Developing Hydrogen as a Future Energy Carrier

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Summary

The key question is; will hydrogen be the replacement for current fuels? An increasing number of people believe this to be so for a number of reasons. Hydrogen is the first element in the periodic table, is the smallest known atom and is thought to be the most plentiful in the universe. Hydrogen is seen as an environmentally friendly fuel but there are questions about where the required quantities would come from.

The concept of a hydrogen economy is rapidly gaining international momentum to meet the future needs of transport and an evolving distributed electrical energy sector. New Zealand's energy sector could benefit from initiatives now being directed at the promotion of hydrogen as a renewable energy leading to sustainable development. Development of hydrogen for use as an energy carrier to ostensibly replace fossil fuels is touted by many as an ideal choice and for New Zealand, may lead to a range of economic, environmental and social benefits. The attraction of hydrogen by many people is that it is viewed as a clean, transportable, renewable fuel that can be made from abundant global resources. It is an energy storage medium (energy carrier) with a very long shelf life. While hydrogen does have a low-energy density compared to other storable fuels, the attraction for its use relates to its, manufacturability, clean combustion, transportability and storage.

Several major nations and groups (e.g. USA and the EU) have and are developing strategies and national policies to guide development of hydrogen for energy use. While New Zealand does not currently have a specific strategy for the development of hydrogen energy there are several legislative and policy measures that enable considerable progress to be made. The range of energy-related Government initiatives include the Growth and Innovation Framework and Sustainable Development Initiatives arising from this, the National Energy Efficiency Strategy (NEECS), and other energy policies that potentially can have a positive effect on the wider renewable energy options.

In New Zealand, hydrogen aligns particularly well with the sustainable development initiatives in the energy sector where the desired outcomes are to promote more efficient and less wasteful use of energy and to ensure renewable sources of energy are developed and maximised. Overarching this is to provide energy options that ensure consumers have a secure supply of electricity. As New Zealand relies heavily on transport for the functioning of its economy (e.g. imports, exports) this must extend to security of transport energy.

However, developing hydrogen for use as a major energy carrier will require solutions to many challenges in the areas of infrastructure, technology, and economics some of which are alluded to in this paper.

The global context

It is often claimed that during the next twenty years the energy sector will undergo changes as fundamental and far-reaching as those seen in the telecommunications area during the past twenty. Central to these changes is the desire for security of energy supply and for energy that is cheap, renewable and has minimal environmental effects. Hydrogen has been touted as a prime candidate for being the prime energy carrier of the future — this is commonly called the Hydrogen economy.

The use of hydrogen would see a fundamental change in the supply and use of primary energy sources initially for the electricity and transport sectors. The sectors are presently supported by an embedded infrastructure, developed and proven technology, along with policy and political issues. The move to a hydrogen-based fuel scenario will require a level of paradigm shift that is not only a technology challenge but also an educational one.

Hydrogen could provide widespread benefits such as minimal environmental impacts due to rapid advances in hydrogen conversion and storage technology. Hydrogen could be viewed as a clean, storable, and transportable fuel that can be made from abundant resources; the most obvious are natural gas or water. It is first on the periodic table and is thought to be the most abundant element in the universe.

Few energy carriers have the versatility to be able to be used for electricity generation for use in buildings as well as able to be used as a transport fuel. Many of the world's developed economies and energy multinationals are increasingly stating the inevitability of moving toward a hydrogen-based

energy economy. Large automobile manufactures are gearing up to produce production-line vehicles to be run on hydrogen within the next few years. Other transport modes such as shipping and aircraft are also looking at the feasibility of using hydrogen as a fuel.

The move toward a hydrogen based energy economy stems from three key drivers:

- Increasing environmental concerns and global climate change policies.
- Rapid advances in technologies applicable to hydrogen.
- Increasing demands for clean, renewable, transportable energy.

Each of these acting in isolation would be a powerful enough drive for change. But these are issues affecting the world and the combination is proving to be a very strong force for change. These considerations are applicable to New Zealand and very strongly suggest that our country should begin now to develop national knowledge and capability to underpin its own transition to a hydrogen economy and be well placed to benefit fully from the opportunities offered by hydrogen energy.

International energy and economic forecasts have identified immense market potential and high growth rate for developing a hydrogen economy for example Price Waterhouse Coopers forecast that by 2020 hydrogen technologies will exceed US$1.7 trillion dollars in worldwide sales. The Boston Consulting Group has predicted that fuel cells will power one car in 5 being produced in 2020; Frost & Sullivan report #7834-18 predicts that between 2015-2020, sales of Fuel Cell Electrical Vehicles (FCEV) will exceed sales of conventional vehicles.

Forecasts such as these have contributed to the rationale for several major countries and groups writing strategies for developing hydrogen as a fuel for the future. Some of these are listed below:

The US Hydrogen Roadmap[1] provides a 'blueprint' for the long-term efforts required for hydrogen energy development. US$1.2b is to be spent on developing hydrogen technology.

Spencer Abraham, Secretary of Energy, US Department of Energy in 2003 delivered the announcement for the increased US effort to developing hydrogen energy. In his speech[2] he made the statement "It is my vision that a child born today will, by the time he/she is 20, be buying, as its first car, a Hydrogen car". This announcement of a significant level of funding for hydrogen research will accelerate international implementation of the hydrogen economy.

The European Union (EU) has also launched an initiative to develop Hydrogen and Fuel Cells[3]. The Group driving this comprises top level representatives from major EU automotive and energy companies, public utilities, research institutes, transport companies and policy makers. They will assess the potential benefits of using hydrogen and fuel cells in EU transport, energy production and many other areas, and help pave the way for more focused EU action in this field. Their agenda will be to develop a strategy for hydrogen and fuel cell research and deployment and commercialisation actions, taking into account issues such as innovation, marketing, distribution and infrastructure, safety, public/private partnerships and investments in the hydrogen sector.

Other countries have also begun developing plans for the integration of hydrogen energy into the mix of options currently available. The following are those that have published strategies:

Germany's Hydrogen Vision[4]

Hydrogen Plan of Iceland[5]

Japan's Hydrogen Vision[6]

Towards a Hydrogen Economy (BP)[7]

The Italian Hydrogen National Programs: strategies, resources and perspectives[8]

The New Zealand context

Energy researcher Jonathan Leaver, from UNITEC in Auckland has advanced a robust model[9] to show that by 2030, 30-50% of the NZ vehicle fleet could be converted to fuel cell efficient vehicles using hydrogen. Jonathan Leaver's model predicts a 2020 introduction of fuel cell technology into New Zealand's vehicle fleet, with 30-50% market penetration by 2030. This predicts 150PJ of conventional fuel being displaced by hydrogen, which is equivalent to 1 million tonnes of hydrogen p.a. and equates to a NZ$ 4.5 billion industry p.a. (2003 dollars) for transport fuel costs alone.

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[1] http://www.energy.gov/HQPress/releases03/aprpr/pr03089.htm
[2] http://www.edie.net/news/Archive/6601.cfm
[3] http://europa.eu.int/rapid/start/cgi/guesten.ksh?p_action.gettxt=gt&doc=IP/02/1450|0|RAPID&lg=EN&display=
[4] http://www.iea.org/workshop/2002/hydrogen/keynotes/Germany.pdf
[5] http://www.iea.org/workshop/2002/hydrogen/keynotes/Iceland.pdf
[6] http://www.iea.org/workshop/2002/hydrogen/keynotes/Iceland.pdf
http://www.iea.org/workshop/2002/hydrogen/keynotes/Japan.pdf
[7] http://www.iea.org/workshop/2002/hydrogen/keynotes/bp.pdf
[8] http://www.iea.org/workshop/2002/hydrogen/keynotes/Italy.pdf
[9] Leaver, J. (2003). Int. Jnl. of Hydrogen Energy 28, p. 795.

The strong indications are that the change to widespread use of hydrogen will occur and will be world-wide. This presents New Zealand with some great opportunities as an early adopter to capitalise on the development of what could be a very large new industry worth billions of dollars. Already there is a fledgling research effort and there are a number of energy policy initiatives that have the potential to encourage future hydrogen energy production and use. The current policy statements and legislation provide the basis for developing leading edge technological solutions for a hydrogen economy which is in-line with government aspirations for developing New Zealand's economic base as well as improving our positive environmental image. A selection of these policies is briefly discussed below.

Growth and Innovation Framework

In February 2002, following extensive consultation, the Government issued a report entitled "Growing an Innovative New Zealand[10]". This report contained what is now known as the Growth and Innovation Framework (GIF), this being an umbrella policy document for government action. The Government's aim for the GIF is to return New Zealand's per capita income to the top half of the OECD, and then to maintain that standing.

The two key aspects for building an economy capable of sustaining the higher growth rates needed are:

- Strengthening the foundations (including such elements as sustaining a stable macroeconomic framework and an open and competitive microeconomy, and a solid research development and innovation framework), and
- Building more effective innovation (including elements such as enhancing the existing innovation framework, enhancing the talents and skills of New Zealanders, increasing global connectedness (including encouraging foreign direct investment), and focussing initial government efforts on three sectors (biotechnology, information and communications technology and creative industries) deemed to have both high growth potential combined with the ability to enhance productivity across the whole economy).

There are four broad means by which the framework will be given effect:

1. Ministerial leadership across all related portfolios, including alignment of policies that impinge on economic transformation with the growth and innovation objectives. This will particularly impact on government agencies such as the Ministry for Economic Development (MED), Ministry for the Environment (MfE), Energy Efficiency and Conservation Authority (EECA), Ministry of Research, Science and Technology (MoRST), Foundation for Research, Science and Technology (FRST), Ministry of Foreign Affairs and Trade (MFAT) and NZ Trade & Enterprise,
2. Policy and programme development in each of the key areas of enhancing innovation, talent and skills, and global connectedness,
3. A specific budget allocation, and
4. A GIF Cabinet advisory board.

The Government is proactive in supporting growth working co-operatively with other sectors to achieve it and emphasising the importance of sustainable growth and development. As part of the proactive policy the Government has strategic development initiatives aimed at improving infrastructure, services and resources by, for example ensuring efficient electricity and other infrastructure markets, or by amendment to the Resource Management Act.

However, a key aspect to achieving GDP growth will be through strengthening foundations through a solid research development and innovation framework. This could have both positive and negative effects on industry players. The Government is concerned:

- about the low level of private investment in this area,
- with aspects of commercialisation of ideas, and
- with linkages between research institutions to other researchers (including internationally) and with industry.

Sustainable Development Programme of Action for Energy

The Sustainable Development Programme of Action[11] (also known as the Sustainable Development Initiative or SDI) is another of the government's major over-arching documents designed to guide and underpins policy development. It was released in January 2003. It is tied in to the Growth and Innovation Framework, draws together a number of key issues, and signals that the government intends to apply a sustainable development approach to its policy and decision-making processes.

Energy has been identified as one of the target areas for sustainable development because of its correlation to economic growth, potential environmental impact, and because both consumers and industry are heavily reliant on its supply.

The major objective of the programme of action for energy is to ensure continued delivery of energy services to all classes of consumer in an efficient, fair, reliable and sustainable

[10] Anon. (2002). Growing an Innovative New Zealand. Report for the Office of the Prime Minister, Wellington.
[11] Anon. (2003). Sustainable Development for New Zealand Action Plan. Report for Department of Prime Minister and Cabinet, Wellington.

manner. It acknowledges that renewable energy sources will become increasingly important in providing security of supply. Three desired outcomes are identified:

- Energy use in New Zealand becomes progressively more efficient and less wasteful,
- Renewable sources of energy are developed and maximised, and
- New Zealand consumers have a secure energy supply.

Energy Policy Framework

The SDI for Energy now includes what was previously known as the Energy Policy Framework, issued by the Government in October 2000.

The major objective of the Framework has already been outlined above. However, the overall outcomes the Government seeks are:

- Environmental sustainability, including continuing improvement in energy efficiency and a progressive transition to renewable sources of energy,
- Costs and prices to consumers which are as low as possible, while still ensuring that prices reflect the full costs of supply including environmental costs,
- Reliable and secure supply of essential energy services,
- Fairness of pricing, so that the least advantaged in the community have access to energy services at reasonable prices, and
- Continued public ownership of publicly owned assets.

Some of the policies and programmes relating to energy are discussed later, but include:

- Energy efficiency and renewable energy policies (including establishing the Energy Efficiency and Conservation Authority (EECA) as a stand-alone Crown entity with expanded funding, and developing the National Energy Efficiency and Conservation Strategy),
- Climate change policies (including ratification of the Kyoto Protocol, and development of a comprehensive range of policy measures to assist in meeting commitments under the Protocol),
- Electricity reforms (including provision of a governance structure now known as the Electricity Commission for efficient market operation, market rules that promote demand-side participation and facilitate renewable energy while being consistent with policies on energy efficiency and climate change, facilitating distributed generation either by lines companies or other parties, ensuring security of supply, etc), and
- Gas and transport sector reforms.

The National Energy Efficiency and Conservation Strategy

The National Energy Efficiency and Conservation Strategy[12] (NEECS), was released in September 2001. It is one of several foundation documents for the government's climate change initiatives. The strategy aims to improve energy efficiency by 20% and increase the use of renewable energy by 2012. In October 2002, the renewable energy target was clarified to be an increase in consumer energy from renewable sources of 30PJ by 2012 over levels recorded for the year 2000.

The NEECS has six goals:

1. Reduce CO_2 emissions,
2. Reduce local environmental impacts (though recognising local impacts of expanded renewable energy supply),
3. Improve economic productivity,
4. Promote industry development,
5. Improve economic resilience, and
6. Improve health and welfare.

The renewable energy target within the NEECS includes all additional energy above the 2000 datum irrespective of government incentives e.g. the Manapouri Tailrace. The data will be normalised to account for the influence of weather.

Climate Change Office initiatives

The Climate Change Office is hosted by the Ministry for the Environment (MfE), but retains a separate identity. The office has responsibility to the Convenor of the Ministerial Group on Climate Change (Hon Pete Hodgson). It draws on staff from MfE, MED, EECA, MAF and Treasury and has commenced a range of initiatives some of which relate to promoting energy use that does not contribute to climate change effects.

This office was responsible for efforts related to the ratification of the Kyoto Protocol, which was achieved in December 2002 following the enactment of the Climate Change Response Bill.

Resource Management (Energy and Climate Change) Amendment Bill

The Resource Management Act[13] was recently amended to include promotion of renewable energy opportunities setting out clear directions for local government and other parties.

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[12] Energy Efficiency and Conservation Authority (2001). National Energy Efficiency and Conservation Strategy — Towards a Sustainable Energy Future. Report prepared by Energy Efficiency and Conservation Authority and the Ministry for the Environment, Wellington.
[13] http://www.mfe.govt.nz/laws/rma/amendments.html

Of particular relevance is section 7 of the RMA which requires decision-makers to have particular regard to the efficient use of energy, the effects of climate change, and the benefits of renewable energy.

The definition of renewable energy in the Bill is "energy from a source that occurs naturally and the use of which will not permanently deplete New Zealand's energy sources of that kind, because the source is generally expected to be replenished by natural processes".

Distributed generation regulations

This is an initiative centred on the Ministry of Economic Development. Officials have worked with a range of organisations and parallel studies including the Centre for Advanced Engineering study on this topic. Behind the proposed regulations is a recognition that distributed generation will be of increasing importance in future and already plays a significant role in the national electricity mix.

The regulations aim to reduce potential barriers to investment in distributed generation. In particular the proposed regulations have the objective of providing certainty to investors, by means of:

- Clear information requirements and limitation on application processing times,
- Standard contracts,
- Defined interconnection costs with recognition of avoided transmission cost,
- Ongoing connection terms, except where safety requirements are breached.

Assurances to lines companies, by means of:

- Requiring network connection and safety requirements to be met, and
- Requiring payment of reasonable additional costs imposed by distributed generation.
- Dispute resolution procedures, by means of recourse to an arbitrator.

Parliamentary Commissioner for the Environment Review of the electricity sector

The Parliamentary Commissioner for the Environment (PCE) is required (under the Electricity Amendment Act 2001) to assess the environmental performance of New Zealand's electricity sector. Particular attention is given to the performance of the Electricity Commission against the requirements of the associated Government Policy Statement. The framework is "to certify that energy services from electricity are provided in an environmentally sustainable manner through ongoing environmental performance assessments of New Zealand's electricity sector". Annual reports addressing the sustainability of sector operation will be produced.

Research, science and technology initiatives

While the government has set goals for the production of additional energy from renewable sources (i.e. NEECS see above) there are as yet no specific strategic research policy initiatives for enhancing energy from hydrogen in New Zealand. The Foundation for Research, Science and Technology (FRST) makes its research investments in response to signals from Government — through strategies such as GIF or Sustainable Development — and through letters of expectations and high-level instructions from the Minister of RS&T. FRST translates these signals and the strategies developed by various sectors into its portfolio framework for investment. For example, FRST currently promotes research on a range of new energy technology options where the outcomes will lead to developments that give due regard to sustainability concepts. However, without integration into a robust research framework some initiatives and opportunities may lack the credibility needed to achieve the gains indicated.

FRST is currently consulting on development of a revised portfolio framework. Under the draft portfolio framework research relating to developing hydrogen energy could fall into mainly two portfolios; the *Optimising Use of Resources* portfolio for research directly relating to production of energy or the manufacturing portfolio *Advanced Materials Development*. However, rather than being a sector-aligned portfolio (i.e. the current energy portfolios), the new portfolio structure is outcome based. The overarching factor for future investment in research will still be dependent on demonstrating alignment to government priorities such as GIF and the Sustainable Development Initiatives.

Agency co-ordination is essential to the successful implementation of GIF and other government strategies. But operational co-ordination, while necessary, is not sufficient in itself. For the Government's GIF goals to be achieved, it is critical that the strategy work and consequent policy alignment are led by the central policy ministries. High-level discussions with FRST, MoRST, MED, Treasury and others have been held to develop a structure and performance measures.

Research providers who have been involved in recent funding rounds with FRST will be aware of the Growth and Innovation Framework elements required to be included in proposals. These included outlines of linkages with other researchers and commercial groups, human capital development, an emphasis on capturing commercial benefits, and an indication of likely economic benefit flowing from the research.

Funding mechanisms

The Government has a range of R&D funding initiatives, some pre-existing while others were prompted by the Growth and Innovation Framework.

The Government has established the New Zealand Venture Investment Fund which will invest $100m of public money and $200m of private money over 3 years in seed, start-up and early-stage investment through private sector fund

managers. It is improving tax treatment of R&D expenditure, has introduced the Grants for Private Sector R&D (GPSRD) initiative, has increased funding of basic research through the Marsden Fund and New Economy Research Fund (NERF), and is improving our intellectual property framework to ensure New Zealand receives full value for innovations. The Government has also recently introduced the Pre-seed Accelerator Fund and Targeted Equity Investment initiative to assist with the commercialisation of ideas generated in Crown Research Institutes and universities.

Where's the hydrogen?

The U.S. industry annually produces nine million tons of hydrogen, primarily for use as a feedstock and very little as an energy carrier (with the exception of NASA). Steam methane reforming accounts for 95% of hydrogen produced in the U.S. and this catalytic process involves reacting natural gas or other light hydrocarbons with steam to produce a mixture of hydrogen and carbon dioxide[14].

Technical problems still exist for finding a cheap way to separate hydrogen from other compounds and to store the fuel efficiently and safely. However, hydrogen can be produced from a variety of sources, including wind, solar, biomass, fossil fuels, nuclear or solar heat-powered thermochemical reactions, solar photolysis or biological methods. Production from electrolysers which extract hydrogen from water is not as efficient or cost effective as using fossil fuels in steam methane reforming and partial oxidation, but this process would allow for more distributed hydrogen generation and open possibilities for using electricity made from renewable resources. The primary by-products would be oxygen from the electrolyzer and carbon dioxide from electricity generation.

Numerous thermochemical cycles have been proposed for the manufacture of hydrogen from water[15] but practical economic application of the concept remains a major technical challenge.

What is clear is that if hydrogen is to meet tougher global environmental standards it has to be either produced from renewable sources (biomass or solar driven electrolysis for example) or if derived from fossil fuels, linked with carbon sequestration.

To enable wide-spread use of hydrogen one of the key issues to be addressed is the availability of a suitable catalyst. Platinum is known to be excellent for chemically separating hydrogen, but the rare metal costs about $US8000 ($NZ13,988) for 500 grams and calculations have shown the global resource is less than what would be required for the expected number of fuel cells. Researchers at Wisconsin University have made progress in developing alternatives. They tested more than 300 metal combinations before finding that a mix of nickel, tin and aluminium that could separate hydrogen from a mixture rich in glucose, a sugar common in many organic wastes. The combination metal catalyst has been patented and is controlled by the Wisconsin Alumni Research Foundation.

The most likely immediate application of hydrogen would be in fuel cells, which combine hydrogen and oxygen to make electricity, heat and water. With Toyota, Honda, GM, Nissan, Ford, Daihatsu, Mazda, and DaimlerChrysler all having hydrogen fuel cell vehicles operating on public roads somewhere in the world and planning to introduce dozens more this year, people are beginning to wonder where exactly these hydrogen vehicles will be fuelling up.

But critics have been negative due to the many uncertainties and perceived costs (e.g., storage issues, infrastructure, scale of plant, fuel cell developments) even though there are demonstration projects in place already such as at Munich airport. Other key questions are do we build large central hydrogen production plants then transport the gas in pipelines to the places of demand, or do we produce small units for installation at each house or factory? Many of these are the same questions that were probably asked prior to the introduction of petrol.

Fuel Cell Today's worldwide hydrogen fuelling station report[16], combined with Fuel Cells 2000's worldwide hydrogen fuelling station reference chart[17] creates an impressive informational package and practically dismisses the popular 'chicken and the egg' dilemma.

There is no doubt that, long-term, the transport sector could use substantial amounts of hydrogen from renewable resources. In the medium term, however, it is quite likely that a substantial amount of hydrogen could come from natural gas. Even with the depletion of Maui stocks New Zealand has reasonable supplies of natural gas into the near future. Natural gas is a relatively cheap route to producing hydrogen and there are some potential carbon benefits if high efficiency fuel cell vehicles were used.

Developing a market position for radically new innovation begins with the niche markets that are receptive to new technologies. These include technically oriented industrial markets such as the electrical energy and transport sectors. The pathway to market is most likely to be through early adopters of the technology presented at pilot sites and prototype demonstrations. This is a key component of the implementation pathway. Implementation will occur initially through niche distributed generation applications using fuel cell technology as the converter of hydrogen into usable energy.

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[14] Anon (2002). Getting serious about motley fuels. Red Herring, July 2002, pp. 70-85. .

[15] L.C. Brown, J. F. Funk & S. K. Showalter (2000). Initial Screening of Thermo chemical Water-Splitting Cycles For High Efficiency Generation Of Hydrogen Fuels Using Nuclear Power. NERI/DOE Report GA–A23373, (http://web.gat.com/pubs-ext/miscpubs/A23373.pdf).

[16] http://www.theautochannel.com/search/search.html?words=Fuel Cells

[17] http://www.theautochannel.com/search/search.html?words=Fuel Cell Today

These early adopters will be large electrical generators/utilities and petrochemical companies with which the research partners already have strong links and to which we already provide research capability. These include companies like Meridian, Shell, Orion Energy, Genesis and Contact Energy.

Following on from the demonstrations/proof of concept projects will be prototype installation. This will include public transport owners and large manufacturers that have significant/niche energy issues to resolve. At this stage product manufacturers and suppliers will be involved in the technology transfer process. An example is the Christchurch City Council who are pursuing a clean air policy and who have strong links with the New Zealand bus manufacturer (Designline, Ashburton) to provide transport to meet this requirement.

Current research being undertaken by CRL Energy and IRL on innovative ways to produce hydrogen is paving the way for New Zealand to capitalise on the path to hydrogen based energy. This outcome is identified in many documents including the recently released National Energy Efficiency and Conservation Strategy document as being essential to the future economic, environmental and social well-being of this country.

Initiatives to make progress

The World Summit on Sustainable Development (WSSD), held in Johannesburg in 2002, gave considerable impetus to the global dialogue on energy sector reform. Energy was near the top of the WSSD's reform agenda, and the Summit resulted in a number of important political decisions: (i) to provide access to energy services to 2 billion people currently without it; (ii) to clean up existing energy technologies; (iii) to enhance efficiencies; (iv) to expand the share of renewable energy; and (v) to phase out certain subsidies. These decisions established a new basis for future international cooperation on energy, underscoring public/private partnerships.

The European Union and the United Kingdom in particular, took the lead in organising coalitions of countries committed to the link between energy and sustainable development. New Zealand was among more than sixty countries to sign up to the EU's declaration on Energy for Poverty Eradication and Sustainable Development, launched at the WSSD — the so-called "Johannesburg Renewable Energy Coalition" — and New Zealand has also committed to the UK-led "Renewable Energy and Energy Efficiency Partnership" (REEEP). The Government has liaised with industry regarding these initiatives, and there has been official and private sector participation from New Zealand in the group of meetings since WSSD.

The New Zealand Agency for International Development (NZAID) has launched renewable energy projects in the Pacific involving New Zealand suppliers of small scale wind and photovoltaic applications and energy system planning and design. The Pacific Islands Renewable Energy Project (PIREP), currently underway, will identify capacity and development needs required to overcome barriers to successful renewable energy initiatives in the region.

MED has developed views on New Zealand's future energy mix and associated costs through the preparation of input reports for both renewable resource development (covering costs and availabilities)[18] and fossil fuel generation[19].

The scenarios presented in MED's Energy Outlook[20] are the results of modelling the complex interactions of the New Zealand energy market using MED's SADEM energy model. This model is a partial equilibrium model (confined to the energy sector) which identifies a market clearing price consistent with supply and demand being in balance.

The Energy Outlook concludes that there is considerable potential for different energy types to play a large and vital role in our future energy mix.

NZ Govt ministers are building relationships to facilitate the development of a partnership involving the United States and New Zealand working towards the development of a sustainable Hydrogen Economy in the future along with bolstering trade relations between the two nations

In addition to promoting the Hydrogen Economy, Mr Duynhoven has stated that he will continue to promote New Zealand's oil and gas exploration potential to the other member nations and play a leading role at this event to ensure that New Zealand's interests in international energy security issues such as maintaining oil stocks are adequately protected".

Conclusions

The Crown has embarked on a number of initiatives aimed at both stimulating growth and innovation while addressing the issue of sustainability. Government officials are working with the energy industry to ensure that renewable and sustainable energy sources play a greater role in the national energy mix.

Hydrogen energy can play a part in these initiatives, and has been assessed as an emerging energy option that could make a significant contribution in future. However, while the pace of technological advance in this area is rapid estimates are that implementation would most likely be transitional over a 10 – 50 year period and could be likened to the implementation of petrol at the start of the 20th Century.

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[18] East Harbour Management Services Limited (2002). Availabilities and Costs of Renewable Sources of Energy for Generating Electricity and Heat. Report prepared for the Ministry of Economic Development.

[19] East Harbour Management Services Limited (2002). Costs of Fossil Fuel Generating Plant. Report prepared for the Ministry of Economic Development.

[20] Ministry of Economic Development (2003). New Zealand Energy Outlook to 2025. Report by Energy Modelling and Statistics Unit, Energy Markets Information and Services Group, Resources and Networks Branch, Ministry of Economic Development, Wellington.