Sinks*** Forestry (expanding) ***High Emitters*** Electricity generation (thermal) Dairy (8% of national herd) ***Medium Emitters*** Paper and Paper Product Manufacturing (6% GDP, 2% FTEs) Forest Processing and Logging (4% GDP, 2% FTEs) Port Fishing Industry (0.4% GDP, 0.5% FTEs) ***Low Emitters*** Wholesale and Retail Trade (12% GDP, 17% FTEs) Services (6% GDP, 9% FTEs) Construction (4% GDP, 9% FTEs) Horticulture (3% GDP, 6% FTEs) Tourism Fertiliser works Electricity generation (geothermal) Electricity generation (hydro)	***Local Renewables*** Hydro (electricity) Geothermal (electricity) Biomass Geothermal (heat) ***Imported*** Gas Electricity Coal ***Local (other)*** Cogen (electricity) Electricity generation (thermal)	***Local Renewables*** Wind Hydro (electricity) Geothermal (electricity) Biomass Geothermal (heat) ***Imported*** Gas Electricity Coal ***Local (other)*** Cogen (electricity) Electricity generation (thermal)	***Geothermal (electricity)*** major concentration of high temperature resources about 7c/kWh high tourism value ***Hydro*** very limited resource at reasonable cost ***Wind*** cost greater than 8.25 c/kWh ***Geothermal (heat)*** includes largest application in the World (timber processing) low temperature resources, e.g. Tauranga ***Gas*** reliant on import from outside region ***Biomass*** significant local resource

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.5 Gisborne/ Hawkes Bay	GDP (1998) = $4.5 billion GDP growth (1993-1998) = 3.5%/a Population = 192k Population growth (1991-1996) = 0.9%/a High proportion of Maori (>20%) Employment (1998) = 70.3k FTEs Region is dominated by horticulture, farming and forestry	***Carbon Sinks*** Forestry (expanding) ***High Emitters*** Chemical plant Food processing ***Medium Emitters*** Forest Processing and Logging (expanding) (>1.6% GDP, 0.7% FTEs) Meat Processing (6% GDP, 10% FTEs) Other manufacturing Port Fishing Industry (0.4% GDP, 0.4% FTEs) ***Low Emitters*** Wholesale and Retail Trade (11% GDP, 15% FTEs) Horticulture (5% GDP, 9% FTEs) Livestock (4% GDP, 7% FTEs) Finance (3% GDP, 1% FTEs) Construction (3% GDP, 5% FTEs) Services Tourism Fertiliser works Electricity generation (hydro)	***Local Renewables*** Hydro (electricity) Biomass Cogen ***Imported*** Electricity Gas Coal ***Local (other)*** Geothermal (heat)	***Local Renewables*** Hydro (electricity) Wind Biomass ***Imported*** Electricity Gas Coal ***Local (other)*** Geothermal (heat)	***Hydro*** Very limited resource at reasonable cost ***Wind*** cost greater than 10 c/kWh ***Electricity*** high ACLF quality/ACLF affected by Tuai generation ***Gas*** reliant on import from outside region local resource investigated, yet to be developed ***Biomass*** significant local resource

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.6 Taranaki	GDP (1998) = $3.2 billion GDP growth (1993-1998) = -2.7%/a Population = 105.6k Population growth (1991-1996) = -0.1%/a 91% European population Employment (1998) = 42.7k FTEs Region is dominated by farming and oil and gas industry	***High Emitters*** Oil and Gas Production (7% GDP, 1% FTEs) Petroleum and Chemical Products (incl. Methanol and Ammonia/Urea) (6.5% GDP, 1.5% FTEs) Dairy Products (6% GDP, 4% FTEs) (15% of national herd) Electricity generation (thermal) ***Medium Emitters*** Meat processing (3% GDP, 4% FTEs) Port (2) Fishing Industry (0.1% GDP, 0.1% FTEs) ***Low Emitters*** Dairy farming (9% GDP, 15% FTEs) Wholesale and Retail Trade (9% GDP, 14% FTEs) Services Engineering Electricity generation (hydro)	***Local Renewables*** Hydro (electricity) ***Imported*** Electricity Coal ***Local (other)*** Gas Cogen (electricity) Electricity Generation (thermal)	***Local Renewables*** Wind Hydro ***Imported*** Electricity Coal ***Local (other)*** Gas Cogen (electricity) Electricity Generation (thermal)	***Hydro*** very limited resource at reasonable cost ***Wind*** cost greater than 12.5 c/kWh ***Electricity*** export constraints ***Gas*** Taranaki is New Zealand's gas centre

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.7 Wanganui/ Manawatu	GDP (1998) = $5.3 billion GDP growth (1993-1998) = 1.2%/a Population = 230k Population growth (1991-1996) = 0.4%/a Maori = 18% of population Employment (1998) = 85k FTEs	***Sink*** Forestry (expanding) ***High Emitters*** Chemical plant Dairy processing (8% of national herd) Food processing ***Medium Emitters*** Forest Processing Defence Meat processing Other Manufacturing Fishing Industry (0.2% GDP, 0.3%) ***Low Emitters*** Services Incl. Education (12% GDP, 16% FTEs) Wholesale and Retail Trade (12% GDP, 12% FTEs) Livestock (4% GDP, 8% FTEs) Construction (4% GDP, 6% FTEs) Finance (3%GDP, 1% FTEs) Tourism Engineering Dairy farming Electricity generation (wind) Electricity generation (hydro)	***Local Renewables*** Hydro (electricity) Wind Biomass ***Imported*** Electricity Gas Coal ***Local (other)*** Cogen (electricity)	***Local Renewables*** Wind Hydro (electricity) Biomass ***Imported*** Electricity Gas Coal ***Local (other)*** Gas Cogen (electricity)	***Hydro*** limited resource at reasonable cost/ accessibility ***Wind*** cost greater than 7.25 c/kWh prime wind resource ***Electricity*** region has import and export constraints, particularly export north ***Gas*** reliant on import ***Biomass*** significant local resource in north of region; developing south

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.8 Wellington	GDP (1998) = $12.3 billion GDP growth (1993-1998) = 2.2%/a Population = 429k Population growth (1991-1996) = 0.7%/a Maori = 13% of population Employment (1998) = 186k FTEs	***Sink*** Forestry (expanding) ***High Emitters*** Chemical plant International airport Food processing ***Medium Emitters*** Defence Meat processing Timber Processing (expanding) Other manufacturing Port Fishing Industry (0.2% GDP, 0.3% FTEs) (local processing accounts for 50% of the national industry GDP contribution) ***Low Emitters*** Services Incl. Education (24% GDP, 29% FTEs) Wholesale and Retail Trade (11%GDP, 15% FTEs) Finance (8% GDP, 4% FTEs) Tourism Engineering Construction Dairy farming Electricity generation (wind) Horticulture	***Local Renewables*** Hydro (electricity) Wind Biomass ***Imported*** Electricity Gas Coal ***Local (other)*** Cogen (electricity)	***Local Renewables*** Wind Hydro (electricity) Biomass ***Imported*** Electricity Gas Coal ***Local (other)*** Cogen (electricity)	***Hydro*** limited resource at reasonable cost/ accessibility ***Wind*** cost greater than 7.25 c/kWh prime wind resource ***Electricity*** predominant supply is from DC cable ***Gas*** reliant on import ***Biomass*** local resource in Wairarapa

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.9 Nelson/ Tasman/ Marlborough	GDP (1998) = $3.1 billion GDP growth (1993-1998) = 4.0%/a Population = 121k Population growth (1991-1996) = 2.0%/a Highest median age in country due to number of retirees Employment (1998) = 47.9k FTEs This is a major fishing processing centre.	***Sink*** Forestry (expanding) ***High Emitters*** Food Processing (4% GDP, 6% FTEs) Milk processing ***Medium Emitters*** Fishing Industry (6% GDP, 8% FTEs) Forest Processing and Logging (expanding) (4% GDP, 3% FTEs) Meat processing Other manufacturing Port ***Low Emitters*** Wholesale and Retail Trade (11%GDP, 15% FTEs) Services Incl. Defence (9% GDP, 10% FTEs) Horticulture (5% GDP, 8% FTEs) Construction (>1% GDP, >2% FTEs) Tourism Engineering Dairy farming Marine farming Electricity generation (hydro)	***Local Renewables*** Hydro (electricity) Biomass ***Imported*** Electricity Coal ***Local (other)***	***Local Renewables*** Hydro (electricity) Wind Biomass ***Imported*** Electricity Coal ***Local (other)***	***Hydro*** limited resource at reasonable cost/ accessibility ***Wind*** cost greater than 10 c/kWh ***Electricity*** Possible import constraints ***Gas*** no natural gas pipeline connection reliant on bottled, etc. gas supply ***Biomass*** large local resource

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.10 **West Coast**	GDP (1998) = $0.83 billion GDP growth (1993-1998) = 0.7%/a Population = 32.6k Population growth (1991-1996) = 0.6%/a Employment (1998) = 11.9k FTEs Has the lowest population density in the country	***Sink*** Forestry (expanding) ***High Emitters*** Dairy (5% GDP, 7% FTEs) Cement (4% GDP, 1.5% FTEs) ***Medium Emitters*** Coal/Gold Mining and Quarrying (6% GDP, 5%FTEs) Forest Processing and Logging (expanding) (5% GDP, 3% FTEs) Fishing Industry (2% GDP, 3% FTEs) Meat processing Port ***Low Emitters*** Wholesale and Retail Trade (9% GDP, 14% FTEs) Tourism (5% GDP, 10% FTEs) Services Electricity generation (hydro)	***Local Renewables*** Hydro (electricity) Biomass ***Imported*** Electricity Waste oil (cement kiln fuel) ***Local (other)*** Coal	***Local Renewables*** Hydro (electricity) Biomass ***Imported*** Electricity Waste oil (cement kiln fuel) ***Local (other)*** Cogen (electricity) Coal	***Coal*** significant resource available multiple use, including coal bed methane ***Hydro*** some resources available at reasonable cost ***Electricity*** import constraints large uptake of local hydro would be subject to export constraint ***Gas*** no natural gas pipeline connection reliant on bottled, etc. gas supply ***Biomass*** local resource ***Other*** Waste oil availability

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.11 Canterbury	GDP (1998) = $12.6 billion GDP growth (1993-1998) = 3.6%/a Population = 490k Population growth (1991-1996) = 1.3%/a Maori =7% of population Employment (1998) = 193k FTEs	***Sink*** Forestry (expanding) ***High Emitters*** Dairy (7% of national herd but growing) Food processing International airport ***Medium Emitters*** Meat processing Fishing Industry (more geared to large scale commercial operations) (0.6% GDP, 0.8% FTEs) Other manufacturing Defence Port (2) Timber Processing (expanding) ***Low Emitters*** Wholesale and Retail Trade (12% GDP, 17% FTEs) Services Incl. Education (11% GDP, 15% FTEs) Construction (4% GDP, 7% FTEs) Finance (4% GDP, 1.5% FTEs) Tourism Dairy farming Engineering (including foundries) Fertiliser works Electricity generation (hydro) Horticulture	***Local Renewables*** Hydro (electricity) Biomass Cogen (electricity) ***Imported*** Electricity Gas Coal ***Local (other)*** Coal	***Local Renewables*** Wind Hydro (electricity) Biomass Cogen (electricity) ***Imported*** Electricity Gas Coal ***Local (other)*** Cogen (electricity) Coal	***Coal*** imported ***Hydro*** significant resources available at low/reasonable cost ***Wind*** cost greater than 10 c/kWh ***Electricity*** large uptake of local hydro may be subject to export constraint ***Gas*** no natural gas pipeline connection reliant on bottled, etc. gas supply ***Biomass*** local resource

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.12 Otago	GDP (1998) = $4.4 billion GDP growth (1993-1998) = 2.2%/a Population = 188k Population growth (1991-1996) = 0.8%/a Employment (1998) = 70k FTEs	***Sink*** Forestry (expanding) ***High Emitters*** Milk processing Food processing International airport ***Medium Emitters*** Meat processing (including fish) Fishing Industry (0.5% GDP, 0.6% FTEs) Other manufacturing Coal mining Gold mining ***Low Emitters*** Wholesale and Retail Trade (11% GDP, 15% FTEs) Education (5% GDP, 10% FTEs) Livestock (4% GDP, 7% FTEs) Tourism (4% GDP, 7% FTEs) Electricity Generation (hydro and biomass) and Distribution (3% GDP, 0.7% FTEs) Services Port (2) Timber Processing (expanding) Dairy farming Engineering (including foundries) Fertiliser works Commerce Horticulture	***Local Renewables*** Hydro (electricity) Biomass Cogen (electricity) ***Imported*** Electricity Gas Coal ***Local (other)*** Cogen (electricity) Coal	***Local Renewables*** Wind Hydro (electricity) Biomass Cogen (electricity) ***Imported*** Electricity Gas Coal ***Local (other)*** Cogen (electricity) Coal	***Coal*** some resource available ***Hydro*** significant resources available at reasonable cost ***Wind*** cost greater than 12.5 c/kWh ***Electricity*** large uptake of local hydro may be subject to export constraint ***Gas*** no natural gas pipeline connection reliant on bottled, etc. gas supply Dunedin has a reticulation system ***Biomass*** local resource

Region	Economy and Population	Major Industries (Demand & Supply)	Energy Resources		Energy Notes
			Current	Future	
13.13 Southland	GDP (1998) = $2.6 billion GDP growth (1993-1998) = 2.0%/a Population = 94k Population growth (1991-1996) = -0.6%/a Maori = 11% of population Employment (1998) = 40k FTEs Strongly agricultural region	***Sink*** Forestry (expanding) ***High Emitters*** Milk processing Food processing Electricity generation (thermal) ***Medium Emitters*** Meat processing (7% GDP, 8% FTEs) Smelter (aluminium) (4% GDP, 3% FTEs) Fishing Industry (1% GDP, 1.4% FTEs) Other manufacturing Coal mining Gold mining Port (2) Timber Processing (expanding) ***Low Emitters*** Wholesale and Retail Trade (10% GDP, 14% FTEs) Livestock (9% GDP, 15% FTEs) Construction (3% GDP, 6% FTEs) Services Tourism Dairy farming Engineering (including foundries) Fertiliser works Electricity generation (hydro) Horticulture	***Local Renewables*** Hydro (electricity) Biomass Cogen (electricity) ***Imported*** Electricity Gas Coal ***Local (other)*** Cogen (electricity) Coal	***Local Renewables*** Wind Hydro (electricity) Biomass Cogen (electricity) ***Imported*** Electricity Gas Coal ***Local (other)*** Cogen (electricity) Coal	***Coal*** some resource available ***Hydro*** some resources available at reasonable cost ***Wind*** cost greater than 8.25 c/kWh ***Electricity*** dominated by Manapouri (supply) and smelter (demand) large uptake of local hydro may be subject to export constraint ***Gas*** no natural gas pipeline connection reliant on bottled, etc. gas supply ***Biomass*** local resource