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永續性潔淨能源發展於紐西蘭酪農業的可行性研究

A feasibility study on the development of a sustainable clean energy source for the New Zealand dairy industry

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ABSTRACT

"We cannot solve our problems with the same thinking we used when we created them."
Albert Einstein

The central proposition of this study states that exploring natural gas as a clean fossil fuel option is seen as a pragmatic approach when combined with commercial innovation, particularly when it comes to long-term supply and demand sustainability options, and in meeting environmental concerns. More importantly, it addresses the long-term sustainability of New Zealand's dairy industry by maximising energy efficiency and minimising energy and operating costs, contributing to feasible options for lowering greenhouse gas (GHG) emissions, and creating future stability in terms of capital and operational cost structures. For this to be achieved the study explores options associated with combining fuel cell technology to generate electricity from natural gas.

There is little doubt that the agricultural sector is one of New Zealand's largest GHG emitters. The need to start investing in cleaner technologies is one of a number of measures to achieve sustainable transformation over the next 20 to 40 years and beyond in both an economic and environmental context. It requires a combined effort in terms of sound policy, government and industry leadership, and stakeholder cooperation and agreement to build and shape the future required to meet global energy and climate goals. The study will set out to establish that continued success of the New Zealand dairy industry depends on its ability to take a lead position in promoting innovative investment in clean energy technology, infrastructure development, and the promotion of a sustainable environment. To maintain global competitiveness the dairy industry cannot rely upon utility companies to drive the development and use of changing energy

forms to contribute to industry trade expansion, profitability, and long-term sustainable economic growth for New Zealand. “Economic growth and technological change are accompanied by what the great economist Joseph Schumpeter called creative destruction. They replace the old with the new. New sectors attract resources away from old ones. New firms take business away from established ones. New technologies make existing skills and machines obsolete.” (Acemoglu & Robinson, 2012, p. 84). Bold new decisions will need to be taken to forge ahead with the adoption of cleaner energy sources and smarter technology to meet future energy needs. This will become critical given New Zealand’s ageing hydro-electricity infrastructure and the high capital cost of new generation resources in a country that is geographically isolated from world markets. The study concludes with recommendations and suggestions for future research on the development of a sustainable clean energy source in the form of an off-the-grid power generation system for the New Zealand dairy industry.

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LIST OF ABBREVIATIONS

AC	Alternating Current
Btu	British Thermal Unit
CCHP	Combined Cooling, Heat and Power
CCPI	Climate Change Performance Index
CH_4	Methane
CO_2	Carbon Dioxide
COGS	Cost Of Goods Sold
CSG	Coal Seam Gas
dB	Decibel
DC	Direct Current
DOE	United States Department of Energy
ECT	Energy Charter Treaty
EECA	Energy Efficiency and Conservation Authority
EECS	Energy Efficiency and Conservation Strategy
EIA	Energy Information Administration
ESMAP	World Bank Energy Sector Management Assistance Program
ETS	Emissions Trading Scheme
EU	European Union
FPCM	Fat and Protein Corrected Milk
FAO	Food and Agriculture Organization of the United Nations
FTE	Full-Time Equivalent (Employee or Staff)
GATS	General Agreement on Trade in Services
GATT	General Agreement on Tariffs and Trade

GFC	Global Financial Crisis
GHG	Greenhouse Gas
GWh	Gigawatt Hour (unit of electrical energy equal to one billion [10^9] watt hours or one thousand megawatt hours)
H_2S	Hydrogen Sulphide
HVDC	High Voltage Direct Current
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
kg	Kilogram
kgMS	Kilogram of Milk Solids
kW	Kilowatt (unit of power equal to one thousand watts of electrical power)
kWh	Kilowatt Hour (unit of energy equal to one thousand watt hours – kWh is the billing unit for delivered electricity by utilities)
kW/m	Mechanical Power in kW (available to produce the electrical power)
lbs	Pound
LCOE	Levelized Cost of Energy
LFF	Liquid Fossil Fuel
LNG	Liquid Natural Gas
LPG	Liquid Petroleum Gas
MJ	Megajoule (equal to one million or 10^6 joules)
MAF	Ministry of Agriculture and Forestry
MED	Ministry of Economic Development
MkWh	Million Kilowatt Hours

MMBtu	One Million British Thermal Units (a measurement of gas based on a standard heat value or stored energy. A Btu is the amount of heat required to raise one pound of water one degree Fahrenheit)
Mt	Megatonne (A metric unit equal to one million (10^6) tonnes or one billion (10^9) kilograms)
NASA	National Aeronautics and Space Administration
NIWA	National Institute of Water and Atmosphere
N_2O	Nitrous Oxide
NPV	Net Present Value
NZ	New Zealand
NZES	New Zealand Energy Strategy
O&M	Operations and Maintenance
OECD	Organization for Economic Co-operation and Development
PAFC	Phosphoric Acid Fuel Cell
PEM	Proton Exchange Membrane or Polymer Electrolyte Membrane
PKE	Palm Kernel Expeller
PJ	Petajoules (equal to one quadrillion 10^{15} joules. A joule is equal to the energy expended in applying a force of one newton [$N = kg \frac{m}{s^2}$] through a distance of one metre)
PV	Photovoltaic
RES	Renewable Energy Sources
RMA	Resource Management Act 1991
ROI	Return On Investment
SCBA	Social Cost Benefit Analysis
SEIP	Stationary Energy, Industrial Processes
SG&A	Selling, General and Administrative Expenses
SGIP	Smart Grid Interoperability Panel

SOFC	Solid Oxide Fuel Cell
TJ	Terajoules (equal to one trillion or 10^{12} joules)
TRIPS	Agreement on Trade Related Aspects of Intellectual Property
TWh	Terawatt Hours
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
WACC	Weighted Average Cost of Capital
WEC	World Energy Council
WTO	World Trade Organization

1. INTRODUCTION

Increased production of energy, chemicals, and other materials brought about by an escalation in the world's population (7 billion at 31 October 2011), has significantly affected levels of pollution and resulted in grave deterioration of the Earth's natural environment and fragile ecology. Richard A Muller, Professor of Physics at UC Berkeley, MacArthur Fellow and co-founder of the Berkeley Earth Temperature Project, recently announced "Three years ago I identified problems in previous climate studies that, in my mind, threw doubt on the very existence of global warming. Last year, following an intensive research effort involving a dozen scientists, I concluded that global warming was real and that the prior estimates of the rate of warming were correct. I'm now going a step further: Humans are almost entirely the cause." (Banajee, 2012). Other scientists have been making the same claim for the past 20 years and Professor Muller's turnaround is a triumph for the science of global warming but a major blow to the ranks of climate change sceptics. But is the interpretation of Muller's "conversion" from a so-called climate change sceptic all that it has been made out to be? It appears more likely that his past comments were misjudged by those with a foot firmly in the climate change camp. There is a strong argument that Muller has always been concerned about global warming and the effects of climate change. He simply disagreed with the robustness of the science behind the "hockey stick" graph. The graph was relied upon by the Intergovernmental Panel on Climate Change (IPCC) to highlight unprecedented levels of an increase in global temperatures, particularly during the twentieth century. (Lyons, 2012). Muller essentially believed that it was important to show beyond reasonable doubt through the application of rigorous scientific research that global warming does indeed exist and threatens our very existence as we know it.

This thesis topic explores, in particular, the dairy industry in New Zealand, given the significant and wide-reaching changes to the landscape and natural environment brought about by its rapid expansion in the past decade and its key position as New Zealand's number one export industry. Consequently, discourse on water usage, security of supply, and sustainable energy has increased among policy makers, stakeholders and the general public. Hence, the main aim of this study is to explore the potential for an alternative, sustainable energy source for the New Zealand dairy industry. In particular, it will investigate how fuel cell technology combined with the use of natural gas may help the New Zealand dairy industry producers and farmers improve upon their environmental sustainability through (1) reducing operating costs; (2) lowering GHG emissions; and (3) minimizing exposure to fluctuating energy costs. Science has proven that carbon dioxide (CO_2) emissions weaken our environment's natural defenses. This tendentious study will examine how natural gas when used in conjunction with a distributed generation system can produce clean, consistent, and affordable electricity.

1.1 Discussion of Context

The IPCC is an organization that assesses the scientific, technical and socio-economic information relevant for the understanding of the risk of human-induced climate change (http://www.ipcc.ch). "Over the last three decades, GHG emissions have increased by an average of 1.6% per year, with CO_2 emissions from the use of fossil fuels growing at a rate of 1.9% per year" (IPCC Fourth Assessment Report, Climate Change, 2007). With global energy use and supply projected to continue growing, without policy changes by governments and industry more than 80% of the energy supply will continue to be based on fossil fuels through the timeframe 2025 - 2030. "Fossil fuels are a natural fuel such as coal or gas, formed in the geological past from the remains of animals and plants" (The Compact Oxford English Dictionary). IPCC has reported that projected emissions of energy-related CO_2 in 2030 are 40% - 110% higher than in 2000, with per capita emissions in developed countries even greater. For 2030, GHG emission projections show 25% - 90% increase compared to 2000. The anthropogenic impact on the environment and climate change (where humans are causing global warming) becomes easier to understand when we see energy demand surging and "64% of people think fossil fuels will still be the world's primary energy source in 2030" (The Economist, November 12, 2011, p. 21). The Climate Change Performance Index (CCPI) aims at enhancing transparency of national and international efforts to avoid dangerous climate change, but only covers emissions from CO_2 arising from the use of fossil fuels. Deforestation, agriculture and waste activities which are responsible for around 20% of GHGs will hopefully be included in the next CCPI edition. CCPI was developed to accompany countries along the path to reducing CO_2 and the effects of climate change, and to show the strengths and weaknesses in the development of their national and international climate policies.

Key components and weightings of the CCPI are (1) emission trends 50%; (2) emissions levels 30%; and (3) climate policy 20%. On the 2012 CCPI for Organization for Economic Co-operation and Development (OECD) member countries (which enables a comparison of emitters with more or less similar basic conditions) "New Zealand ranks 32 with a score of 54.5 among 58 countries, up five places from the country's 2011 ranking of 37 with a score of 53.73" (The Climate Change Performance Index, 2012, p. 18).

While the score correlates to a ‘poor’ rating, the New Zealand Government is focused on creating a balance between protecting the environment and economic development. As oil producing countries in the Middle East and elsewhere grapple with internal supply flow shrinkage and the effects of peak oil –the point at which oil supply begins to decrease – a shift to clean and renewable energy sources becomes essential as the availability of cheap and plentiful oil declines. According to ExxonMobil “Natural gas will be the fastest-growing major fuel to 2040, with demand rising by more than 60%. Much of this growth will come from electric utilities and other consumers shifting away from coal in order to reduce CO_2 emissions. By 2025, natural gas - which emits up to 60% less CO_2 emissions than coal when used for electricity generation - will have overtaken coal as the second most popular fuel, after oil.”

So what does the future look like and what will be the global impact? ExxonMobil’s “Outlook for Energy: A View to 2040” provides the following insights.

- Global energy demand will be about 30% higher in 2040 compared to 2010, as economic output more than doubles and prosperity expands across a world where population will grow to nearly 9 billion people.
- The need for energy to make electricity will remain the single biggest driver of demand.
- By 2040, electricity generation will account for more than 40% of global energy consumption.
- Gains in efficiency through energy-saving practices and technologies - such as hybrid vehicles and new, high-efficiency natural gas power plants – will temper demand growth and curb emissions.

1.2 Central Proposition

Exploring natural gas as a clean fossil fuel option is seen as a pragmatic approach when combined with commercial innovation, particularly when it comes to long-term supply and demand sustainability options, and in meeting environmental concerns. This is a study of the development of a sustainable clean energy source for the New Zealand dairy industry, and will explore the following research question:

To what degree can an "off-the-grid" power generation system utilizing an innovative fuel cell technology and natural gas (1) reduce operating cost; (2) lower GHG emissions; and (3) minimize exposure to fluctuating energy costs?

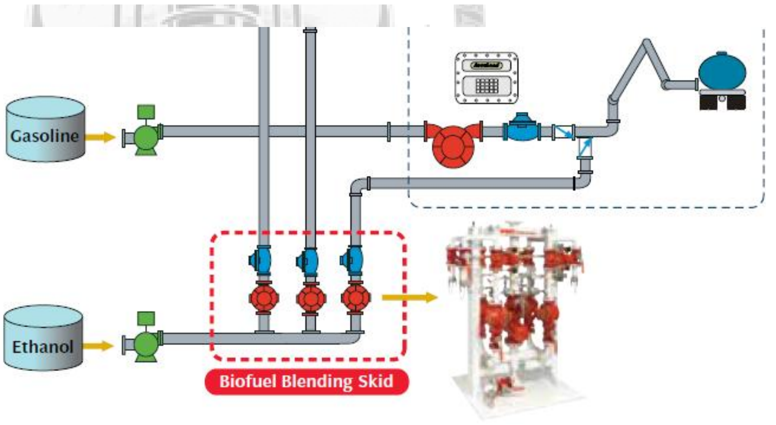
By reviewing existing literature, and evidence from research, the study will draw conclusions on the strategies suggested in the research methodology and will be informed by the literature review. A key component of this feasibility study is about ensuring the long-term sustainability of New Zealand's dairy industry by maximizing energy efficiency and minimizing energy costs. In the South Island, the primary energy source for most milk processing plants is coal which is used to generate thermal (steam) energy. But in the North Island reticulated natural gas and other alternative energy sources are available to meet process energy demands. The methodology approach has been to use a combination of qualitative and quantitative data from primary and secondary sources. "Decision problems involving accounting data typically are specified in quantitative terms. The criteria in such problems usually include objectives such as profit maximization or cost minimization. The qualitative characteristics of the alternatives can be just as important as the quantitative measures. Qualitative characteristics are the factors in a decision problem that cannot be expressed effectively in numerical terms" (Hilton, 2010, p. 589). The study evaluates an assumed investment by the dairy industry to make its products utilizing electricity generated by distributed systems that are located on-site and off-the-grid that produce full-time power 365 days of the year. According to Wikipedia (the web free encyclopedia) "feasibility studies aim to objectively and rationally uncover the strengths and weaknesses of an existing business or proposed venture, opportunities and threats as presented by the environment, the resources required to carry through, and ultimately the prospects for success. In its simplest terms, the two criteria to judge feasibility are cost required and value to be attained. Generally, feasibility studies precede technical development and project implementation. Moreover, it is an analysis and evaluation of a proposed project to determine if it (1) is technically feasible, (2) is feasible within the estimated cost, and (3) will be profitable" (http://www.wikipedia.org).

Through answering the question, the objective is to present findings, recommendations, and suggestions for future research that may go some way toward improving energy security and providing a clear path to energy independence. The sustainability of all life forms, the continuation of the human race, and slowing the rapid decline of biodiversity on Earth depends on it.

1.3 Limitations

Certain restrictions had to be taken into account in completing this study. It attempted to address, essentially through a financial cost benefit analysis, the question of reducing operating costs, lowering GHG emissions, and minimizing exposure to fluctuating energy costs. But this had to be completed within the context of exploring the technical feasibility, cost structures, and profitability of an off-the-grid power generation system that utilizes fuel cell technology to generate electricity from natural gas. The idea of operating a fuel cell on biogas created from plant waste, or methane recaptured from landfills and farms was also explored.

Figure 1: Smith Meter International Biofuel Blending Skid



Source: FMC Technologies

Typical sources for biogas include water treatment facilities (Anaerobic Digester Gas) and biomass plants (gasification of biomass to create methane-based “syngas”). The composition of gas used to fuel any fuel cell is very important. Large skids of equipment costing many thousands of dollars are required to clean-up gas and make it suitable for use in a fuel cell or in a micro-turbine. These skids often consist of state-of-the-art metering technology for positive displacement and turbine meters, along with digital flow control valves to provide optimum measurement accuracy. Landfills, for example, are generally not a good source for gas because it can be difficult to know for sure what the composition of detritus is within the landfill and this tends to change over time as the landfill ages. The quality of the biogas that results from the cleaning process may often be questionable with no guarantee that it will not have any adverse effects on the fuel cell. Furthermore, the clean-up process may be cost prohibitive compared to the cost of using natural gas. Had there not been a time limitation for this study, a more thorough investigation could have been undertaken on external factors associated with reducing dairy industry CO_2 emissions. The study could also have undertaken a more in-depth investigation of feasibility factors in terms of the project's total economic cost and total economic benefits, more commonly known as Social Cost Benefit Analysis (SCBA). The value proposition of a SCBA would most likely have highlighted the disparate interests of the various industry stakeholders. For example, the dairy industry is New Zealand's biggest export earner and farmers and producers will likely view the study in light of the financial cost benefit analysis when assessing the conclusions reached. On the other hand, environmental groups and organizations will no doubt place greater importance on the outcomes that can be achieved in terms of addressing global warming and reducing industry CO_2 emissions. Therefore, a self-imposed limitation on the extent of research was necessary to remain within the scope of the thesis concentration.

2. LITERATURE REVIEW

To help achieve a balance between protecting the environment and economic development, the New Zealand Government introduced an Emissions Trading Scheme (ETS) which took effect on 1 July 2010. The ETS is designed to change behaviour and reduce emissions and is New Zealand's key mechanism for meeting the country's commitments under the Kyoto Protocol. There is no binding international agreement about the GHG emissions beyond 2012, although New Zealand has signed up to the 2009 Copenhagen Accord (http://unfccc.int/meetings/cop_15/copenhagen_accord/items/5262.php) and has submitted to the United Nations Framework Convention on Climate Change (UNFCCC) a conditional emissions reduction target range of 10% - 20% below 1990 levels by 2020.

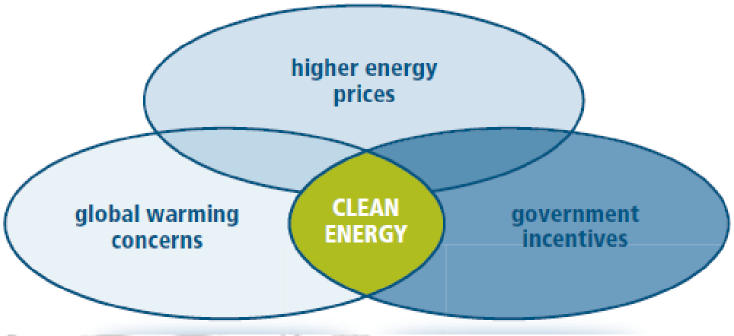
A key issue is how to ensure New Zealand's dairy industry remains economically competitive on the world stage when farmers in the European Union (EU) and United States of America (US) for example, receive increased payout for milk and assistance with technology development through a range of subsidies. For a geographically isolated country like New Zealand, the answer lies in (1) being an efficient producer; (2) having a streamlined transportation system incorporating land, sea, and air to reach domestic and export markets in an efficient, timely, and cost-effective manner; (3) exploring innovative ways to meet the rising demand for food; and (4) remaining focused on environmentally sustainable farming practices which incorporate the introduction of innovative clean energy sources.

In March 2011, the government announced a long-term target of a 50% reduction in New Zealand's GHG emissions from 1990 levels by 2050. Agriculture accounts for about half New Zealand's GHG emissions, which mainly come from methane (CH_4) emanating from ruminating animals and nitrous oxide (N_2O) released from patches of urine in grass paddocks. The entry date to the ETS for agriculture has been deferred to 1 January 2015(now indefinitely following legislation passed by 61-58 on 8 November 2012); primarily due to concerns about the cost to New Zealand's agricultural sector and to give farmers time to study new systems and technology for reducing emissions. It should be noted that New Zealand farmers receive no government subsidies, and it is considered that making the farming sector comply with the ETS at this point in time may give unfair advantage to competing economies that receive subsidies.

The Farm Subsidy website states that the EU spends around €55 billion a year on farm subsidies, representing more than a third of farmer's income (http://www.farmsubsidy.org) In 2008, France (the EU's biggest food producer) received €9,940 million in EU farm subsidies or approximately €18,862 (NZ$28,521) per farm and in the same year the United Kingdom received €3,755 million or approximately €12,517 (NZ$18,927) per farm. The XE currency exchange homepage exchange rate as at 5 August 2012 was 1 EUR = 1.51208 NZD (http://www.xe.com) Interestingly, the Oxfam International states that Europe's cows receive over $2 a day in subsidies, more than the income of half the world's population (Oxfam Briefing Paper, 2012). As competitors in the global dairy industry, these two countries receive an unfair monetary advantage when weighed against operating costs of a typical New Zealand dairy farm. A herd manager, for example, earns an average of NZ$42,000 per year.

Average pay for herd and farm managers ranges between NZ$45,000 and NZ$60,000 and people in charge of large or multiple dairy farms earn an average of NZ$71,000 (CareersNZ, 2012). Also of concern is the agribusiness Rabobank forecast of a growth slowdown for New Zealand dairy exports over the next decade in the face of increased competition from other market suppliers. For example, “milk production in the EU is expected to increase by between 55% and 60% in the five years following the 2015 EU milk quota abolition” (Astley, 2012). Physical land use constraints in New Zealand due to the country’s small size, lack of suitable land for conversion, and increased competition from EU farmers in receipt of generous subsidies makes for a difficult market industry. However, with the strong New Zealand dairy co-operative mechanism, continued innovation in technology and systems improvements, on-farm efficiencies resulting in increased per-cow milk production, and development of new ways to save energy, the dairy industry should still be an attractive sector. It will continue to be an important and valuable contributor to New Zealand’s economy. Governments around the world are facing an urgent need to address the sources of energy that are required to meet the demand for continued economic growth in both developing and developed countries. Many initiatives include establishing alternative renewable energy sources that are cleaner than fossil fuels. Advancements in science and engineering technology have resulted in new ways to more efficiently generate electricity. As a result there is an emerging array of new means to harness clean and renewable energy sources that are potentially more efficient, cleaner, safer, and capture GHG emissions and prevent their entry into the atmosphere. The result is hopefully a reduction of CO_2 emissions and global warming. In April 2009 United States President Barack Obama committed to invest US$150 billion over 10 years in clean energy research and development and a few months later in June, the United States House of Representatives agreed for the first time to cap carbon dioxide emissions (Spicers, 2009). *"We know the country that harnesses the power of clean, renewable energy will lead the 21st Century."* President Barack Obama (Presidential Address to Congress, February 2009).

Figure 2: Clean Energy Influences



Source: Spicers Portfolio Management Ltd

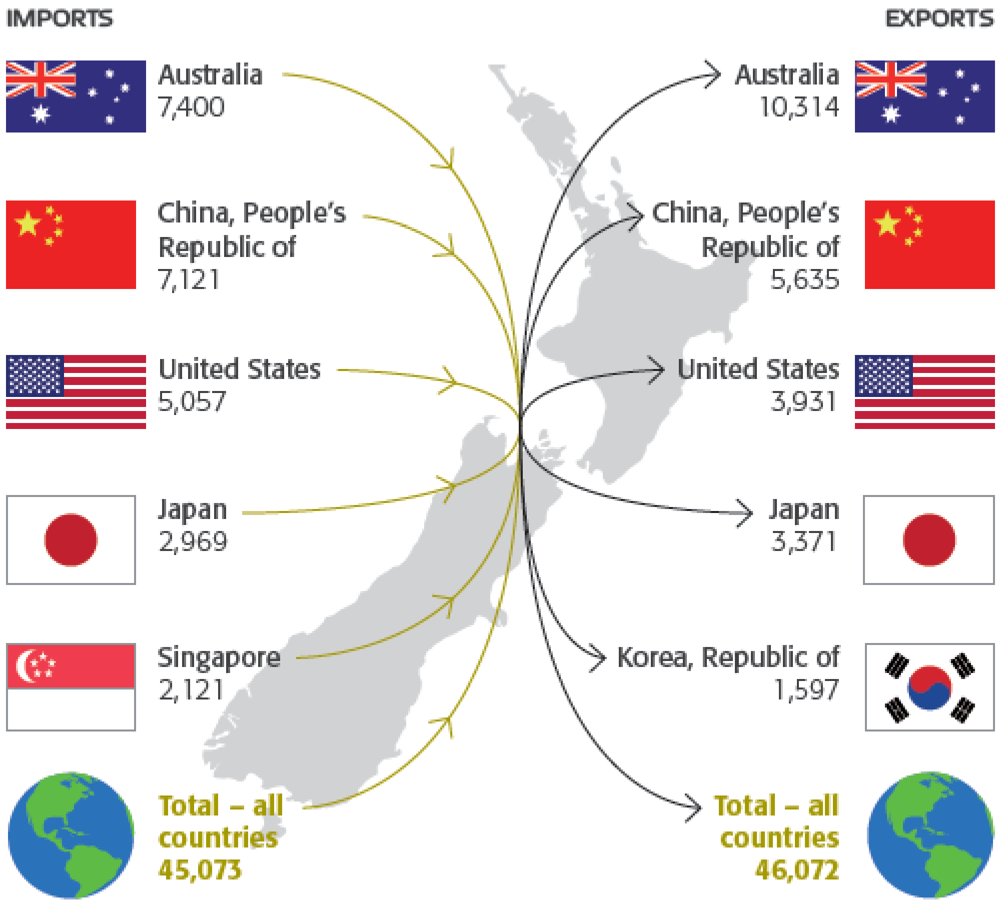
Following the March 2011 Fukushima nuclear crisis in Japan and the intense worldwide focus on safety of nuclear energy, public opinion in New Zealand is as strong as ever with regard to ensuring that clean and renewable energy sources are the most suitable way to shoulder the electricity load.

Several combinations may need to be used for consistency of supply and demand. For example, wind resources may be more predictable and regular than the rainfall required for hydro-electricity generation. It could be a supplementary resource to hydro when insufficient water is available. Likewise, geothermal power production also has excellent potential. But it is also about striking a balance to ensure security of electricity supply in order to meet demand from all sectors when weather-dependent renewable generation is unavailable. That includes the use of fossil fuels (i.e. coal, oil, and natural gas) in the foreseeable future as a means of generating electricity. The key aim is to develop technologies that make the use of such fossil fuels cleaner and reduce CO_2 emissions.

2.1 New Zealand Environment

Comparable in size (268,680km) to the United Kingdom and the Philippines, New Zealand is an island country in the south-west Pacific. New Zealand comprises the North Island and South Island, and a host of smaller islands. The North Island is mainly rolling hill country, much of which is farmed. The South Island is divided by the Southern Alps, which run most of its length and rise to over 3,000 metres. Extensive areas are set aside as national parks and the temperature varies anywhere from a low of 2°C in winter (in the South Island) to highs of 35°C in summer. The New Zealand energy sector is reliant upon imports of liquid petroleum fuels which are supplemented by a small amount of New Zealand crude from the Marsden Point Oil Refinery at the top of the North Island. The South Island energy sources are coal and hydro, while the North Island sources include gas, hydro and geothermal. New Zealand's demand for electricity from its 4,405,200 population (2011) continues to grow and is increasing by around two percent year-on-year. With its reliance on international oil markets, New Zealand is directly affected by geopolitical instability, climatic events, natural disasters, and large increases in demand. Electricity is essential to New Zealand's economy and as consumer spending continues to play a greater role in economic growth, the need for efficient use of energy will impact on the New Zealand electricity market over the medium to long-term. "Petroleum and petroleum products are New Zealand's largest imports ($7.2 million), followed by mechanical and electrical machinery and equipment ($5.5 million). Imports from the top three countries of origin, Australia, China, and the United States, contribute to over 40% of all imports. Milk powder, butter, and cheese are New Zealand's largest exports ($11.3 million), followed by meat, logs, wood, and wood articles ($8.6 million)" Statistics NZ (2012).

Figure 3: Main Trading Partners, 2011 (NZ$ million)



Source: Statistics New Zealand

"Overall, the primary sector accounts for 7.6% of gross domestic product (GDP) and contributes over 50% of New Zealand's total export earnings" (New Zealand Economic and Financial Overview, 2012). The following key facts are also of interest (New Zealand Energy Data File, 2012):

1. New Zealand produced 17 million barrels of oil in 2011, equivalent to 43% of domestic oil product demand.
2. The first oil well in New Zealand was drilled in 1866 at Moturoa.
3. Wind electricity generation increased by 19% in 2011.

4. In 2011, 77% of New Zealand’s electricity generation came from renewable sources. This is one of the highest levels of renewable electricity generation in the OECD.
5. The average price for New Zealand crude on the international market was US$111 per barrel in 2011.
6. New Zealand households spent, on average, $190 per month on electricity and gas combined in 2011.
7. New Zealand had the sixth lowest petrol price in the OECD in 2011.
8. Meat and dairy industries in New Zealand consumed about 12 megajoule (MJ) per dollar of GDP they produced in 2011.
9. All sectors combined consumed approximately 4 MJ per dollar of GDP in 2011.
10. 52 oil and gas exploration and development wells were drilled in 2011.

The primary renewable energy sources in New Zealand are hydro, geothermal, and wind, with the predominant source being hydro-electricity. The major electricity generators in New Zealand are Meridian Energy, Contact Energy, Genesis Energy, Mighty River Power, and TrustPower. These five generators have a significant retail customer base and are able to hedge against wholesale prices they receive for electricity produced. It might appear unusual that a retailer is also able to generate electricity. The Electricity Industry Reform Act 1998 divided the electricity sector into four operating segments – Generation, Retail, Transmission, and Distribution with restrictions on ownership, above a limited threshold, between Generation/Retail on the one hand, and Transmission/Distribution on the other. Transpower, for example, owns the high voltage electricity transmission system in New Zealand and ensures electricity is delivered or ‘distributed’ to where it is required to meet supply and demand. Vector and Orion for example, are New Zealand distribution companies that work with Transpower to ensure electricity is delivered to homes and businesses, but the Act prohibits them from becoming ‘retailers’. The basis of this is to protect the end user and consumer from being captured by monopolies in the electricity supply market.

2.2 Dairy Industry

“The New Zealand dairy industry has a long history, with the first dairy cow, Shorthorns, introduced into New Zealand in 1814. As the nation developed and with the introduction of refrigeration in the early 1880s (the first refrigerated meat left New Zealand for England in 1892), small dairy factories began to be built around the country to process butter and cheese. In September 1872 the first dairy co-operative was started in Otago for the purpose of cheese making. By 1890 there were 150 factories nationwide, 40% being co-operatives. The Dairy Industry Act 1894 brought a regulating system of factory inspections and export quality grading system for milk payment. The number of factories peaked at about 600 in 1920, with around 85% being operated under the co-operative arrangement. With technology improvements, refrigerated transport, and processing efficiencies, the dairy industry experienced continued growth with the merger of small factories and the appearance of larger co-operatives.

Fig 4: New Zealand Dairy Farm

Source: DairyNZ Factsheet

In the late 1990s, four remained: the New Zealand Dairy Group, Kiwi Co-operative Dairies, Westland Milk Products, and Tatua Co-operative Dairy Company. The Dairy Group and Kiwi Co-operative absorbed the New Zealand Dairy Board, and in 2001, became Fonterra Co-operative Group" (The Encyclopedia of New Zealand, 2012). Other competing dairy producers, websites, the date they were founded, and litres of annual milk production are: Tatua Co-operative Dairy Company (http://www.tatua.com) (1914, 190m litres); Westland Milk Products (http://westland.co.nz) (1937, more than 500m litres); Open Country Dairy Ltd (http://opencountry.co.nz) (2004, 900m litres – the country's second largest processor); Synlait Milk Ltd (http://www.synlait.com) (2000, more than 500m litres); Miraka Ltd (http://miraka.co.nz) (2011, 210m litres), and New Zealand Dairies Ltd (2006, 150m litres). New Zealand Dairies Ltd went into receivership in June 2012 due to the bankruptcy of its parent Russian owner. Fonterra was given Commerce Commission approval to purchase the assets in September 2012. "In 2009-10 Fonterra, the country's leading milk producer, collected 89% of national production but sold 4% to competitors with rights of access to raw milk" (Stringleman, 2011). Fonterra's global homepage says that it collects about 16 billion litres of milk each year from its farmer shareholders (https://www.fonterra.com/global/en).

An array of safe top quality products are made by the New Zealand dairy industry from grass-fed cows on farms that are highly automated with the latest technology and stringent health and safety standards. Holstein-Friesian is now the prevalent dairy cow breed making up 43% of total dairy cows. Other breeds include Jersey and Ayrshire, plus several other various breeds. Products include whole milk, milk powders, cream, cheese, butter, protein products (e.g. casein), yoghurt, ice-cream, organic dairy products, and infant formulas. According to Business New Zealand, in 2011 dairy industry exports totaled $12.1 billion making it the country's largest export earner with approximately 95% of all production being exported. China holds 18% share of exports, with the Philippines, Algeria, Australia, and Saudi Arabia each holding 4% share in 2011. Contributing 25% to New Zealand's merchandise export earnings, over a third of the world's dairy trade comes from New Zealand dairy exports. "Key dairy industry facts are outlined as follows:

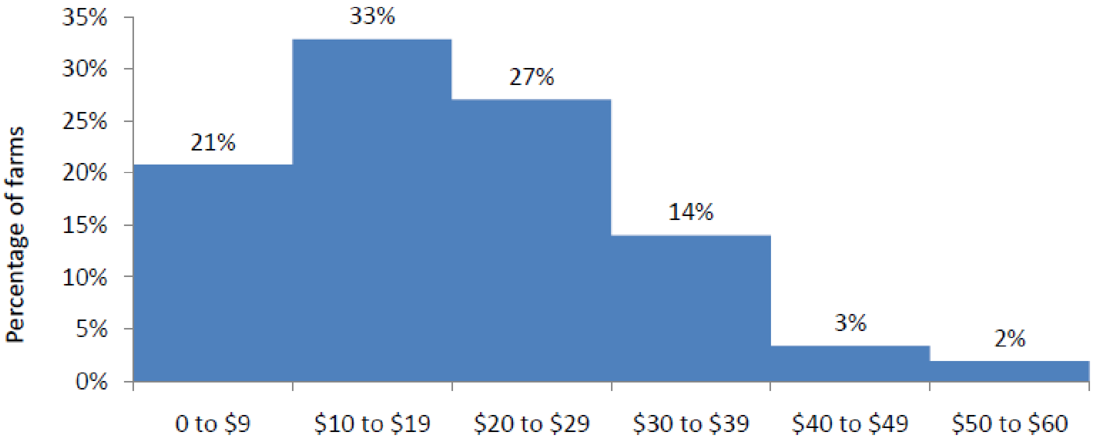
- For the year ending 30 June 2011, New Zealand dairy farms processed 17.3 billion litres of milk, the average herd size is 386 cows, 24% of herds have more than 500 cows and over 450 of these herds have more than 1,000 cows.
- There were 4.5 million cows being milked in 2011 or an average of 11,658 herds.
- In 2010 there were approximately 1.5 million hectares used for dairy farming.
- On average, New Zealand dairy cows produce 3,800 litres per head per year.
- The majority of dairy herds (76%) are in the North Island, with 30% in the Waikato.
- In 2010, 65% of dairy farmers who invest in farm businesses were owner operators. The remaining 35% have a part share or equity partner.
- For the year ended 30 June 2011, dairy export revenue came from whole milk powder (37%); with the rest comprising butter, AMF (Andhydrous Milk Fat) and cream (18%); cheese (14%); skim milk, buttermilk, powder and infant foods (16%); casein, protein products and albumins (12%); and other dairy products (3%).

- New Zealand produces approximately 2% of total world production of milk at around 16 billion litres per annum.
- Main dairy exports are concentrated milk (58% share), butter (21%), cheese (11%), whey and milk products (6%), and not-concentrated milk (2%) in 2011.
- New Zealand's cow population is rapidly growing (4.5 million), at a rate faster than the country's population (4.4 million).
- Approximately 95% of all New Zealand dairy production is exported.
- Dairy production has increased by 77% during the past 20 years" (http://www.dairynz.co.nz).

According to the Food and Agriculture Organization (FAO) of the United Nations, by country the largest producer and consumer of milk in the world is India with 16% (110 billion litres per annum). More than half or approximately 55% of India's production is buffalo milk. However, New Zealand is the world's largest global milk exporter even though it only produces approximately 2% (16 billion litres per annum) of global production. New Zealand milk production per thousand kilograms of milk solids is shown in Appendix 1. "It takes about one kilogram of dry pasture eaten by a cow to produce one kilogram (about a litre) of milk. In New Zealand, cows are generally milked twice a day taking about two hours per milking. Mature cows eat about 17 kilograms of dry pasture each day and drink up to 50 litres of water. Grazed pasture costs less than five cents per kilogram to produce. Including capital farm costs, the cost of producing one litre of milk is 10–12 cents. In 2007/08 New Zealand farmers were paid more than 90 cents per litre" (The Encyclopedia of New Zealand, 2012). To build a complete picture of the New Zealand dairy industry, three areas require additional commentary. They are (1) an awareness of the median price of a typical dairy farm (a possible entry barrier to many younger generation farmers with aspirations of owning their own farm); (2) factors such as payouts to dairy farmers and the effect profitability may have on their ability to enhance electricity efficiency on the potential for base-load savings through exploring alternative clean energy options; and (3) an analysis of the distribution of dairy farms around the country and what this means for the future of dairying.

The 2008 global financial crisis (GFC) and more recently the European sovereign-debt crisis resulted in significant monetary constraints on all sectors of society. Debt funding is a reality in modern day dairying and it is well known that New Zealand dairy farms are heavily indebted enterprises. Many farmers are servicing too much debt and such pressures, together with sensitivity to interest rate fluctuations has made a profitable lifestyle increasingly difficult for many farmers. Indeed, a number of dairy farmers appear to be relying on future capital gains from farm sales as their primary source of income and financial security over the long-term. “New Zealand dairy farmers had an estimated $10.6 billion of term debt (mostly in mortgages) by the end of the 2002 season. By the end of the 2009 season, this had risen to about $28 billion. The nearly three-fold increase in debt over a mere seven years is cause for concern to the industry. In the 2009 season, farmers’ interest and rent accounted for 33% of gross farm revenue, up from 12% in the 2002 season” (Morrison, 2010). The risk of lower dairy returns, particularly as a result of increased global competition, will negatively impact on debt servicing and farmer drawings. Put simply, it affects not only farmers’ standard of living but other areas such as the retail sector in rural communities and the New Zealand economy in general because of a reduction in discretionary spending power. As New Zealand’s top export earner these concerns are critically important. Figure 5 indicates that nearly one-third of dairy farmers’ income will be used to service interest borrowing costs of the 19% of farmers with debt in excess of $30/kgMS.

Figure 5: Closing Term Liabilities per kgMS



Source: DairyNZ Economic Group, 2008-09 Owner Operators

Kilogram of milk solids (kgMS) is the industry standard measurement for determining comparative milk price, payouts from processors to farmers, and milk production output. “Assuming that one cow is milking 25 litres of milk, the fat percentage is 3.85% and protein is 3.45%. To convert to milk solids, the first step is to convert the litres of milk to kg. The multiplier 1.03 converts litres to kilograms. The example demonstrates that 25 litres x 1.03 equals 25.75kg of milk (5.5 gallons). The next step is to add the fat and protein percentages, i.e. 3.85 + 3.45 = 7.3% solids. Therefore, the fat and protein content of the milk is 7.3% of 25.75kg/day or 1.8kg of milk solids per cow per day” (Kennedy, 2010). One mechanism of determining the return of capital investment in dairy farm land is to calculate how much milk solids per hectare can be produced, rather than focus on milk per cow. This is achieved by multiplying the stock rate (i.e. three cows per hectare) by the milk solids per cow. “On average, New Zealand dairy cows produce 3,800 litres per head, which is equal to 10.4 litres of milk per cow per day” (Go Dairy, 2012). The following calculation shows the total milk solids per hectare that a typical New Zealand dairy farm produces. “The average size of a New Zealand dairy farm is 172.2 hectares” (Land Information New Zealand, 2012).

Step 1: 10.4 litres x 1.03 kg = 10.7 kg of milk

Step 2: 10.7 x (3.85 + 3.45) 7.3% = 0.8 kgMS/cow/day (292 kgMS/year)

Step 3: 3 cows x 0.8 kgMS = 2.4 kg MS/hectare/cow/day (876 kgMS/year)

Step 4: 876 kgMS x 172.2 = 150,847 kgMS

This means the average annual production from an average size dairy farm herd is 150,847kg of milk solids, per hectare (876kg) and per cow (292kg). “Fonterra is revising its milk payout forecast range for the 2012-13 season down 30 cents, to $5.25/kgMS from $5.50/kg. That means $500 million less for the New Zealand economy than predicted for this dairy season. The opening season forecast was $5.65 - $5.75 before retentions for a fully shared-up farmer. Westland Milk Products also downgraded its payout forecast earlier this month. The West Coast co-operative is now forecasting a $5.00 - $5.40/kgMS payout instead of a budgeted $5.70 - $6.10. Given farm working expenses before interest and tax were around $4.20/kgMS, Fonterra’s key milk price forecast of $5.25/kgMS leaves little or no free room” (Fox, 2012). For example, using these calculations a typical dairy farmer is left in the following financial position.

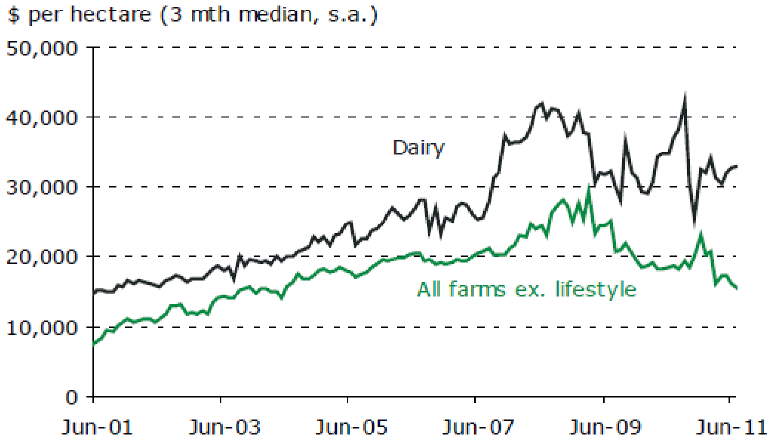
Statement of Income

Revenue	
Sales Revenue – Fonterra 150,847kg/MS x $5.25/kg	$791,946
Operating Expenses	
COGS, SG&A, Depreciation etc. 150,847kg/MS x $4.20/kg	$633,557
Earnings Before Income and Taxes (EBIT)	$158,389

Europe's debt problems continue to affect milk prices for New Zealand farmers. "The final milk price for 2010-11 was $7.60/kgMS with a dividend of $0.65 per share before retentions. Fonterra's 2011-12 final payout to farmers was $6.40/kgMS, down 19% on the previous year, with the high New Zealand dollar and increased production by other countries having eroded global market returns. This comprised a farm-gate payout of $6.08/kg for milk solids (down from $7.60 last year) and a $0.32 dividend per share. New Zealand milk output rose to a record of nearly 1.5 billion kilograms or 11% on the previous year, and Fonterra reported a profit of $642 million for the year to July, despite one-off tax credits of $202 million" (Executive News, 2012).

Some of the smaller dairy co-operatives competing against Fonterra are beginning to make in-roads on increasing production output and farm-gate payouts. "Small Waikato dairy co-operative Tatua has reported a near doubling of profit to $200 million and announced a payout to farmers of $8.00/kgmMS, far above Fonterra's $6.40 /kgMS" (Executive News, 2012). Turning to farm ownership affordability, Figure 6 shows that the median sale price for dairy farms as at June 2011 was $30,000 per hectare, considerably lower since the height of around $42,000 in June 2010. Farm sale prices for dairy units are still healthy with a 67% or $12,000 per hectare price difference premium attainable for dairy farms over all other farm sales as at June 2011. The higher sales price for dairy farms reflects the importance of this industry to the economy.

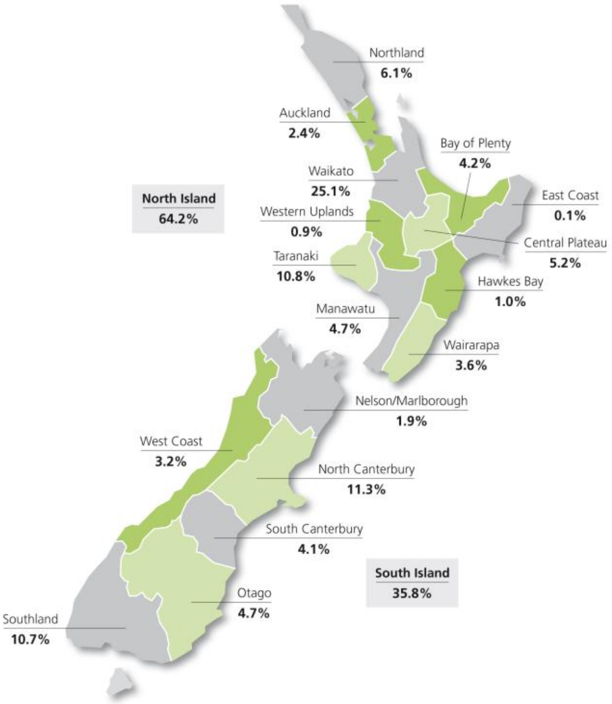
Figure 6: Farm Sales, Median Price



Source: ANZ, National Bank, REINZ

“Fonterra, New Zealand’s largest co-operative with 10,500 farmer-shareholders, confidently predicts that the Chinese dairy market will treble over the next decade. The dairying regions of Canterbury, Otago and Southland, are growing by as much as 5% a year. In July 2010, China’s Bright Dairy invested $82 million in Canterbury’s Synlait Milk Ltd to expand its milk-processing plant. Fonterra will build a $150 million milk powder plant at Darfield in Canterbury to meet additional future milk volumes” (NZ Listener, 2010). With these factors taken into consideration, a focus of this study will be on exploring how this energy-intensive business can find ways to develop and introduce energy savings tools to reduce costs and GHG emissions. New initiatives are underway, for example in 2010 a pilot Dairy Energy Action Programme from Fonterra, the Energy Efficiency and Conservation Authority (EECA) and the Ministry of Agriculture and Forestry (MAF) launched a pilot programme over 150 dairy farms, which included an energy audit with the aim of helping farmers cut their energy spend by at least 10%. This would be worth around $16 million annually if achieved throughout the sector. “Dairy farms account for nearly 2.5% of the country’s electricity use, with the average dairy farm consuming

Figure 7: Regional Distribution of Dairy Cows 2010-11



Source: DairyNZ

88,000kWh per year (costing around $14,000). A 10% reduction in electricity use and associated CO_2 emissions spread across the 150 pilot farms, would deliver annual savings of around $210,000 per year” (Rural Bulletin, 2010). The pilot programme found:

- Dairy farmers could save 16% on power consumption and cost-effective annual energy savings of at least 68.4mkWh in the dairy shed.
- The average farm milking operation, including irrigation, in the sample used 112,100kWh of electricity in the 2009/10 season.
- Water heating accounted for 24% of consumption, water pumping 22%, refrigeration 17% and vacuum pumps 15%.
- Over 70% of savings opportunities relate to water heating and EECA is now looking at how electricity efficiency can be enhanced, primarily by heat recovery technology.
- Farmers in the pilot have been quick to take up savings ideas with 23% already adopting at least one recommendation delivering at least 161,000kWh of total annual savings.
- With 42% of participants reporting they will probably adopt recommendations over the next three years, savings from the audits could rise to 297,000kWh.
- Audits contracted individually can cost between $1,500 and $2,000 so Fonterra is looking at achieving economies of scale by clustering audits in districts to save travel time and costs.
- A post-pilot survey showed 46% of farmers will adopt savings technologies if their costs can be recouped within three years (NZ Energy & Environment Business Week, 2012).

"Energy efficiency usually comes with a very attractive payback. Typically, every dollar invested in an energy audit brings a return of $7.50 in savings" (New Zealand Management, 2011). *"What is given by the land should return to the land"* is a well-known proverb about showing mutual respect for the land and what it has to offer all living beings. In return, those who reap a living from the land have an obligation to return something to the land and leave it in the same or better condition than when they took control of it. It is encouraging that the dairy sector is beginning to take environmental and sustainable dairy practices seriously by improving energy performance. Fuel cell technology may go some way to help the industry achieve a reduction in operating costs through improved energy efficiencies, a corresponding reduction in CO_2 emissions, and increased stability to energy costs.

2.3 Energy Industry

According to the Ministry of Economic Development, in 2011, 77% of New Zealand's electricity generation came from renewable sources (Energy Data File, 2012). This is the second highest ranking for countries in the OECD for the contribution that renewable energy makes to electricity. Natural gas has a more favourable impact on the environment than coal and for the New Zealand dairy industry there are advantages in substituting natural gas for coal when it can reduce the level of CO_2 emissions by between 40% and 60% depending largely on factors such as age and efficiency of coal units. There have been recent breakthroughs in natural gas extraction which underline changes and a shift away from New Zealand's reliance on oil and coal extraction to cheaper and relatively clean sources like natural gas to power economic growth and improve living standards.

It will be imperative for governments to develop long-term initiatives together with industry leaders to ensure the sustainability and reduction in carbon emissions over the next 20 to 40 years. New technologies particularly associated with gas extraction have been receiving a great deal of attention in recent times. Hydraulic fracturing or “fracking” for example, involves the release and extraction of natural gas from shale rock deep below the ground. This is achieved through a process of fracturing the shale rock by drilling and injecting a combination of water, quartz sand, and chemicals into the ground at high pressure. The associated pressure build-up causes natural gas to flow into the well through a series of fissures or cracks in the shale rock. In some respects the ability to obtain natural gas from shale rock has undermined the case for renewable energy as a source for electricity. But this practice is not without its critics. Likewise coal seam gas (CSG) which is methane gas found in coal seams, is another controversial area that the coal industry is exploring as a means of utilizing to counter the effects of peak oil.

Dr M King Hubbert, a renowned geophysicist and expert in the field of estimating energy resources, accurately predicted in 1956 that United States oil production would peak in the early 1970’s. Around 1980 the world began to produce more oil than what was being discovered. Today, about four barrels of oil are consumed for every one barrel that is found. With the help of Hubbert’s peak model and other methodologies, it is predicted that world oil and liquid gas will peak around 2030 (http://en.wikipedia.org/wiki/Peak_oil). According to the World Energy Outlook of 2010, the International Energy Agency (IEA) stated that conventional crude oil production “never regains its all-time peak of 70 million barrels per day reached in

2006” (http://www.energybulletin.net) Oil producing countries already in decline include the United States (1970), Indonesia (1997), Australia (2000), United Kingdom (1999), Norway (2001), and Mexico (2004). An interesting debate about such developments as tapping shale deposits and CSG exploration has been taking place in recent months. “One argument is that the environmental movement is really less concerned with immediate environmental impacts and more concerned about fracking (and deep-sea oil extraction) sounding the death-knell on the “peak oil” theory. In other words, if lobbying and scare tactics can keep major new oil and gas sources in the ground, then peak oil might just come true” (NZ Energy & Environment Business Week, 2012). It could be argued that this is a rather cynical view that plays into the hands of oil and gas multinationals bent on promoting fossil fuel development over wind and solar. All stakeholders in the energy industry, including governments, must step back and consider the role that the public and private sector have in creating a level playing field for developing a sustainable and secure low carbon energy future. Most would agree an element of initial start-up support by governments for new technologies is a good way to create confidence and attract private sector investors in new energy initiatives that would otherwise not occur.

But after they become profitable and support is no longer necessary, the question is whether governments that continue to subsidize fossil fuels and renewable energy development simply create a false reality and delay the real task of addressing energy reform? Alongside the tax breaks to big oil companies over many decades, agricultural lobby groups also share an element of responsibility through their promotion, for example, of multi-billion dollar subsidies for corn ethanol.

"Corn ethanol generated more carbon dioxide than gasoline after taking into account the emissions caused when new land was cleared to replace the food lost to fuel production" (The New York Times, 2012). The fluidity of global trade patterns, increased reliance on bilateral and regional trade agreements around the world, and changing forms of energy use created by a combination of supply and demand constraints is bringing about important discourse on the future of energy. In the United Kingdom, the energy secretary, Ed Davey, published a draft bill setting out the framework for investment in new power stations. Central to Mr Davey's plan is a regime that involves the state setting minimum prices for power generated from different sources. "The idea is to let the government set the power mix – so much to come from renewables; so much from nuclear and gas and so on – and hence achieve its overall desire for more electricity to come from cleaner technologies" (Financial Times, July 2012). George Osborne, Chancellor of the Exchequer wants to cut incentives for renewables. Mr Osborne believes wind could crowd out future investment in gas-fired stations and saddle the consumer with excessive costs.

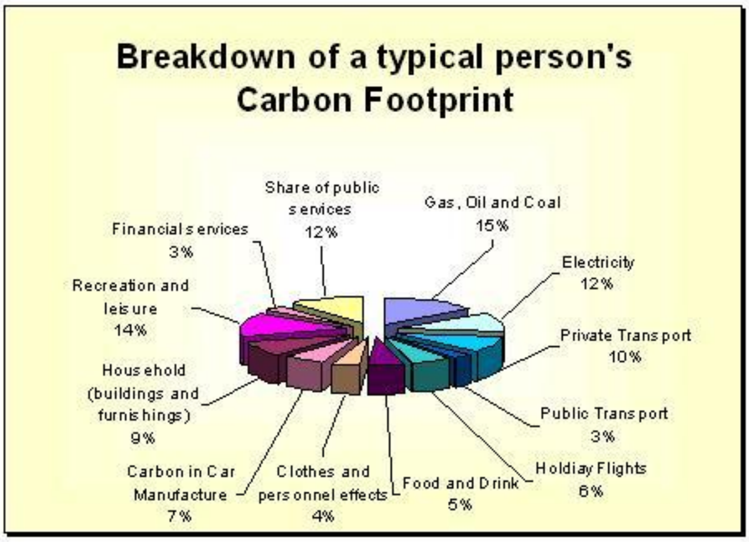
Such debates are proceeding in New Zealand with a similar point of reference. The Tiwai Point aluminium smelter near Invercargill at the bottom of the South Island, for example, "employs nearly 1,000 workers and uses one-seventh (14.29%) of New Zealand's electricity to produce more than 250,000 tonnes of aluminium annually" (The National Business Review, 2012). Analysts say that if it closes or greatly reduces its power usage, national power prices will fall significantly, impacting on the value of the three state-owned energy companies (including Meridian its electricity supplier) scheduled for partial privatization in early 2013.

“Trade unions and Southland community leaders have called on the government to step in as owner of Meridian and enable the smelter to keep operating at full capacity” (Executive News Service, September 2012). Rio Tinto owns 79% of the Tiwai Point aluminium smelter (the balance is owned by Sumitomo Chemical) and must honour its current power price contract without distorting the electricity supply market to benefit its own commercial gains at the expense of taxpayer funded incentives. In the energy sector it could be argued that venture capital should remain the responsibility of the private not public sector and the folly of governments that view their responsibilities in this role exacerbate delays in addressing necessary regulations on carbon and air pollution. Comparable with the debate underway in the UK, incentives in the form of tax breaks and other subsidies result in long-term additional costs for consumers and a distortion of actual costs relative to the actual value provided by some technologies. If governments concentrate on setting the benchmark on reducing GHG emissions then it should follow that the market will develop the best clean or renewable technology to shoulder the electricity load.

2.4 International Legislation

Energy activities are governed by country specific laws and international legislation, treaties, and protocols. There is little point in the New Zealand Government enacting legislation to reduce GHG emissions if it does not align with general international law applicable to energy and natural resource activities, including nation sovereignty over natural resources and sustainable development. Today the world is faced with a number of conflicting views on climate change which is exacerbated by a vacuum or limited means of measuring the effects that human activity has on the environment. A carbon footprint has historically been defined by the UK Carbon Trust as "the total set of GHG emissions caused by an organization, event, product or person" (http://www.ukcarbontrust.com). Carbon footprint has also been described as the total amount of GHG emissions associated with a product, along its supply chain, and sometimes includes emissions from consumption, end-of-life recovery and disposal. It is interesting to see in Figure 8 how a typical person's carbon footprint is spread across various activities and areas of everyday life. The major UK supermarket chain Tesco has been displaying the carbon footprint of its own-label milk since 2009. In 2007 New Zealand became the focus of public and media attention from supermarket and farmer interests in the UK because of the carbon footprint of New Zealand food products that the country exports to the UK and Europe. "Dr Caroline Saunders, Lincoln University professor of trade and environmental economics, was instrumental in 2007 in proving New Zealand lamb had significantly less carbon output in its production and delivery than UK lamb, despite its distance to market." (Rennie, 2012). The term "food miles" or how far food has travelled to reach consumer markets became a major focus. However, other factors such as water and fertilizer use, harvesting techniques, renewable energy application, and mode of transport should be included in the calculation of a product's

Figure 8: Breakdown of a Typical Person's Carbon Footprint



Source: The Encyclopedia of Earth

carbon footprint. The Lincoln University scientists found that “lamb raised on New Zealand’s clover-choked pastures and shipped 11,000 miles by boat to Britain produced 1,520 pounds of carbon dioxide emissions per ton while British lamb produced 6,280 pounds of carbon dioxide per ton, in part because poorer British pastures force farmers to use feed. Similar figures were found for dairy products.” (McWilliams, 2007).

Some key fundamentals on the international stage to deal with GHG emissions and climate change include the United Nations Framework Convention on Climate Change (UNFCCC) which is an international environmental treaty that came about at the UN Earth Summit in Rio de Janeiro in June 1992. From the UNFCCC came the Kyoto Protocol in 1997 which established legally binding obligations for developed countries to reduce their GHG emissions. New Zealand has been at the forefront of international legislation in a number of areas, particularly governing Antarctica. For example, the Antarctica (Environmental Protection) Act 1994, is a piece of New Zealand legislation that provides for the comprehensive protection of the Antarctic environment and to recognize Antarctica as a natural reserve devoted to peace and science and to implement the Protocol on Environmental Protection to the Antarctic Treaty. New Zealand is conscious of the Energy Charter Treaty (ECT), a multilateral treaty in the energy sector, which came into force in April 1998. It provides a legally binding set of rules for international energy investments and trade. The ECT was signed by New Zealand, Australia, United States, Canada and Japan in December 1991, together with 47 other nations, consisting of most western and eastern European countries. In 1994 agreement was reached on the terms to turn it into a binding treaty, but New Zealand pulled out of negotiations after they became protracted and it was no longer felt applicable to

New Zealand. “The ECT plays an important role as part of an international effort to build a legal foundation for energy security, based on the principles of open, competitive markets and sustainable development” (Energy Charter, 2012). However, there are other means to achieve similar results that sit better with New Zealand’s interests and efforts. The World Energy Council (WEC), of which New Zealand is a member, is the UN-accredited energy body that informs global, regional and national energy strategies through hosting events, publishing studies, and facilitating policy dialogue (http://www.worldenergy.org). More recently the WEC has explored the relationship between international trade and natural resources with a particular focus on trade in energy goods and services.

As energy sources are developed and newly developed technology is introduced to new and emerging markets, the unique factors governing energy trade in goods and services (rather than the mining, transfer, and supply security arrangements between nations along with the protection of foreign direct investment associated with state owned assets), will increasingly fall within the boundary of mechanisms such as the ECT and rules embodied in the World Trade Organization (WTO) system. The WTO is a multilateral trade organization which deals with the rules of trade between nations in a global sense including trade in goods, including the General Agreement on Tariffs and Trade (GATT), services under the General Agreement on Trade in Services (GATS), and intellectual property under the Agreement on Trade-Related Aspects of Intellectual Property (TRIPS). It is a system of international regulation where member governments negotiate trade deals, and try to sort out trade disputes between each other. This is undertaken through a disputes settlement system comprising panels (which decide facts) and an appellant body (which deals with questions of law). The WTO was born out of the last General Agreement on Tariffs and Trade (GATT) ‘Uruguay Round’ and was formed on 1 January 1995. During 1948 to 1995 GATT was the international body that mainly dealt with trade in goods (http://www.wto.org).

2.5 Milk Production Emissions

The Global Dairy Agenda for Action on Climate Change is a statement of commitment by the dairy industry supply chain to take action to address climate change. New Zealand is a signatory to the agenda which was signed at the World Dairy Summit in Berlin on 24 September 2009. “In response to growing awareness and understanding of the causes and impacts of climate change, the signatories and participants of this Agenda for Action also recognized the need to raise awareness on the role of dairy production in climate change, as well as the contribution that dairy farming and dairy products make to global nutritional, social and economic wellbeing.” (http://www.dairy-sustainability-initiative.org/Public/Menu.php?ID=36). In October 2011, independent scientist Dr Rob Carlton, who specializes in calculating carbon footprints, wrote a report titled “The carbon cost of palm kernel expeller and its contribution to the dairy carbon footprint in New Zealand.” Relying on the findings from the report, Greenpeace New Zealand reveals that the “1.4 million tonnes of palm kernel expeller (PKE) imported into New Zealand during the 2010/11 dairy season, could have produced up to 8.9 million tonnes of GHG emissions. This is the equivalent to 12% of New Zealand’s entire annual GHG emissions. As 90 per cent of imported PKE goes to the dairy sector, and 95 per cent of dairy farms are owned by Fonterra, the report makes it clear that Fonterra's use of PKE - which has increased exponentially since 2005 - is likely to be having a significant effect on the carbon footprint of its milk products. New Zealand currently buys over a third of global PKE stocks" (http://www.greenpeace.org/new-zealand/en/press/pke-report-2011/). According to Greenpeace tropical forest destruction is responsible for around a fifth of GHG emissions, and ending deforestation is a central part of a global strategy to tackle climate change. There is a strong argument that Fonterra, New Zealand's largest company and the world's biggest dairy exporter has a moral and ethical responsibility to ensure the country's dairy industry practices are undertaken in accordance with accepted national and international expectations. Sustainability is the key element to ensuring that unnecessary environmental degradation and actions that negatively contribute to climate change are minimized or eliminated. "The average global emission from milk production, processing and transport is estimated to be 2.4 CO_{2}-eq per kg of fat and protein corrected milk (FPCM) at farm gate (plus or minus 26%)" (FAO, 2010). A comparison of the carbon footprint or CO_2 emissions per kg of milk between three major producer countries is outlined in Figure 9.

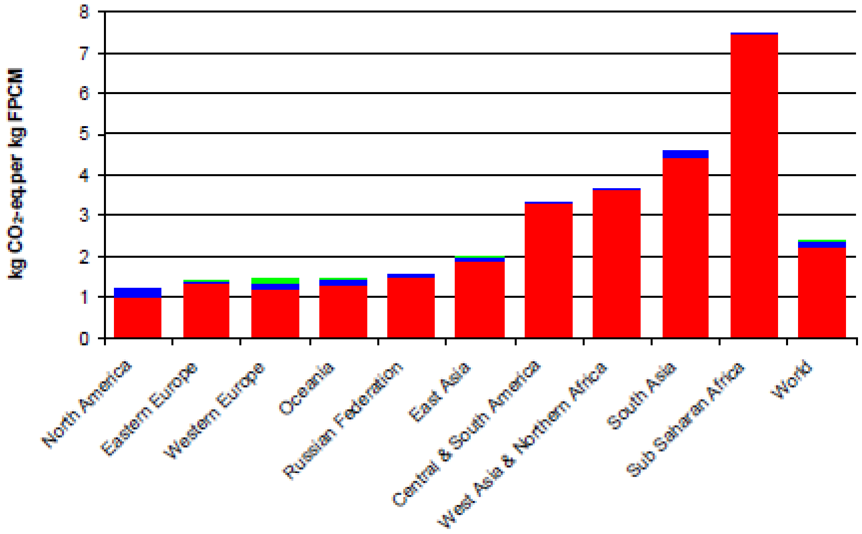
Figure 9: Results from Prior Life Cycle Assessment Studies of Dairy Production

Reference	**Country**	**CO_{2}- eq per kg of milk**
Basset-mens et al., 2009	New Zealand	0.65 – 0.75
Foster et al., 2007	United Kingdom	1.14
Blonk et.al., 2008	Netherlands	1.2
Thomassen	Netherlands	1.5 – 1.6
Capper et al., 2009	United States of America	1.35

Source: FAO, 2010

It shows the CO_2 equivalent per kg of milk is between 0.65 and 0.75. In comparison it is between 1.14 (UK) and 1.35 (US) CO_2-eq per kg of milk for the other countries. Appendix 8 shows a flowchart of the milk life cycle and associated GHG emissions. Efficient farming practices no doubt contribute to New Zealand having the least emissions of the four countries and it provides a stark contrast to Fonterra's use of PKE identified earlier. It would be unfortunate for the use of PKE to reverse the strong placing that the New Zealand dairy industry has achieved with regard to low GHG emissions associated with milk production on the international stage. Figure 10 is from the Food and Agriculture Organization of the United Nations 2010 report on Greenhouse Gas Emissions from the Dairy Sector. It shows the estimated GHG emissions per kg of fat and protein corrected milk (FPCM) at farm gate, averaged by main regions and the world. The red colour represents milk production including farm emissions, blue represents milk transport and processing, and green represents deforestation. Given its geographical isolation Oceania (New Zealand and Australia) compare favourably with the United States and Europe.

Figure 10: Estimated GHG Emissions per kg of FPCM



Source: Cited in "A sustainable dairy sector" report for the European Dairy Association, 2008

2.6 The Kyoto Protocol

Wikipedia states that the Kyoto Protocol to the UNFCCC aims to fight global warming. “Under the protocol, signatory nations commit to a reduction of four GHG (carbon dioxide, methane, nitrous oxide, and sulphur hexafluoride) and two groups of gasses (hydrofluorocarbons and perfluorocarbon) produced by them, relative to their annual emissions in a base year, namely 1990” (http://www.wikipedia.org). The Kyoto Protocol has been ratified by New Zealand and from 2008 to 2012 the country is required to reduce its GHG emissions to an annual average equal to or below its 1990 emissions level or to take responsibility for the excess emissions. By harnessing renewable resources and clean energy sources, it is hoped that these will help reduce energy sector emissions and contribute to meeting New Zealand’s commitment to the Kyoto Protocol. “In 1990 New Zealand was emitting the equivalent of 61.2 million tonnes of CO_2” (Listener, 2011). “On 9 November 2012 the government announced that it will not sign up to the second stage of the Kyoto Protocol which will set fresh legally binding obligations for emissions reduction from 1 January 2013, but will instead sign up to the UN Convention Framework which is not legally binding. New Zealand would however apply the broad Kyoto framework of rules to its next commitment and would make no change to domestic policy settings based on Kyoto.” (Executive News Service, November 2012).

2.7 New Zealand Legislation

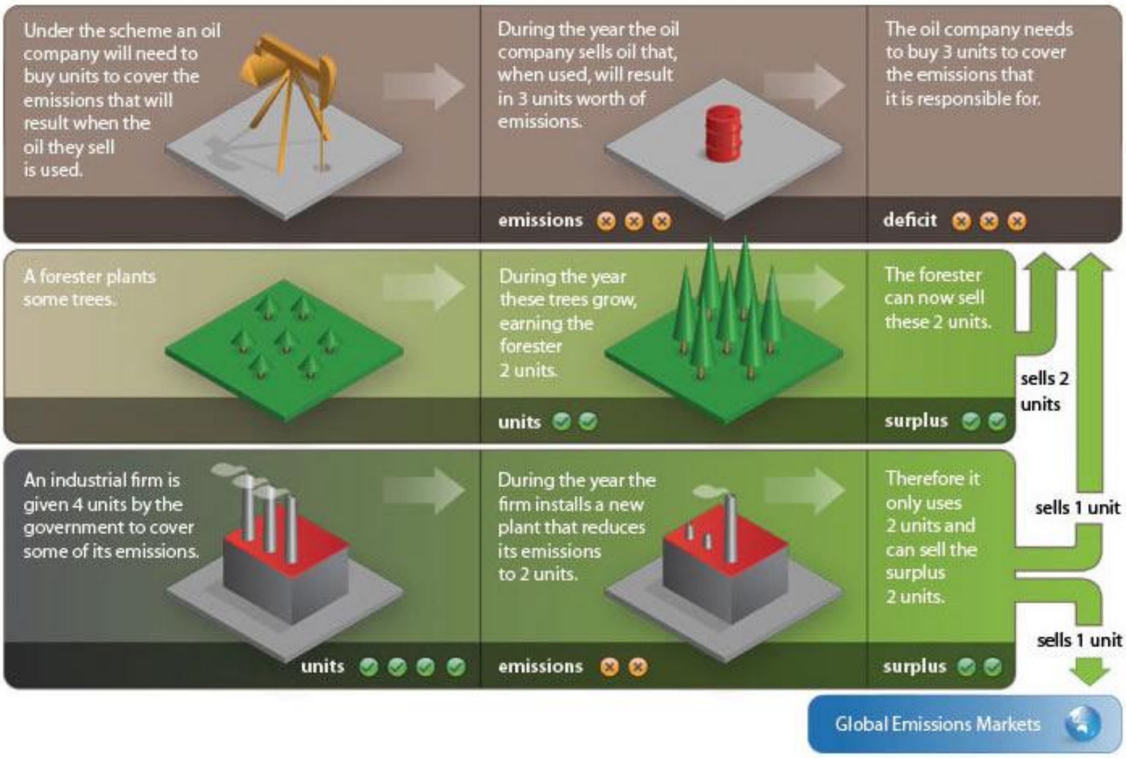
New Zealand’s energy sector operates within the legal framework and government energy policy. To understand the current environment it is worth having an appreciation of the history that has lead the country to where it is today and the environment within which New Zealand currently operates. New Zealand’s indigenous Maori, a Polynesian people, make up around 15% of the population. A lot of legislation impacts on the mining and energy sector and also the natural resources of New Zealand. For example, the Foreshore and Seabed Act was enacted on 24 November 2004, and concerns the ownership of New Zealand’s foreshore and seabed with many Maori groups (Hapu and Iwi) claiming that Maori have a rightful claim to title. The government must consult with Maori over land use consents under the Resource Management Act 1991 (RMA). The RMA regulates access to natural and physical resources such as land, air and water, with sustainable management of the resources being the overriding goal. The principles of the Treaty of Waitangi (partnership, participation, and protection) must also be taken into account in the consultation process for approving land use consents. Among other things, the Treaty recognises Maori ownership of their lands and other properties.

The Crown (Government) owns the in-ground petroleum resource and any company wanting to prospect, explore or mine petroleum in New Zealand must obtain a permit from Crown Minerals under the Crown Minerals Act 1991. This includes petroleum on the New Zealand continental shelf and coal-seam gas. Furthermore, most seabed minerals within 12 nautical miles from the coast are owned by the Crown. The Climate Change Response Act (2002) is the legal framework that allowed New Zealand to ratify the Kyoto Protocol. The Act sets out procedures for the management of New Zealand’s unit holdings that represent target allocations for GHG emissions. It also provides the Minister of Finance with mechanisms to trade those units on the international market. Recently passed by Parliament was the Climate Change Response (Emissions Trading and Other Matters) Amendment Bill which amends the Climate Change Response Act 2002. It modifies the emissions trading scheme (ETS), provides further powers to make regulations, and makes technical and operational changes. “The objectives of the Bill were to:

- Ensure that the ETS more effectively supports the Government’s economic growth priorities.
- Ensure that the ETS is flexible enough to cater for a range of international outcomes in the period 2013 to 2020.
- Improve the operation and administration of the ETS.
- Change the current treatment of the synthetic greenhouse gases sector in the ETS” (Explanatory Note, Government Bill).

Using three examples, Figure 11 below illustrates how emissions trading works.

Figure 11: New Zealand Emissions Trading Scheme (ETS)



Source: Climate Change Information, NZ

The New Zealand Climate Change Information homepage is a particularly useful source of information (http://www.climatechange.govt.nz). The ETS currently requires stationary energy, industrial processes (SEIP) and liquid fossil fuel (LFF) participants to surrender only one emission unit for every two tonnes of CO_2 equivalent emissions emitted; and an option for SEIP, LFF and forestry participants to pay a fixed price of $25 per emission unit. Key measures in the Bill which was passed by New Zealand's parliament by 61-58 on 8 November 2012 are to (1) maintain the one-for-two surrender obligation after 2012, without specifying an end date in legislation; (2) maintain the $25-a-unit fixed price option after 2012, without specifying an end date in legislation; and (3) remove a specified entry date for surrender obligations on biological emissions from agriculture. A widely expressed concern about the Bill was that it removes a specified entry date for the surrender obligations on biological emissions from agriculture. Delaying the inclusion of agricultural emissions indefinitely (the agricultural sector is one of New Zealand's largest emitters) reduces the urgency for the sector to reduce pollution and start investing in cleaner technologies. Another important piece of legislation that complements New Zealand environmental law is the Ozone Layer Protection Act 1996 (outlining broad controls for ozone-depleting substances) and the Ozone Layer Protection Regulations 1996 (containing the rules relating to specific substances). Finally we come to the energy strategies that need to comply with legislation. The strategic direction of the energy sector and role that energy plays is governed by the New Zealand Energy Strategy (NZES). Another strategy that sits alongside the NZES is the New Zealand Energy Efficiency and Conservation Strategy (NZEECS) which is specifically focused on the promotion of energy efficiency, energy conservation and renewable energy.

The New Zealand Energy Efficiency and Conservation Authority (EECA) is responsible for implementing the Government's strategies for energy efficiency (http://www.eeca.govt.nz). The Electricity Commission administers the market for wholesale electricity in New Zealand. Market participants include state-owned enterprises, trust-owned companies, and public companies. To ensure a standard of competition in the sector and the cheapest possible electricity prices for consumers, the market is split into six key areas. These are – administration and market clearing, regulation, generation, transmission, distribution, and retailing. This ensures there is no avenue for companies to monopolise the market or establish duopolies.

3. RESEARCH METHODOLOGY

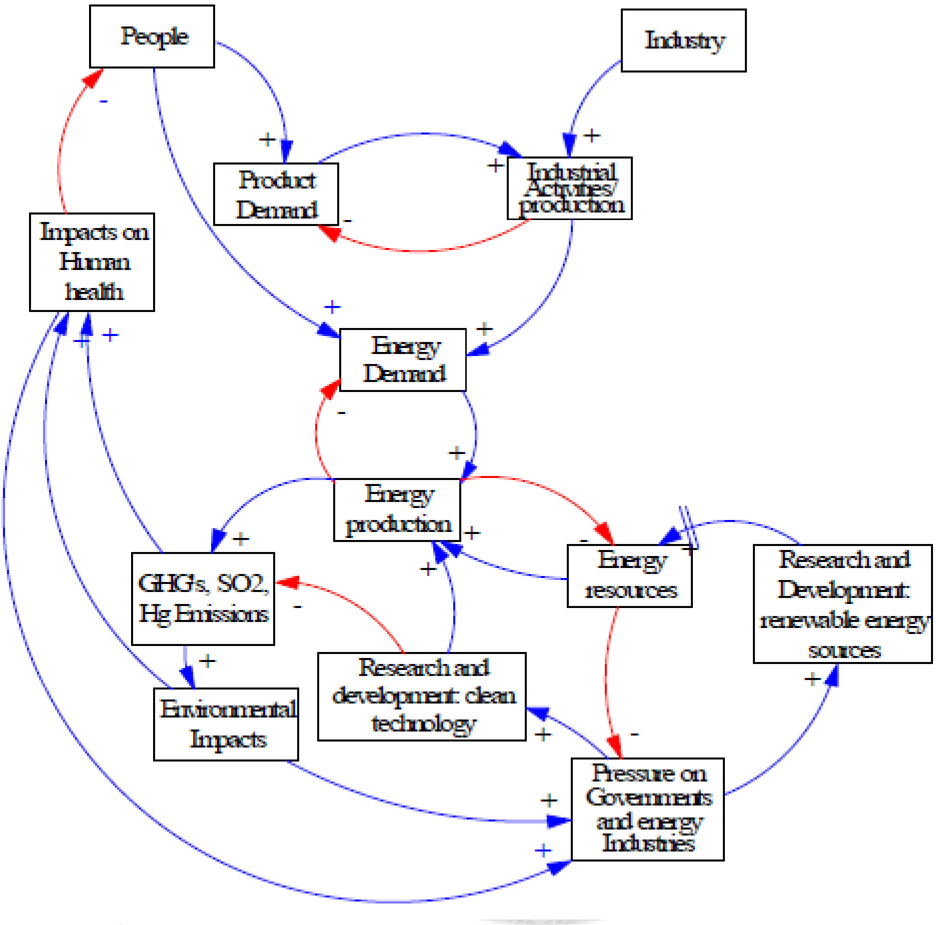
The generic framework under which this study is undertaken is premised on qualitative and quantitative research and the argument or reasoning of the specifics of three different fuel cell systems and how they could best meet the needs of (1) a large scale dairy processing operation performed by companies such as Fonterra (http://www.fonterra.com) and Synlait (http://www.synlait.co.nz); and (2) an average size dairy farm operation in New Zealand. Energy cost reduction is essential to sustainability. It becomes a matter of innovation through minimizing energy inputs while maximizing energy outputs in an environmentally friendly manner. In addressing the central proposition "a feasibility study on the development of a sustainable clean energy source for the New Zealand dairy industry" the research methodology has a focus on fuel cell technology best positioned to address the research question.

The result is a preference toward modeling the specifics of a fuel cell system against the "needs" of a dairy farm operation to determine (1) to what extend does a fuel cell satisfy those needs; (2) what is the cost to do so; and (3) how does this compare to maintaining the status quo. For a dairy farm operation, the research supports Proton Exchange Membrane, also known as Polymer Electrolyte Membrane (PEM) fuel cell technology as being the preferred system that best provides a platform for the delivery of reduced operating costs, lowering GHG emissions, and minimizing exposure to fluctuating energy costs. The United States Department of Energy (DOE) has stated that fuel cell technology has the potential to revolutionise the way nations are powered, offering cleaner, more efficient alternatives to the combustion of gasoline and other fossil fuels (http://energy.gov).

This study explores the feasibility of ClearEdge Power’s PEM fuel cell technology (http://clearedgepower.com), and its application to an average size New Zealand dairy farm. A comparison will also be drawn with larger stationary systems that may be suitable for dairy processing plants, namely a Solid Oxide Fuel Cell (SOFC) produced by Bloom Energy (http://www.bloomenergy.com), and UTC Power’s PureCell system which is a Phosphoric Acid Fuel Cell (PAFC) system (http://www.utcpower.com).

The causal loop in Figure 12 demonstrates the achievement of effectiveness (e.g. increased pressure on governments and energy industries by people) thus creates efficiency (e.g. research and development on clean technology) and results in a reduction of GHG and other harmful emissions. This dove-tails into simulation or scenario analysis and the effect of “if I do this, then that will happen”. It is essentially about bringing together, understanding, and applying elements of a formula that are proven to work. “The causal loop illustrates the relationship between economic growth (industrial activities), society (population/people), and government actions play important roles in driving the energy sector. The direction energy systems take are consequently dependent on them as well as the impacts of the energy systems affecting them” (Cantú, 2005). The energy systems causal loop diagram also assists in helping to explain the research methodology and the factors that impact on this study. For example, a delay symbol (two vertical lines) is introduced in the diagram which denotes over an extended period of time that energy and resources will continue to be utilised until research and development brings forward growth of renewable energy sources. Energy production in the meantime will require increased energy resources which will have a negative effect on the depletion of those resources (e.g. increased use of fossil fuels will cause a corresponding increase in pressure brought on governments and the energy industries by environmental groups and people in society).

Figure 12: Energy System Causal Loop Diagram



Source: Cantú, 2005

3.1 Energy and Environmental Sustainability

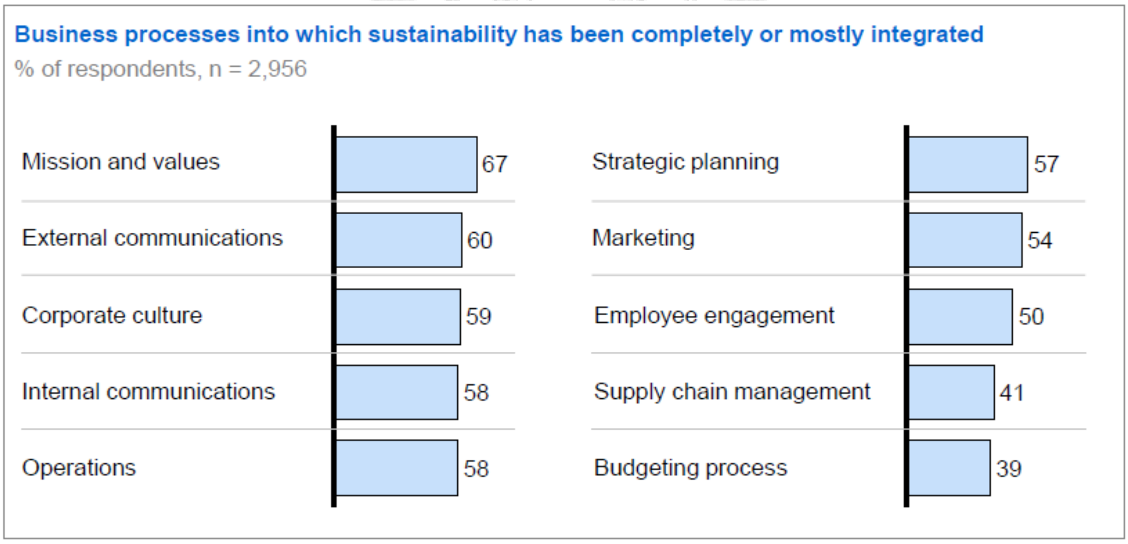
As the spotlight begins to focus on the desire for companies to integrate sustainable practices into their everyday operations, sustainable transformation is becoming an important concept. This includes initiatives being developed by companies to create shareholder value while ensuring their operations remain environmentally sustainable.

Companies should champion sustainability in their practices in the following areas which are coming under increased scrutiny by stakeholders:

- Outside influences – limited resources and society’s expectations for a greater choice of sustainable products and services.
- Industry competition – public perception to do more, industry pressure, and increased board governance accountability.
- Adding value – working smarter, reducing costs, and developing new sources of innovation.
- Community involvement – corporate social responsibility proclamations in mission statements.

McKinsey and Company (http://www.mckinsey.com) has studied how companies are integrating sustainability into their operations and Figure 13 shows the degree of business processes into which sustainability has been completely or mostly integrated.

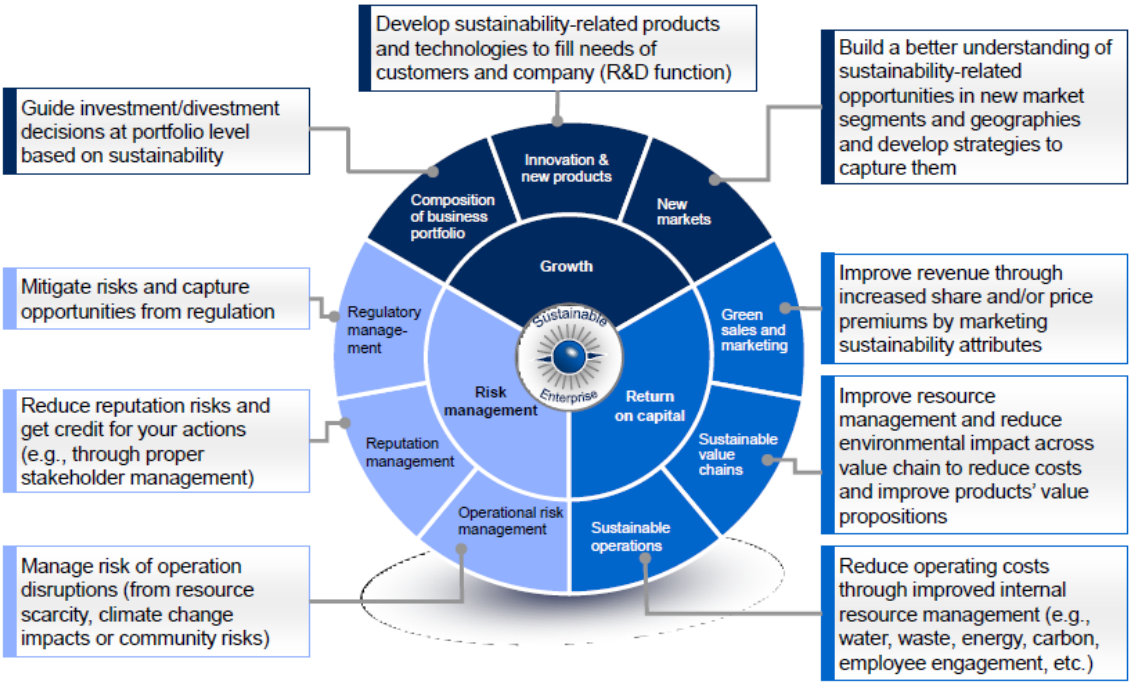
Figure 13: Integration of Sustainability in Business Processes



Source: McKinsey Quarterly Survey (July 2011)

The results of McKinsey’s survey indicate that many companies have integrated sustainability practices and have acknowledged this issue at the high level, for example, in external communications (60%) and corporate culture (59%). However, there is more work to be completed on integrating sustainability into budgeting processes (39%) and supply chain management (41%). It is encouraging that 50% of the companies surveyed have included sustainability into their employee engagement and this area should see an incremental increase as company management increasingly conveys this message among employees. Sustainability in terms of behaving in an environmentally sustainable way that protects the environment and includes ethical behaviour are critical to New Zealand’s management and use of its natural resources. While New Zealand has about 0.1% of the world’s population, its economy produces about 0.3% of the world’s material output. It is one of the wealthier economies and its people enjoy a good standard of living. The drive for economic growth and an increasing population is resulting in the depletion of natural resources around the world and is not sustainable – New Zealand is no exception. The compass in Figure 14 illustrates the value chain levers that could be considered essential enablers for the guidance of energy companies to use in highlighting the benefits of fuel cells and their introduction of this clean energy technology to the New Zealand dairy industry.

Figure 14: Value Creation Levers of a Sustainable Transformation



Develop sustainability-related products and technologies to fill needs of customers and company (R&D function)

Guide investment/divestment decisions at portfolio level based on sustainability

Build a better understanding of sustainability-related opportunities in new market segments and geographies and develop strategies to capture them

Mitigate risks and capture opportunities from regulation

Improve revenue through increased share and/or price premiums by marketing sustainability attributes

Reduce reputation risks and get credit for your actions (e.g., through proper stakeholder management)

Improve resource management and reduce environmental impact across value chain to reduce costs and improve products' value propositions

Manage risk of operation disruptions (from resource scarcity, climate change impacts or community risks)

Reduce operating costs through improved internal resource management (e.g., water, waste, energy, carbon, employee engagement, etc.)

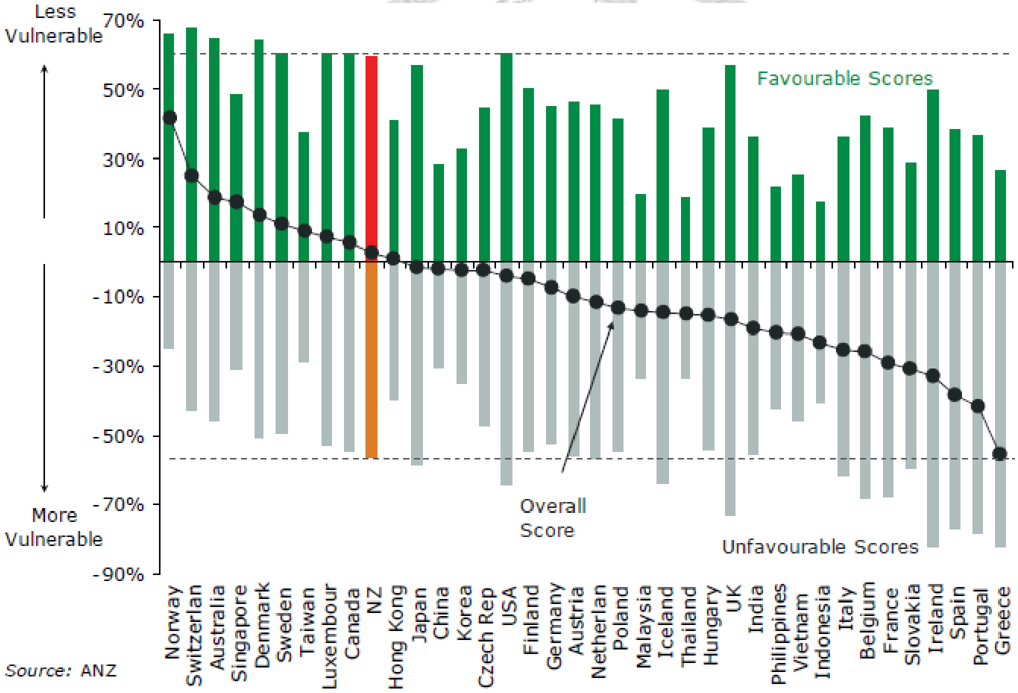
Source: McKinsey Sustainable Enterprise Service Line, McKinsey & Company

Despite an abundance of natural resources, New Zealand is a net importer of energy, primarily because of its reliance on oil products. According to the World Bank, World Development Indicators (updated 26 April 2011) New Zealand energy consumption is 4,190kg of oil equivalent per capital (http://data.worldbank.org/indicator). “In 2011, a net total of 43,138GWh of electricity was generated, 77% of which was from renewable sources. Hydro was the major source of electricity generation at 58%, followed by gas at 18%, geothermal at 13%, with coal, wind, wood, biogas, oil and waste heat making up the balance. Electricity generation from wind was up 19% from 2010 levels. In 2011, almost as much electricity was generated by wind (1,931GWh) as was generated by coal (2,026GWh)” (Energy Data File, 2012). “The government’s energy policy aims for 90% of electricity generation to come from renewable sources by 2025” (PowerSwitch, 2012). The primary Renewable Energy Sources (RES) are hydro, geothermal, and wind, with the predominant source being hydro-electricity.

An analysis of the energy sources would not be complete without mentioning at least one of the non-renewables, namely coal, in order to provide a greater sense of New Zealand's energy sector. The reason being that New Zealand's largest natural resource producer, Solid Energy, has a juxtaposition involvement in both coal and renewable energy (biodiesel, and clean-burning wood pellet fuel) and one argument is this bodes well for the future if a coal mining company is investing in RES (http://www.coalnz.com). In 2001 the government adopted a framework to incorporate environmental considerations into New Zealand's free trade agreements. The "Framework for Integrating Environmental Issues into Free Trade Agreements" guides trade negotiations with other countries and covers (1) environment and trade policies; (2) linkages between trade and environment policy principles; and (3) environment and trade policy principles. The objective is to promote sustainable development while maintaining well-balanced trade and environmental goals.

Fiscal sustainability is also an important bell-weather of New Zealand's sovereign debt vulnerability. Historically commodity markets are influenced not only by regional dynamics but also by economic global shifts. Moreover, the European sovereign-debt crisis has the potential to impact negatively on New Zealand's market prices for exported agricultural products. To date, New Zealand has been fortunate that international markets (particularly countries in the Asia region that account for the majority of dairy product exports) have remained stable and that they have generally remained unaffected by the realities of the European sovereign-debt crisis and consequences of austerity measures. But this may change over coming months as European countries struggle to agree on a way forward in solving their fiscal difficulties. One reason for the stability of New Zealand's key export markets has more to do with demand and supply fundamentals which have been responsible for continued exports of consumption-based commodities rather than the state of financial markets. Figure 15 shows the vulnerability levels of several countries. In particular, the levels have remained fairly stable for China, Japan, and Korea (part of New Zealand's top five export markets) and also for Taiwan, New Zealand's 12th largest export market (Ministry of Foreign Affairs and Trade, 2012). These are all key export economies for New Zealand dairy products.

Figure 15: Sovereign Debt Vulnerability Scores

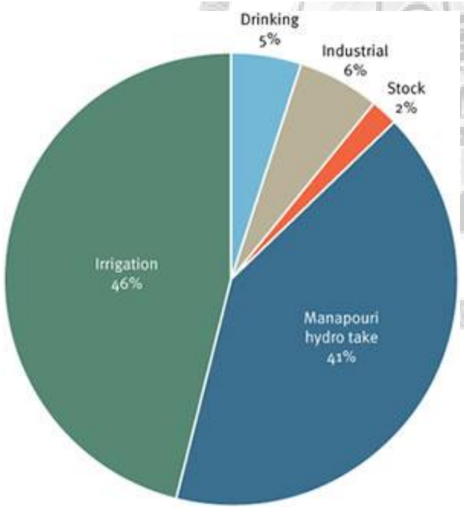


Source: ANZ

Compared internationally, New Zealand has an abundance of fresh water. New Zealand is ranked fourth out of 30 OECD countries for the size of its renewable freshwater resource on a per capita basis. "Within New Zealand, allocated water comprises less than five percent of its renewable fresh water resource. In 2010, there were more than

20,500 resource consents for taking water. The total amount of consumptive water allocated in New Zealand in 2010 was 27 billion cubic metres. This is equivalent to almost half of Lake Taupo in the middle of the North Island. Four times the amount of water is taken from rivers and streams when compared with the quantity of water taken from groundwater. With 4.5 million dairy cows in New Zealand, if each is consuming approximately 50 litres of water per day, a total of 225 million litres or 225,000 cubic metres of water per day is consumed by cows. Figure 16 shows that the majority of consumptive weekly resource consent allocations were for irrigation and hydro-generation. The Manapouri hydro take is eventually discharged to sea" (Ministry for the Environment).

Figure 16: Use of Weekly Allocated Water, 2010

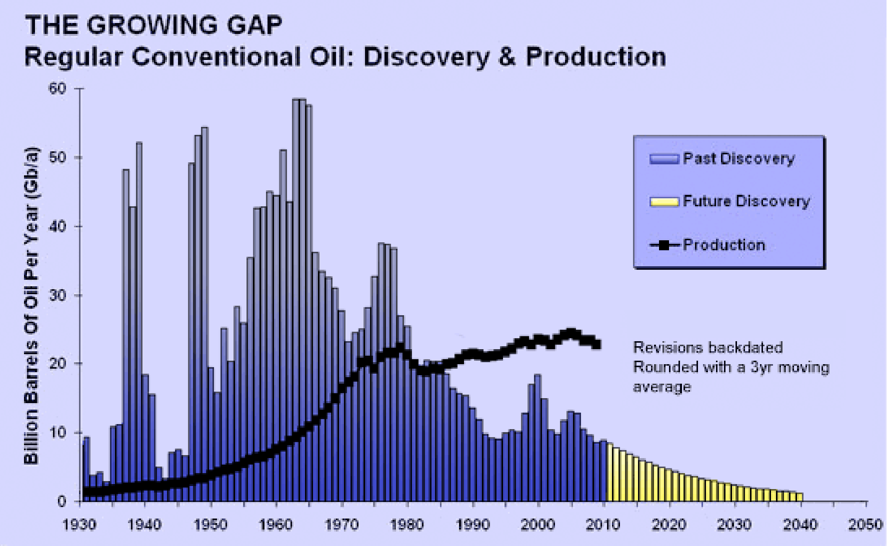


Source: Ministry for the Environment

3.2 Energy Sources

Figure 17 shows the pattern of global oil discovery peaks and consumption from 1930 to 2010, with future discovery predictions to 2040 and beyond. The rate of oil production and refining today is about 85 million barrels per day.

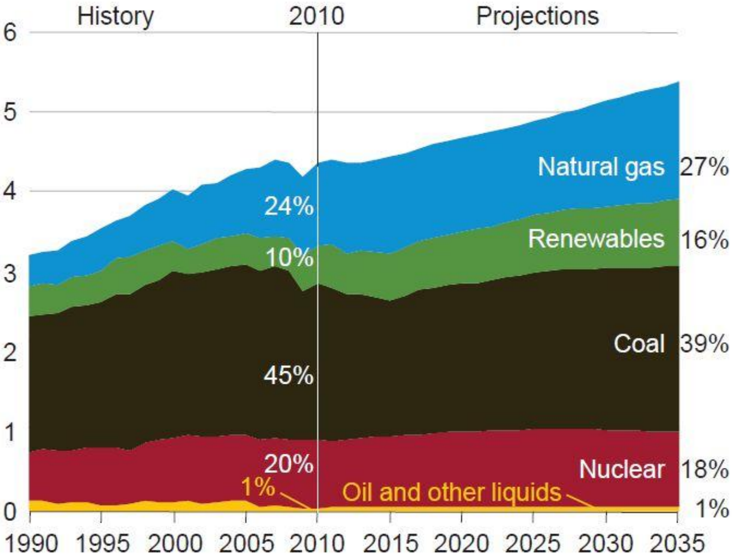
Figure 17: Pattern of Oil Discovery Peaks and Consumption



Source: www.energybulletin.net

Electricity generation from natural gas and renewable fuels is predicted to grow by a combined 9% from 34% in 2010 to 43% in 2035, as outlined in Figure 18. Conversely there is a predicted 8% decline from 65% to 57% in the use of coal and nuclear power as

Figure 18: Natural Gas and Coal Combustible CO_2 Emissions

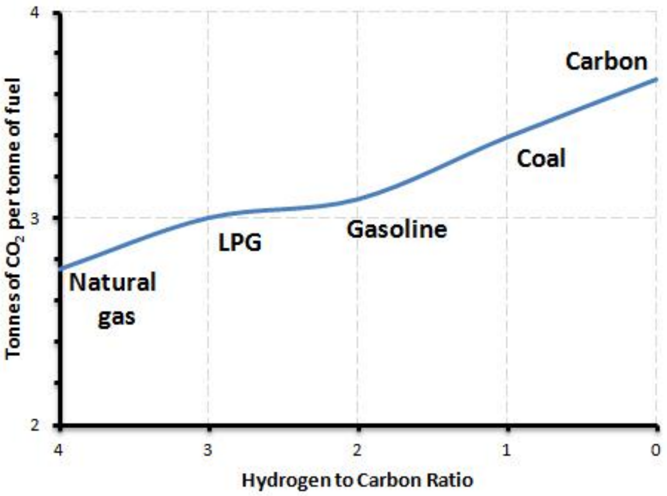


Source: World Nuclear News

a means to generate electricity. On the surface this hardly appears to be a huge swing away from the use of fossil fuels, but it is significant in terms of changing patterns in the supply and demand of energy. It also shows that fossil fuels will remain dominant in the energy mix despite growth in renewable and clean energy sources. This is further evidenced by the prediction that use of oil and other liquids for electricity generation remains unchanged at 1% over the period 2010 - 2035.

When looking at the use of fossil fuels as a continual source for producing energy, Figure 19 shows "that a tonne of methane (natural gas) releases 2.75 tonnes of CO_2 (calculated via the ratio of molecular weights) when combusted, compared to 3.5 tonnes for coal. Combining the release of CO_2 with the release of energy gives the CO_2 released per unit of thermal energy produced" (Hone, 2011).

Figure 19: Electricity Generation by Fuel, 1990-2035 (TWh/year)



Source: David Hone, Climate Change Advisor for Shell

4. CLEAN ENERGY SUPPLY AND DEMAND

The dominance of oil in New Zealand’s supply and demand energy balance for 2011 is outlined in Figure 20. Statistically there is greater demand for natural gas as a consumer energy than supply can meet, represented by a shortfall of 2.06 Petajolues (PJ). As an energy transformation source, natural gas provides 78.33 PJ which is greater than the supply for coal and oil combined at 50.96 PJ. Transport and electricity are high consumers of energy while there is greater demand for natural gas at 1.67 PJ from the agricultural, forestry and fishing industries than there is from renewables at 0.68 PJ. This trend indicates that there are good opportunities for natural gas to be utilized as a clean energy source in the dairy industry.

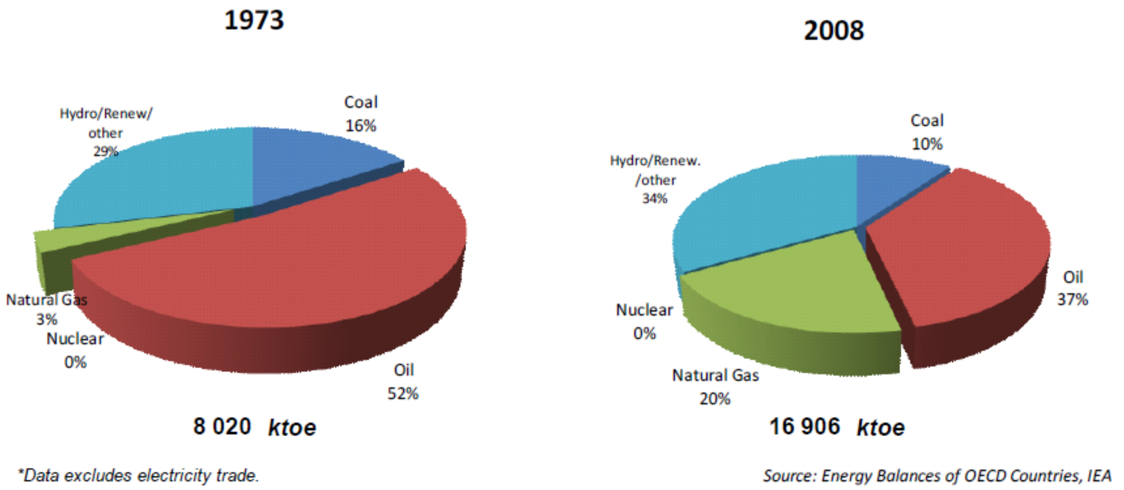
Figure 20: Energy Supply and Demand Balance 2011 (Gross PJ)

Patajoules (Gross Calorific Values)		**Coal**	**Oil**	**Natural Gas**	**Renewables**	**Electricity**	**Waste Heat**	**Total**
SUPPLY	**TOTAL PRIMARY ENERGY**	**60.74**	**276.21**	**158.68**	**320.60**	**-**	**1.52**	**817.75**
	Energy Transformation	-35.64	-15.32	-78.33	-255.19	144.17	-1.52	-241.83
	Non-energy use	-	-11.92	-24.41	-	-	-	-36.33
CONSUMER ENERGY (calculated)		**25.10**	**248.97**	**55.94**	**65.41**	**144.17**	**-**	**539.59**
DEMAND	Agriculture, Forestry and Fishing	2.77	18.52	1.67	0.68	6.97	-	30.61
	Industrial	19.19	14.84	45.03	54.28	54.60	-	187.94
	Commercial	1.28	6.35	5.54	2.38	32.71	-	48.26
	Transport	0.04	206.15	0.05	-	0.21	-	206.45
	Residential	0.75	3.23	5.70	8.08	46.36	-	64.12
CONSUMER ENERGY (observed)		**24.03**	**249.08**	**58.00**	**65.41**	**140.86**	**-**	**537.38**
Statistical Differences		1.07	-0.11	-2.06	-	3.31	-	2.21

Source: Ministry of Economic Development

The supply of natural gas, as shown in Figure 21, has grown significantly over the past 35 years from 3% to 20% due to the development of sizeable gas fields since the 1980’s.

Figure 21: New Zealand Total Primary Energy Supply



*Data excludes electricity trade.

Source: Energy Balances of OECD Countries, IEA

Source: International Energy Agency

However, as New Zealand is not able to import natural gas because of a lack of liquid natural gas (LNG) terminals or pipeline connections to other countries, it is dependent on supply from existing gas fields or major gas discoveries in the future. There may be a business opportunity for natural gas suppliers Nova Energy - part of the Todd Energy Group and one of New Zealand’s leading gas explorers and producers - (http://www.novaenergy.co.nz), or for Contact Energy, a leading energy generator and retailer providing electricity, natural gas and liquid petroleum gas (LPG) to around 650,000 customers nationwide (http://www.contactenergy.co.nz). These suppliers could develop and own a LNG receiving plant and then on-sell gas to other distributors. “Contact Energy, for example, opened New Zealand’s first underground gas storage facility and a new 200 megawatt gas-fired peaker plant in May 2011.

Capable of powering 200,000 homes in ten minutes from a cold start to full-power, the $400 million development is able to inject gas at up to 32 terajoules (TJ) per day and withdraw gas from the facility at rates of up to 45 TJ per day. Contact Energy is giving consideration to expanding the facility and ultimately it could extract or inject up to 160 TJ per day" (Contact Energy). Such developments are encouraging for a dairy industry that becomes reliant on natural gas as a clean energy source for producing its products.

Figure 22: New Zealand Energy Map

Source: The NZ Energy Sector Report

4.1 Oil and Gas

New Zealand had 20 million tonnes or 162 million barrels of crude oil and natural gas liquids: proved recoverable reserves at end 2008 (World Energy Council, 2010). It also had 46 billion cubic metres or 1,612 billion cubic feet of natural gas: proved recoverable reserves at end 2008. "There are some 20 fields and wells in the Taranaki region of the North Island that produce natural gas which is distributed throughout New Zealand and is used for electricity generation, petrochemical production and fuel for industrial and domestic purposes. Gross natural gas production was 186 petajoules (PJ) in the year to June 2011" (New Zealand Treasury, 2012). Many residential housing developments throughout the North Island have reticulated gas available for heating and cooking. Indeed, "over 75% of new home owners in new subdivisions are choosing natural gas as their fuel of choice" (Gas Association of New Zealand, 2012). Many households that do not have reticulated gas supply often use a combination of electricity and large LPG gas bottles for cooking and water heating mostly throughout the South Island, where reticulated gas is not available. In the North Island, the Kupe light oil and condensate gas field lies in the Taranaki basin, a hydrocarbon producing region, approximately 30 kilometres off the west coast in waters about 35 metres deep and covering an area of about 100,000 square kilometres. Most of the basin, including the Maui field, is offshore. Marsden Point is New Zealand's only oil refinery opened in 1964 and expanded in 1979 after the second global oil shock in order to maintain some degree of supply certainty. The Solid Energy website states that the Huntly coal mines produce approximately 1.8 million tonnes of coal a year, which is supplied to Genesis Energy for its Huntly Power Station and the New Zealand Steel Glenbrook Mill (http://www.coalnz.com). Operated by Contact Energy and located on New Zealand's North Island, the Wairakei geothermal power station produces 1,550 gigawatt-hours of electric power per year. It has been generating geothermal power since 1958.

Oil production is dominated by the off-shore Maui gas field which was discovered in 1969 but this resource is running out and accounts for only 17% of remaining gas reserves. More recently the Pohokura field, which started production in 2006, has dominated production. There are large hydrocarbon basins around New Zealand which the private sector continues to explore as the prices for oil and gas increase on the international market. The government is supportive of companies wishing to undertake oil and gas exploration around New Zealand. Proven resources are mostly centred on the Taranaki region but international interest has been shown in the exploration of the Canterbury basin off the east coast of the South Island, and in the Great South Basin, south of New Zealand.

4.2 Coal

At the bottom of the South Island is the Southland District where the local industry and the domestic market make good use of the supplies of coal and lignite at the regional level. Southland has 60% of New Zealand’s total in-ground coal resources (9,392Mt) and represents 72% of New Zealand’s renewable resources (6,257Mt). New Zealand’s total in-ground coal resource is approximately 15.5 billion tonnes of coal. The South Island contains just over 13 thousand million tonnes (84%) of the total due largely to a huge lignite resource in the Southland coal region (9.2 thousand million tonnes) (The New Zealand Energy Sector, 2006). Since 1882, coal mining has been a major industry on the west coast of the South Island and in 2005, 2.5 million tonnes of coal was produced (Minerals West Coast Trust, 2012). About half of New Zealand’s coal is exported (e.g. Japan, Australia) and 9% meets New Zealand’s consumer energy needs with much of it being used to generate electricity and for use in steel mills (e.g. New Zealand Steel’s Glenbrook Mill). While there is an abundance of coal, the difficulty is extracting useable quantities. The problem is twofold; firstly New Zealand has legislation protecting the environment which includes the RMA, and a lot of coal deposits are located in protected National Parks.

The RMA regulates access to natural and physical resources such as land, air and water, with sustainable management of these resources being the overriding goal. There would be large opposition by the community if open cast coal mining was to take place on the west coast of the South Island. However, this may need to be revisited after the Pike River Coal Mine disaster when 29 men died in an explosion in November 2010. It could be argued that open cast mining is a safer means of extracting coal resources, particularly when only 55% of coal is considered economically recoverable in New Zealand and most of that is in the South Island. So while there is plenty of coal the question remains how to safely and economically extract it from the ground. Hence the reason why New Zealand must look at other renewable and clean energy resources instead of relying solely on coal, which does not sit very well with New Zealand’s clean green image. On the question of safety, perhaps there is a case for nuclear power plants, given that China’s coal mines kill 2,000 to 3,000 workers a year, and coal-smogged air there and elsewhere kills many more (The Economist, 2011). The key cost driver for coal electricity generation is fuel cost.

4.3 Nuclear

A discussion of New Zealand’s energy sources would not be complete without comment about nuclear power, which was considered in the 1950s, then again in 1968 and throughout the 1970s (particularly during the world oil crisis). With the discovery of large quantities of natural gas off the Taranaki coast in the early 1970s, and large quantities of coal in the Huntly area that could support a 1000MW thermal power station, the introduction of nuclear power stations was deferred until the late 1980s. At this point, because of New Zealand’s abundance of natural or renewable resources the general mood of the population moved further away from nuclear power, especially after the problems arising from the partial core nuclear meltdown at Three Mile Island in the United States in March 1979. Furthermore, there was an increasing movement against all things nuclear. Many New Zealanders took part in protests against French nuclear weapons testing which took place at Moruroa and Fangataufa, between 1966 and 1996, with fallout deposited throughout the South Pacific (New Zealand Listener, 2011). After the first act of terrorism on New Zealand soil in July 1985 when the French bombed the Greenpeace ship Rainbow Warrior in Auckland Harbour, most New Zealander's were strongly against nuclear power. While nuclear power is not specifically covered under The New Zealand Nuclear Free Zone, Disarmament and Arms Control Act 1987, it has generally been accepted by all political parties and the population that New Zealand's "nuclear free" status is included in the general intent of the legislation and policy framework. For a small country like New Zealand, another financial question is raised about the benefits of nuclear energy and that is one of cost affordability to build a nuclear power plant. Modern nuclear plants are among the most capital-intensive structures ever built. Initial construction of a new reactor consumes close to 60% of a project's total investment, compared to about 40% for coal and 15% for natural gas power plants (the remainder goes to costs such as fuel, maintenance and operations). The nuclear industry is typically the most capital-intensive business in any country that builds nuclear plants (The Wall Street Journal, 2011).

4.4 Hydro

"Between 600mm and 1600mm of rainfall falls in most of New Zealand" (NIWA, 2012). The South Island is particularly wet during winter and as snow melts from ski-fields and the mountain ranges in the Southern Alps over summer, much of the water flows into rivers and dams and feeds the network of eight hydro power stations. The Encyclopedia of New Zealand homepage provides extensive information on the country's hydro power stations. Constructed between 1925 and 2007, the eight hydro power stations in the South Island are: Aviemore, Benmore, Clyde, Manapouri, Monowai, the Opuha Dam, Roxburgh, and Waitaki. Manapouri is the largest hydro power station in New Zealand and is located 220 metres underground in Fiordland National Park and supplies electricity to the Aluminium Smelter at Tiwai Point in Bluff, Southland. Operated by Meridian Energy, Benmore is the site of the High Voltage Direct Current (HVDC) link for electricity transfer between the South and North Islands. Collectively the eight hydro power stations produce 2,140.8 MW of electricity. (http://www.teara.govt.nz) While New Zealand has a relatively high annual rainfall there is a lot of demand on water resources, particularly with dairy farming which accounts for an increasing level of water usage from those farms reliant on irrigation. The RMA is also a piece of legislation that protects the use of water resources from overuse by farmers wanting to irrigate, and with the increasing period of droughts each year being experienced in many regions of New Zealand, a lot of the hydro generation schemes in the South Island are being compromised due to the lack of storage levels in lakes and reduced flow of water in rivers.

The problem has become so great that most summers the territorial local authorities impose restrictions on the use of water (e.g. hand-held hosing days for households located in urban areas during certain hours and days of the week). Dairy farming has a large impact on the sustainable use of water in New Zealand. A typical dairy farm creates about one tonne of effluent a day (2kg per cow based on milking 450 cows) which is washed off the yard with about 20,000 litres of water a day into effluent ponds. “The former Environment Minister, Nick Smith commented in May 2010 that water usage by all major users would be metered from July 2010 at a cost of up to $40m, with users of more than 20 litres a second following within two years and users of over five litres a second within six years. He said water usage is worth $5 billion a year but only

31% nationally is being metered. Domestic users will not have to be metered, but in some areas have that option already" (Executive News, 2010). A number of regions have been investigating the idea of smaller scale hydro generation schemes that do not require high water storage capacity so they can provide electricity for small communities in rural areas. "New Zealand has 5,375 MW capacity of hydropower in operation with actual generation in 2008 of 22,091 GWh. Under construction is capacity of 18 MW with planned capacity of 612 MW. As to the status of development for small-scale schemes (<10 MW) New Zealand has operational capacity of 95 MW generating 402 GWh in 2008" (World Energy Council, 2010).

4.5 Wind

"New Zealand has 322 MW of generation capacity installed with wind power providing annual output of 1,047 GWh. Some 2,500 to 3,000 MW will possibly be installed by 2025, supplying 15-20% of power generation. Currently wind energy is supplying about 2.5% of electricity" (World Energy Council, 2010). Power generation from renewables will become an increasingly popular option for New Zealand but cannot be relied upon to fully meet supply demands. Hydro generation will continue to be a dominant player in the market but other sources like wind generation will be increasingly used to meet shortfalls in electricity supply. "New Zealand Windfarms Ltd website states that it installed 30 metre high turbines which generate enough electricity to power about 200 households a year. Up to 97 turbines have been constructed in stages on the Tararua Ranges near Palmerston North in the North Island as part of the Te Rere Hau project. In total, the wind farm will produce 48.5 MW" (http://www.nzwindfarms.co.nz). The amount of power that a wind farm can produce is subject to wind flows at the site. This will impact on the ability to produce a consistent supply of electricity; unlike nuclear for example, which is able to generate a consistent level of output without interruption. The geographical location of New Zealand is conducive to wind farms but they are expensive and require a long lead-time to completion. Resource consents need to be obtained for wind farms and many people will object to them on the basis that they are unsightly and noisy. Therefore, they are ideally located in rural areas but do have a somewhat negative impact on the landscape from an aesthetics view. Wind power generation is very expensive and the payback period can often take many years. "It is interesting to note that nuclear power in the United States received subsidies of US$15.30 per kilowatt hour between 1947 and 1961 – the first 15 years during which nuclear technology was used for civilian power generation – compared to subsidies of US$7.19 per kilowatt hour for solar power and 46 cents for wind power between 1975 and 1989, the first 15 years when those technologies came into more widespread use" (The Wall Street Journal, 2011). This raises the question as to whether governments should provide greater subsidy levels for solar and wind power, particularly given the state of the losses experienced by New Zealand Windfarms Ltd in its operation of the Te Rere Hau project. "Electricity sold in the six month period to 31 December 2010 achieved an average wholesale price of NZ$43.23/MWh (forecast NZ$69.09/MWh). Due to a combination of factors (e.g. construction delays, low wholesale electricity prices), New Zealand Windfarms expects losses during the period of NZ$1,813,000 on its activities with the Te Rere Hau project" (New Zealand Wind Farms Ltd, 2010).

4.6 Geothermal

“The New Zealand Energy Strategy to 2050 (published in October 2007) has a government target that by 2025 a total of 90% of electricity is to be generated from renewable resources, and approximately 20% of this is expected to be supplied from geothermal fields” (World Energy Council, 2010). Most of the geothermal resources in New Zealand are based in the central North Island (e.g. Rotorua/Taupo/Bay of Plenty) but there is also an area in Northland. This is a rich resource for New Zealand and geothermal production of power has probably the greatest future potential. “Installed capacity is 585 MW providing 3,962 GWh annual output of electricity generation” (World Energy Council, 2010). Consents under the RMA for future development is likely to be easier to gain when compared to wind farm consents and people are already aware of the benefits of harnessing this energy stream. For example, the Kawerau pulp and paper mill in the North Island is the largest direct user in the world of geothermal heat, accounting for approximately 55% of its 210 MW capacity.

4.7 Biomass

Residue from forest harvesting provides a good energy source that can be reused in a number of areas. For example, an environmentally friendly and clean burning heating option in New Zealand is wood pellet burners. The pellets are made from 100% wood residues (e.g. sawdust and wood shavings) and wood burning from sustainable forests is carbon neutral (EECA Energywise, 2012). Wood waste fuel has the potential to be a more economical fuel source when compared to gas and coal. While there are other bioenergy categories such as energy crops, agricultural residues, food and industrial waste, it is worth noting that wood waste fuel currently has a solid following and has a multitude of uses (e.g. chip bark for gardens with export potential to countries such as Japan). The key cost driver for biomass electricity generation is fuel cost.

4.8 Solar

Solar energy use in New Zealand has been limited to solar water heating applications in the domestic and commercial sectors. While photovoltaic (PV) solar generation is fast becoming a serious option for renewable energy in many countries, it does not have a strong following in New Zealand largely because of the inclement weather conditions. It is more suited to countries with a consistent level of high sunshine hours where the energy can be harnessed or converted back to the grid. Solar energy users in New Zealand are mostly utilizing the resource off the grid (e.g. incorporating solar panels in house construction) where those users are leading a self-sufficient lifestyle. However, there are areas in national parks and camping grounds in isolated locations where solar energy is used to heat water for showers and as a means to provide lighting. The key cost driver for solar electricity generation is capital cost.

4.9 Tidal

“Tidal energy is a relatively new technology but is worth noting because New Zealand waters have some of the highest average annual wave power levels as kW/m of wave front (i.e. 72, 43, and 81)” (World Energy Council, 2010). The government has approved the first large-scale commercial tidal power generation scheme to be operated by Crest Energy. “The company will install 200 tidal turbine generators in an eight kilometre by one kilometre submarine field in Northland’s Kaipara Harbour.” (Steward, 2011). The key cost driver for tidal electricity generation is capital cost.

4.10 Biogas

Wikipedia states that biogas is produced by the anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal waste, green waste, plant material, and crops. “Biogas comprises primarily methane (CH_4) and CO_2 and may have small amounts of hydrogen sulphide (H_2S), moisture and siloxanes. Biogas can be used as a fuel. It can be used in anaerobic digesters where it is typically used in a gas engine to convert the energy in the gas into electricity and heat.” (http://wikipedia.org). Ian Bywater, an engineer in Christchurch, New Zealand has invented BioGenCool, a process that extracts the biogas (methane and carbon dioxide) from cow effluent using novel biodigester technology. After production it is then cleaned and used as a fuel in a co-generation plant to generate electricity. Mr Bywater states that a farmer collecting effluent from 850 cows could save up to $30,000 per year in electricity costs by using BioGenCool” (Techlink, 2009). Many Southland dairy farmers are now housing their cows in winter. Dutch-born dairy farmers Abe and Anita de Wolde have farmed in Southland since 1991 and until five years ago kept their cows outside all year round. With heavy rainfall in Southland there is a tremendous amount of bogging and mud and nutrient losses. The de Wolde’s use a combination of outdoor and indoor farming during the two coldest months of winter. “For a herd of 600 cows there is a $40,000 a year saving on fertiliser as a result of harvesting the winter effluent; feed consumption is halved (because the animals are warmer and consume less energy, and because less feed is trampled into the ground); and the de Woldes get an extra 50 days of milk from cows” (Listener, 2010).

5 RENEWABLE ENERGY COSTS

Currently 15% of New Zealand’s energy comes from renewable sources. But what is the cost of RES generation of electricity? New Zealand is heavily reliant on imports of oil and while the cost may be greater to generate electricity from water, geothermal and wind, in the long-term it may be to the country’s advantage to increase development of these RES and clean energy technologies. In order to protect against rising costs of extracting non-renewable energy resources such as coal and gas, New Zealand could shield itself from being too reliant on oil imports, disruption of supply and increasing costs due to unrest in the Middle East, by concentrating more on a combination of RES and clean energy generation systems for future electricity.

To provide a comparison between clean and renewable energy costs, the investment costs and energy production costs of three RES projects in New Zealand will be analyzed and summarized in general terms because grid/utility costs vary to a lesser or greater degree as a result of geographical location. Tables from the December 2007 World Bank Energy Sector Management Assistance Program (ESMAP) Technical Paper 121/07 will be used to show present and projected capital costs, together with projected generation costs. These will then form the basis of a comparison of costs associated with the New Zealand projects and the feasibility of PEM fuel cell technology from ClearEdge Power.

5.1 Wind

New Zealand has 322 MW of generation capacity installed with wind power providing annual output of 1,047 GWh. Some 2,500 to 3,000 MW will possibly be installed by 2025, supplying 15-20% of power generation (World Energy Council, 2010).

Figure 23: World Bank: Present and Projected Wind Turbine Capital Costs (US$/kW)

Capacity	2005			2010			2015		
	Min	**Probable**	**Max**	**Min**	**Probable**	**Max**	**Min**	**Probable**	**Max**
300 W	4,820	5,370	5,930	4,160	4,850	5,430	3,700	4,450	5,050
100 kW	2,460	2,780	3,100	2,090	2,500	2,850	1,830	2,300	2,650
10 MW	1,270	1,440	1,610	1,040	1,260	1,440	870	1,120	1,300
100 MW	1,090	1,240	1,390	890	1,080	1,230	750	960	1,110

Figure 24: World Bank: Present and Projected Wind Turbine Generation Costs (Usc/kWh)

Capacity	2005			2010			2015		
	Min	**Probable**	**Max**	**Min**	**Probable**	**Max**	**Min**	**Probable**	**Max**
300 W	30.1	34.6	40.4	27.3	32.0	37.3	25.2	30.1	35.1
100 kW	17.2	19.7	22.9	15.6	18.3	21.3	14.4	17.4	20.2
10 MW	5.8	6.8	8.0	5.0	6.0	7.1	4.3	5.5	6.5
100 MW	5.0	5.8	6.8	4.2	5.1	6.1	3.7	4.7	5.5

The New Zealand Wind Energy Association states that wind generation currently provides about 4% of New Zealand's electricity (http://www.windenergy.org.nz). On an annual basis that is enough electricity to meet the demand for about 180,000 homes. Project West Wind is a wind farm operation completed in late 2009 on the hillside of coastal Makara about 16 kilometres north of Wellington in the lower North Island.

The wind farm is made up of 62 wind turbines, each generating up to 2.3 MW or a total capacity of 143 MW of electricity. “According to Meridian Energy, the combined output would supply enough power for Wellington’s domestic use” (Wellington City Council, 2012). Key findings from the “IEA Deploying Renewables 2008” report show that in the case of wind energy, a certain minimum level of remuneration, in this case about US$0.08c/kWh is necessary to initiate deployment (International Energy Agency, 2008). The key cost driver for wind electricity generation is capital cost.

5.2 Hydro

“New Zealand has 5,375 MW capacity of hydropower in operation with actual generation in 2008 of 22,091 GWh. Under construction is capacity of 18 MW with planned capacity of 612 MW. As to the status of development for small-scale schemes (<10 MW) New Zealand has operational capacity of 95 MW generating 402 GWh in 2008” (World Energy Council, 2010).

Figure 25: World Bank: Large Hydroelectric Power Plant Capital Costs (US$/kW)

	2005			**2010**			**2015**		
	Min	**Probable**	**Max**	**Min**	**Probable**	**Max**	**Min**	**Probable**	**Max**
Large-hydro	1,930	2,140	2,350	1,860	2,080	2,290	1,830	2,060	2,280
Pumped Storage Hydro	2,860	3,170	3,480	2,760	3,080	3,400	2,710	3,050	3,380

Figure 26: World Bank: Large Hydroelectric Power Generation Costs (Usc/kWh)

	2005			**2010**			**2015**		
	Min	**Probable**	**Max**	**Min**	**Probable**	**Max**	**Min**	**Probable**	**Max**
Large-hydro	4.6	5.4	6.3	4.5	5.2	6.2	4.5	5.2	6.2
Pumped Storage Hydro	31.4	34.7	38.1	30.3	33.8	37.2	29.9	33.4	36.9

There are currently only three small power station projects being undertaken in New Zealand and these are essentially upgrades to existing schemes. They are the Karaponga Power Station (5MW); Waipa Power Project (9MW); and Maruia Falls Power Station (1MW). Karaponga and Waipa are located in the North Island and Muruia Falls is in the South Island (Renewable Power, 2012). “TrustPower is planning to build a 72MW scheme utilizing water from the South Island’s Wairau River in Marlborough. Consent was granted by the Environment Court in November 2010 and it is expected to cost approximately $280 - $320 million and produce enough power for around 47,000 homes. The Wairau Valley Hydroelectric Power Scheme is now undergoing geotechnical studies and design work and this will take at least two years to complete before construction begins” (TrustPower, 2012).

“In November 2010 the Environment Court granted consent for TrustPower to build the Arnold Hydroelectric Power Scheme on the Arnold River on the west coast of the South Island. This planned 46MW scheme will create electricity for around 27,000 homes and is designed to ensure this area of the South Island can be more self-sufficient in terms of energy supply.

Construction at a cost of around $180 - $200 million is expected to commence around mid-2012" (TrustPower, 2012). The key cost driver for hydro electricity generation is capital cost.

5.3 Geothermal

"Most of the geothermal resources in New Zealand are based in the central North Island (e.g. Rotorua/Taupo/Bay of Plenty) but there is also an area in Northland. This is a rich resource for New Zealand and geothermal production of power has probably the greatest future potential. Installed capacity is 585 MW providing 3,962 GWh annual output of electricity generation" (World Energy Council, 2010). Consents under the RMA for future development is likely to be easier to gain when compared to wind farm consents and people are already aware of the benefits of harnessing this energy stream. (e.g. Kawerau pulp and paper mill).

Figure 27: World Bank: Geothermal Power Plant Capital Costs (US$/kW)

Capacity	2005			2010			2015		
	Min	**Probable**	**Max**	**Min**	**Probable**	**Max**	**Min**	**Probable**	**Max**
200 kW Binary	6,480	7,220	7,950	5,760	6,580	7,360	5,450	6,410	7,300
20 MW Binary	3,690	4,100	4,500	3,400	3,830	4,240	3,270	3,730	4,170
50 MW Flash	2,260	2,510	2,750	2,090	2,350	2,600	2,010	2,290	2,560

Figure 28: World Bank: Geothermal Power Plant Generation Costs (Usc/kWh)

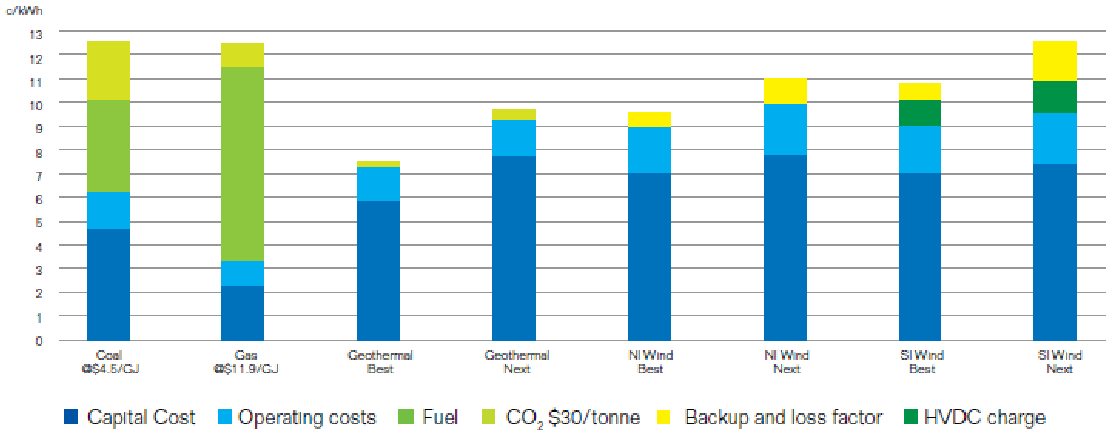
Capacity	2005			2010			2015		
	Min	**Probable**	**Max**	**Min**	**Probable**	**Max**	**Min**	**Probable**	**Max**
200 kW Binary	14.2	15.6	16.9	13.0	14.5	15.9	12.5	14.2	15.7
20 MW Binary	6.2	6.7	7.3	5.8	6.4	6.9	5.7	6.3	6.8
50 MW Flash	3.9	4.3	4.6	3.7	4.1	4.4	3.6	4.0	4.4

Contact Energy is New Zealand’s largest publicly traded energy company and has under construction a new power station that will produce 166MW of electricity. It will include two new steam turbine generators of 83MW each, due for completion in 2013 in the Taupo region of the North Island. The Te Mihi station will initially be an increase in output from the two power stations of about 114MW, enough to power over 100,000 average homes” (Contact Energy Ltd, 2012). The key cost driver for geothermal electricity generation is capital cost.

5.4 Electricity Costs

Figure 29 shows best estimates of New Zealand’s lowest cost plant. The third bar from the left shows the economics of building a geothermal power station. Electricity output would need to be sold for $0.07 cents/kWh to be economic. The 0.07 cents is broken down as 0.056 cents to recover the plant capital cost, 0.01 cent to operate it, and 0.003 cents emission rights. By contrast, the fifth bar from the left shows the construction cost for a wind farm in the North Island and the utility energy cost per kWh. Electricity output from the wind farm would need to be sold for $0.095 cents/kWh to be economic. The 0.095 cents is broken down as 0.07 cents to recover the plant capital cost, 0.02 cent to operate it, and 0.005 cents backup and loss factor.

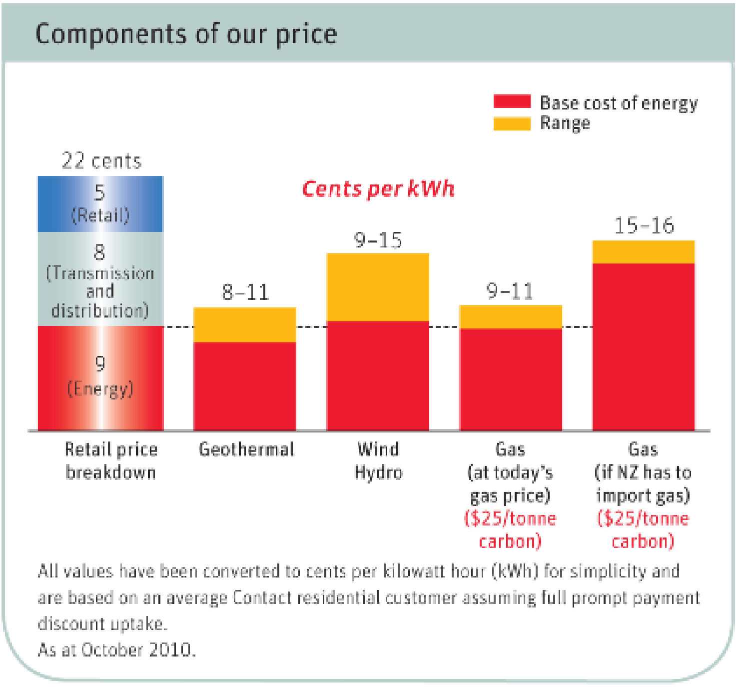
Figure 29: The Electricity Price Required to Justify New Generation Construction (c/kWh)



Source: Infratil Update, March 2011

Contact Energy states that electricity prices in New Zealand will need to increase to ensure investment in new electricity generation occurs to meet future demand.

Figure 30: Contact Energy Electricity Pricing

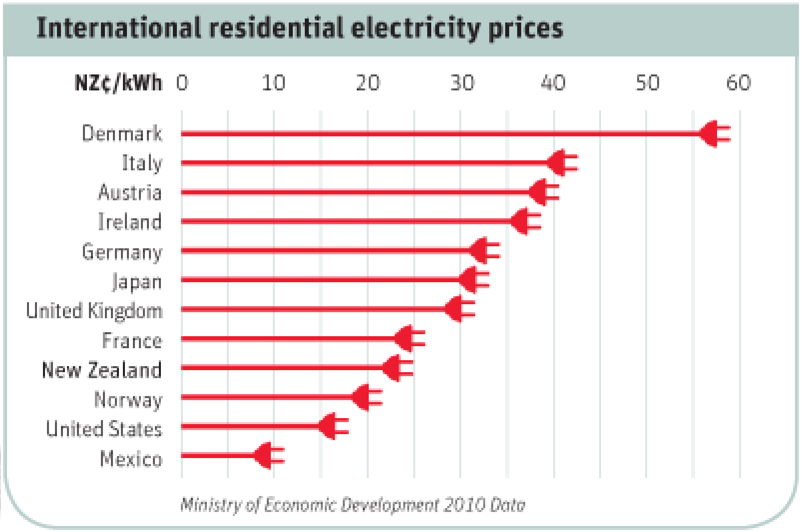


All values have been converted to cents per kilowatt hour (kWh) for simplicity and are based on an average Contact residential customer assuming full prompt payment discount uptake.
As at October 2010.

Source: Contact Energy

Their graph in Figure 30 shows that customers will need to pay between $0.08 and $0.11 cents/kWh for geothermal electricity output, between $0.09 and $0.15 cents/kWh for wind and hydro-electric generated output, and between $0.09 and $0.11 cents/kWh for gas to cover capital plant costs. This increases to between $0.15 and $0.16 cents/kWh for imported gas. However, given the current charges that users pay for electricity in New Zealand it appears that electricity prices are excessive given the current investment costs for building new geothermal, wind and hydro plants. It seems that generators and retailers of energy are making good profits from the New Zealand electricity user.

Figure 31: Electricity Residential Price Comparison

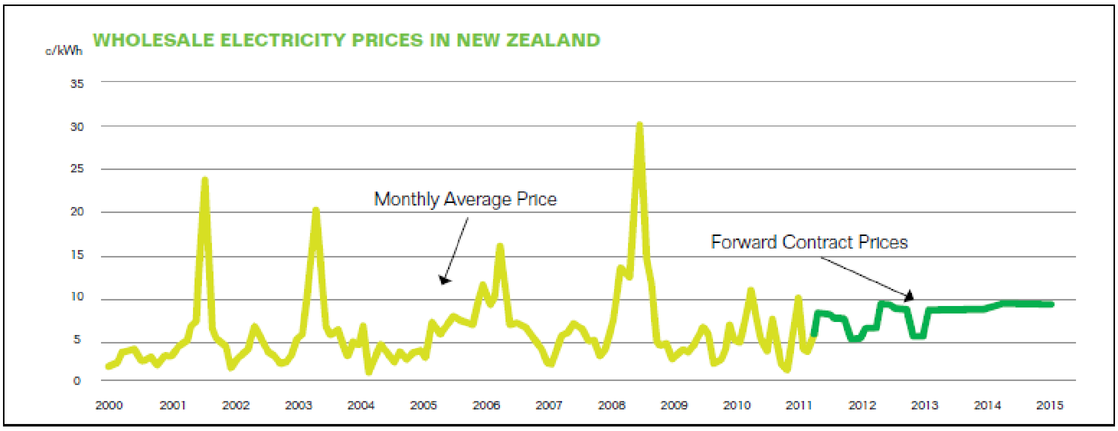


Ministry of Economic Development 2010 Data

On the other hand, Figure 31 shows the cost of New Zealand’s electricity prices compared to other countries. When this is taken into consideration the costs are relatively low. The average New Zealand household consumes about 8,000 kWh of electricity a year. The price margin between residential and wholesale electricity prices is relatively wide. New Zealand’s residential electricity rate is about 25 cents per kWh compared with the wholesale rate of about 8 cents per kWh, a difference of 17 cents per kWh.

Figure 32 shows rising electricity prices reflect the rising cost of generation. An off-the-grid distributed generation system requires investigation as a more stable and cost effective solution and additional source of electricity generation for the New Zealand dairy industry.

Figure 32: Wholesale Electricity Price (c/kWh)



Source: Infratil Update, March 2011

6 CLEAN ENERGY OPTIONS AND INDUSTRY APPLICATION

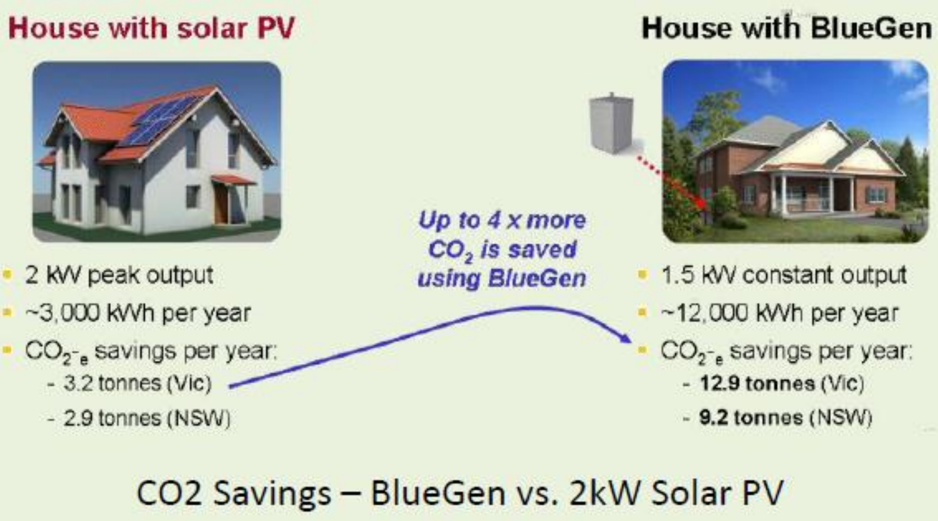
"According to the Clean Energy Patent Growth Index, the fuel cell sector accounted for the largest segment of United States patents for clean energy technologies in 2011, a title held for the entire span of the index period from 2002 to 2011" (http://cepgi.typepad.com). Wal-Mart, for example, powers 27 retail stores using fuel cells and several warehouses operate fuel cell forklifts. Stationary applications include prisons, hospitals, government buildings, grocery and retail establishments, corporate headquarters, wastewater treatment plants, agricultural and beverage processing facilities, and factories.

6.1 Fuel Cell Technologies

The United States Department of Energy (DOE) has stated that fuel cell technology has the potential to revolutionise the way nations are powered, offering cleaner, more efficient alternatives to the combustion of gasoline and other fossil fuels. A comparison of fuel cell technologies in Figure 34 provides a summary of fuel cell type, efficiency, applications, together with their advantages and disadvantages. Stationary power includes both large scale (>200 kW) and small scale (5–100 kW) systems and also encompasses fuel cell units used for telecommunications back-up (1-20 kW). The feasibility of siting a fuel cell needs to take into account the availability of a suitable fuel source (i.e. reticulated natural gas or biogas), supply chain factors, engineers and labour production, government or regional incentives (if any) and energy costs. Innovation and the ability to scale-down fuel cell technology to make it possible for this technology to be utilised by domestic and small to mid-sized businesses will be a key challenge and focus of companies involved in the sector.

For example, Australian manufacturer Ceramic Fuel Cells has used SOFC technology to develop the BlueGen® small-scale electricity generator, which delivers approximately 13,000 kWh of low-emission electricity per year (http://www.bluegen.info/What-is-bluegen) Optional waste heat from BlueGen can be recovered to provide 200 litres of domestic hot water per day; increasing total efficiency by 25% from 60% to 85% making it the world's most efficient in terms of size. Annual CO_2 emission savings achieved by SOFC technology compared with solar PV technology are shown in Figure 33. Although inimical to the notion of government subsidies there could be merits for the renewable energy sector in introducing programs (e.g. feed-in tariffs) and capital subsidies for an interim period to encourage the uptake of cleaner energy systems if it results in a reduction in energy use and CO_2 emissions.

Figure 33: Energy Savings using BlueGen



Source: Fourth International Workshop Report Stationary Fuel Cells

Figure 34: Comparison of Fuel Cell Technologies

Fuel Cell Type	Common Electrolyte	Operating Temperature	Typical Stack Size	Efficiency	Applications	Advantages	Disadvantages
Polymer Electrolyte Membrane (PEM)	Perfluoro sulfonic acid	50-100^{o}C 122-212^{o}F Typically 80^{o}C	<kW-100 kW	60% transportation 35% stationary	• Backup power • Portable power • Distributed generation • Transportation • Specialty vehicles	• Solid electrolyte reduces corrosion & electrolyte management problems • Low temperature • Quick start-up	• Expensive catalysts • Sensitive to fuel impurities • Low temperature waste heat
Alkaline (AFC)	Aqueous solution of potassium hydroxide soaked in a matrix	90-100^{o}C 194-212^{o}F	10-100 kW	60%	• Military • Space	• Cathode reaction faster in alkaline electrolyte, leads to high performance • Low cost components	• Sensitive to CO_2 in fuel and air • Electrolyte management

Figure 34: Comparison of Fuel Cell Technologies

Fuel Cell Type	Common Electrolyte	Operating Temperature	Typical Stack Size	Efficiency	Applications	Advantages	Disadvantages
Phosphoric Acid (PAFC)	Phosphoric acid soaked in a matrix	150-200°C 302-392°F	400 kW 100 kW Module	40%	• Distributed generation	• Higher temperature enables CHP • Increased tolerance to fuel impurities	• Pt catalyst • Long start up time • Low current and power
Molten Carbonate (MCFC)	Solution of lithium, sodium, and/or potassium carbonates, soaked in a matrix	600-700°C 1112-1292°F	300 kW–3 MW 300 kW module	45-50%	• Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Suitable for CHP	• High temperature corrosion and breakdown of cell components • Long start up time • Low power density

Figure 34: Comparison of Fuel Cell Technologies

Fuel Cell Type	Common Electrolyte	Operating Temperature	Typical Stack Size	Efficiency	Applications	Advantages	Disadvantages
Solid Oxide	Yttria stabilised zirconia	700-1000^{o}C 1202-1832^{o}F	1 kw-2 MW	60%	• Auxiliary power • Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Solid electrolyte • Suitable for CHP & CHHP • Hybrid/GT cycle	• High temperature corrosion and breakdown of cell components • High temperature operation requires long start up time and limits

Source: U.S. Department of Energy

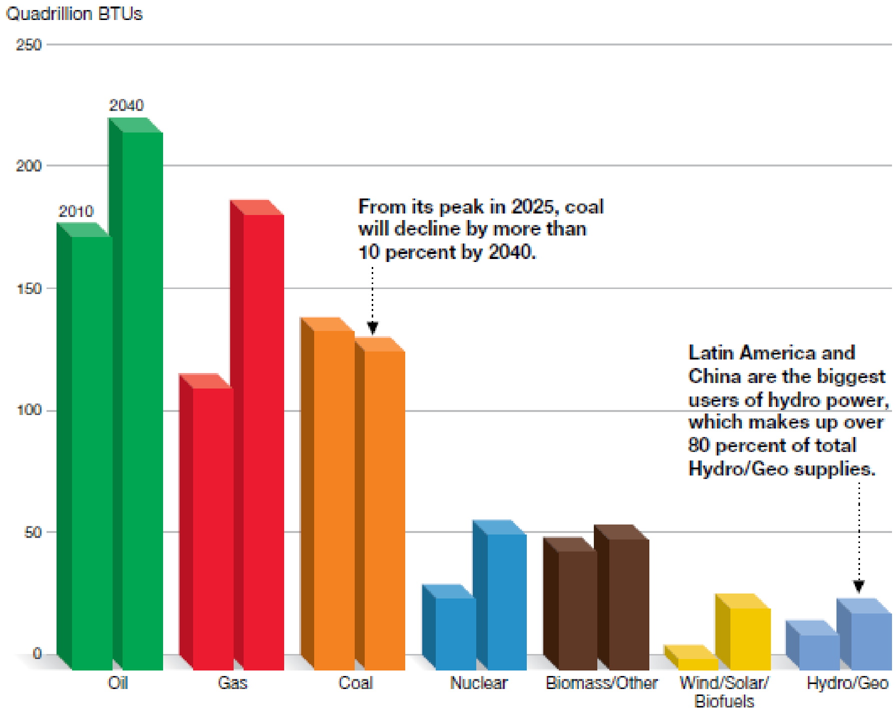
Fuel cells are complimentary, not competitors, to other electricity generation technologies, particularly renewable ones. “Fuel cell benefits include the following:

- Fuel flexible – operation on conventional or renewable fuels.
- High quality, reliable power.
- Exceptionally low/zero emissions.
- Modularity/scalability/flexible installation.
- Not dependent on the power grid.
- Silent operation.
- Lightweight.
- Rugged.
- Can be used with or instead of batteries and diesel generators.
- Can partner with solar, wind, and other renewable technologies.
- Increased productivity.
- Cost savings via high electrical and overall efficiency” (http://www.fuelcells.org).

Renewable energy sources provide 77% of New Zealand’s electricity supply with 58% coming from hydro-electricity. Around one-sixth of hydro-generated electricity from the southern lakes is sent to the North Island via the HVDC transmission inter-island link to meet increasing power demands. However, in recent years a lack of water in the South Island lakes has resulted in reduced electricity production and this creates a great deal of supply uncertainty which is not good for manufacturers and the economy. This is even more concerning given the New Zealand Government has a 2025 target of generating 90% of electricity from renewable sources. Fuel cell technology is one form of infrastructure that can meet future demand for power and heat in times of uncertainty.

Much of the future development and success of distributed generation, or power generation at the point of consumption, will come down to the fuel source required to power the devices such as PAFC, PEM, and SOFC. “Natural gas will grow fast enough to overtake coal for the number two position behind oil. Demand for natural gas will rise by more than 60% through 2040. For both oil and natural gas, an increasing share of global supply will come from unconventional sources such as those produced from shale formations” (ExxonMobil, 2012.) The global energy demand by fuel type is shown in Figure 35 and indicates that gas will continue to be a mainstay source of energy for electricity production.

Figure 35: Global Energy Demand by Fuel Type



From its peak in 2025, coal will decline by more than 10 percent by 2040.

Latin America and China are the biggest users of hydro power, which makes up over 80 percent of total Hydro/Geo supplies.

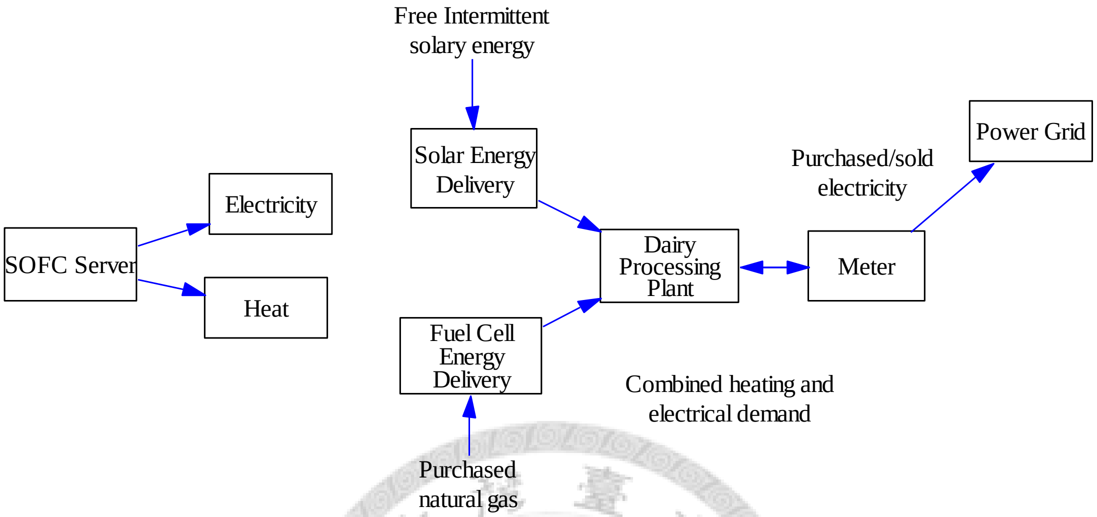
Source: ExxonMobil, 2012 The World Outlook for Energy: A View to 2040

No matter the source, it takes a significant amount of energy to make electricity. Globally, more than 35% of the primary energy consumed on a daily basis is being used to make electricity. Also important to know is that a significant amount of energy is lost in the electricity generation process. For example, “new turbines powered by coal or nuclear (which produce about 55% of global electricity) are, at most, about 40% efficient. That means that for every 100 units of primary energy that go into these plants, only 40 units or less are converted to useable electrical energy. New natural gas plants are more efficient, with a 60% efficiency rate. In addition to the losses during electricity production, a significant amount of electricity is also lost as it is sent to consumers across transmission lines. These “line losses” total about 10% in OECD nations and 15% or more in the non OECD. Improving efficiency in power generation and transmission represents one of the biggest opportunities for curbing growth in energy demand and CO_2 emissions in coming decades” (ExxonMobil, 2012). Bloom Energy and UTC Power (for larger scale dairy processing plants) and ClearEdge (for dairy farm operations) that deliver a continual supply of electricity at the source of where it will be used could provide certainty of supply and meet increasing electricity demands from producers and consumers. It is also a clean technology that serves more than one purpose – water and heat are a by-product and SOFC can be teamed with renewable energy sources like solar.

The fuel cell technology manufactured by Bloom Energy, UTC Power, and ClearEdge Power are capable of net-metering. This is an arrangement between the utility and the customers who generate their own electricity with qualifying systems. “Net-metering measures the difference between the electricity delivered by the utility and the excess electricity produced by the customer using their own generation equipment. Any energy produced that is not used is fed back into the utility grid and is deducted from the customer’s utility bill” (UTC Power).

The flow diagram in Figure 36 provides an example of how the technology is utilised with a combination of fossil fuel and renewable energy streams.

Figure 36: SOFC Practical Application

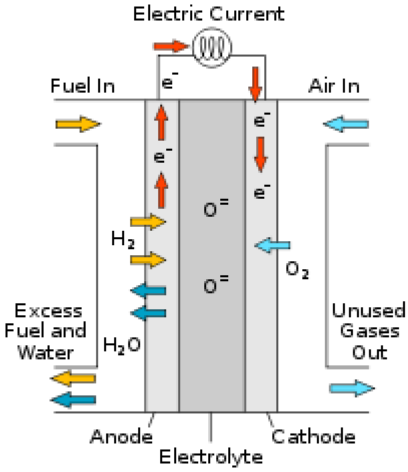


Source: CRL Energy Ltd

6.2 Feasibility of Bloom Energy

One source of clean energy that may be ideally suited for large dairy production companies such as Fonterra, Synlait, and Westland Milk Products to improve upon their environmental sustainability while at the same time contribute to lower CO_2 emissions is SOFC technology. “Solid oxide fuel cell (SOFC) technology is characterized by its ceramic electrolyte. Advantages include its compatibility with natural gas fuels, high efficiency, long-term stability, low emissions, and relatively low cost. High operating temperatures result in longer start-up times and pose mechanical stability challenges, but provide additional opportunities to monetize energy and enhance efficiency, such as through combined

Figure 37: Scheme of a SOFC



Source: Wikipedia

heat and power” (NorTech, 2012). Bloom Energy, headquartered in Sunnyvale, California, United States manufactures an energy server which provides 100 kW of power. It is a distributed generation system that is easily expandable and uses natural gas or biogas as the energy source to produce clean consistent electricity. Office products firm, Staples, installed a 300 kW Bloom Energy Server™ in December 2008 and in the first year its servers generated over two million kWh of power and a reduction of 2.5 million pounds of $CO_{2.}$ Tests have shown that running the Bloom Energy Server cuts CO_2 emissions by 40% to 100% compared to the U.S. grid (depending on fuel choice) and virtually eliminate all Sox, Nox, and other harmful smog forming particulate emissions. Costing between US$700,000 – US$800,000 or NZ$854,000 – NZ$976,000 (1 USD = 1.22 NZD) (www.xe.com) according to Bloom Energy a 100 kW Server makes electricity for US$0.08 – US$0.10 cents/kWh or NZ$0.10 – NZ$0.12 cents/kWh with natural gas and it has a payback period of between three and five years on initial capital cost. Companies using the Bloom Energy Servers include Wal-Mart, The Coca-Cola Company, Google, FedEx Express, and AT&T.

While these Fortune 500 companies are obviously large scale operators, the interplay with public utilities is evidenced by the realisation that public utilities anticipate a future where SOFC technology can be utilised as a base load provider of electricity to the grid. For example, Bloom Energy has sold more than 26 MW in the past year, with another 50 MW of sales (creating up to 1,500 new jobs) coming from Delaware Power planned in the coming year. In the State of Delaware (mid-Atlantic region) of the United States, regional energy provider Delmarva Power plans to add up to 50 MW of Bloom Energy fuel cells to its power system. This will include 3 MW (15 Bloom Energy Servers) located at its Brookside electric substation, and up to 47 MW (235 Bloom Energy Servers) over two stages at the Red Lion Energy Centre that will be connected to the electrical grid (Fuel Cells 2000). In June 2009, eBay Inc installed a 500 kW Bloom Energy Server powered by biogas which delivers 100% renewable energy, allowing them to meet both financial and environmental goals. According to Bloom Energy, the servers have delivered 2.2 million kWh of power and mitigated more than 650,000 pounds of CO_2 emissions in their first six months. In July 2008, Google installed 400 kW and over the first 18 months the project had 98% power availability and delivered 3.8 million kWh of electricity. FedEx Express expects to achieve a return on investment in five years and reduce CO_2 emissions by about 30% after it installed 500 kW Bloom Energy Servers in February 2010 at its Oakland, California premises. Prior to founding Bloom Energy in 2001, Principal Co-Founder and Chief Executive Officer Dr K R Sridher, was Director of the Space Technologies Laboratory at the University of Arizona where he was also a professor of Aerospace and Mechanical Engineering. When the NASA Mars project ended in 2001, he shifted the focus of his team to develop a commercial venture that created electricity from oxygen and fuel. Primary investors in Bloom Energy are Kleiner Perkins Caulfield & Byers, New Enterprise Associates, and Morgan Stanley. Board of Directors include T J Rodgers, Chairman of SunPower (a major U.S. manufacturer of solar energy systems, including solar cells and panels), and General Colin Powell, Former U.S. Secretary of State. Bloom Energy's ES-5000 Server (Appendix 2) employs the planar solid oxide fuel cell (pSOFC) technology Dr Sridhar's team originally created for the NASA Mars project.

“At the core of the server are square ceramic fuel cells about the size of old fashioned computer floppy disks. Crafted from an inexpensive sand-like powder, each square is coated with special inks (lime-green ink on the anode side, black on the cathode side) and is capable of producing 25 watts – enough to power a light bulb. Stacking the cells – with cheap metal alloy squares in between to serve as the electrolyte catalyst – increases the energy output: a stack about the size of a loaf of bread can power an average home” (NASA, 2012).

Figure 38: Bloom Energy ES-5000 Server

Source: Bloom Energy

Figure 39: What is Inside Each Bloom Energy Server?

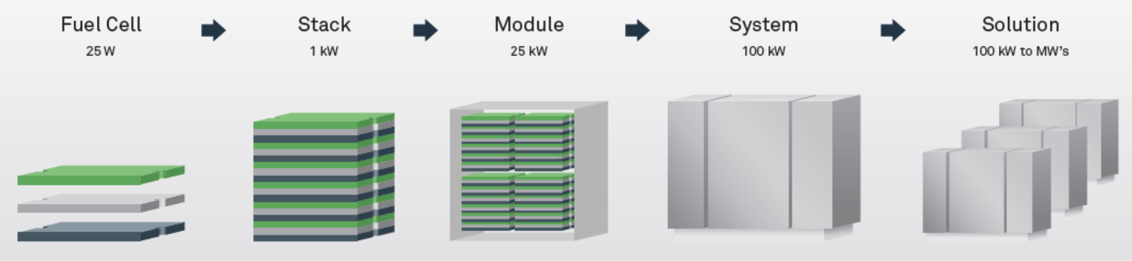
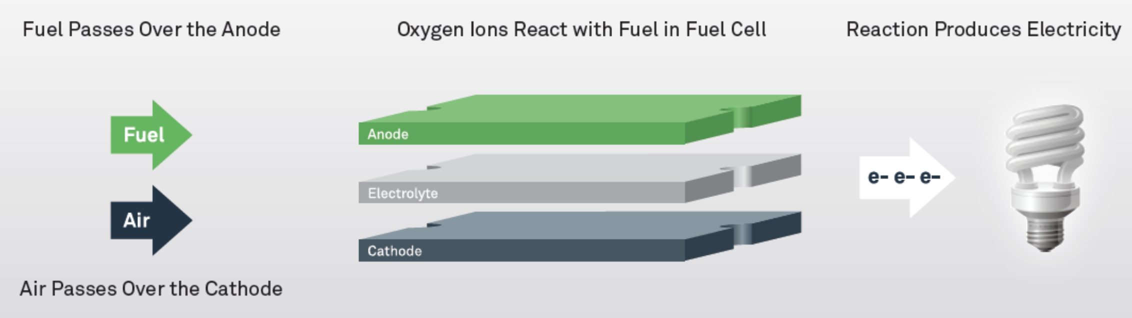


Figure 40: How Does the Bloom Energy Server Fuel Cell Work?



Source: Bloom Energy

In the South Island of New Zealand there is no reticulated natural gas available. So the alternative is either matching a Bloom Energy Server with solar cells or utilising bio gas. Firstly, a problem with solar cells is the intermittent nature of collecting the right quantity of energy that the sun generates. In New Zealand, inclement weather patterns – particularly in winter – would result in unreliable provision as the sole power source for an energy server. This is not conducive with the modern day dairy operations and a 24-hour a day production cycle. One renewable energy source that could provide biogas for the Bloom Energy Servers for dairy processing plants in Canterbury (e.g. Fonterra, Synlait and Westland Milk Products) is the Kate Valley Landfill, located in the middle of the South Island. This landfill was commissioned in 2005. "The landfill has a 35 year life, and with 250,000 tonnes per year of waste entering the landfill (12M tonne capacity) it is the first New Zealand landfill where environmental design standards exceed US and EU landfill design standards for municipal waste landfills. Kate Valley landfill gas could be used to generate electricity (and a possible means to power the Bloom Energy Server). The landfill has the potential to power 8,000 plus homes and electricity could be generated from gas for 60 plus years" (Transwaste Canterbury Ltd). As mentioned earlier in the study, it would be a very costly process to clean up gas from a landfill for use in a fuel cell. The preference would still be a cleaner form of natural gas.

6.3 Feasibility of UTC Power

UTC Power (a United Technologies Company) stationary fuel cell systems convert heat exhaust into cooling and heating, turning potential waste into useable energy. UTC Power claims the PureCell® Model 400 is a combined cooling, heat and power (CCHP) system that attains energy conversion efficiencies as high as 90% compared with 35% for grid efficiency. The PureCell fleet of systems has over 20 years operational experience, with 300 units installed in 19 countries.

They have a combined 10 million operating hours and 1.9 billion kW hours of electricity produced. UTC Power has experience in all five major fuel cell technologies (Phosphoric Acid, Proton Exchange Membrane, Alkaline, Solid Oxide, and Molten Carbonate). The PureCell system is a PAFC plant for cogeneration (e.g. combined heat and power) which was one of the first fuel cells commercialised for stationary applications. Providing clean, efficient, and secure on-site power, the PureCell Model 400 System provides up to 400 kW of assured electrical power plus up to 1.5 million Btu/hour of heat for combined heat and power applications. The model 400 has the ability to operate either in conjunction with the utility grid or without it, a critical feature that enables a facility to stay powered-up if the grid fails. This feature is called “dual-mode” capability.

Figure 41: UTC Power 400 kW Fuel Cell

Source: UTC Power

From an environmental perspective, the system is designed to operate in water-balance – i.e. no consumption or discharge of water in normal operations. Target market sectors include bottling and data centres, that are generally energy-intensive, have power, heating and cooling needs and/or value the clean energy and reliable power attributes of these solutions. As with Bloom Energy, UTC Power offers its PureCell systems through both a purchase (with payback that can be as low as three to five years depending on building location and energy demand) and an Energy Service Agreement which can mean zero up-front capital costs. UTC Power has its headquarters in South Windsor, Connecticut, United States. Vice President and General Manager, Mr Joe Triompo has overall responsibility for UTC Power's operations, and development and innovation of new fuel cell technology. Mr Triompo holds a bachelor's degree in electrical engineering and computer science from the University of Connecticut and has an MS from the Massachusetts Institute of Technology Sloan Fellows program (UTC Power). Customers include The Coca-Cola Company, Price Chopper Supermarkets, GS Power Co/Samsung, and Eastern Connecticut State University.

Figure 42: ClearEdge Power Fuel System

Source: ClearEdge Power

6.4 Feasibility of ClearEdge Power

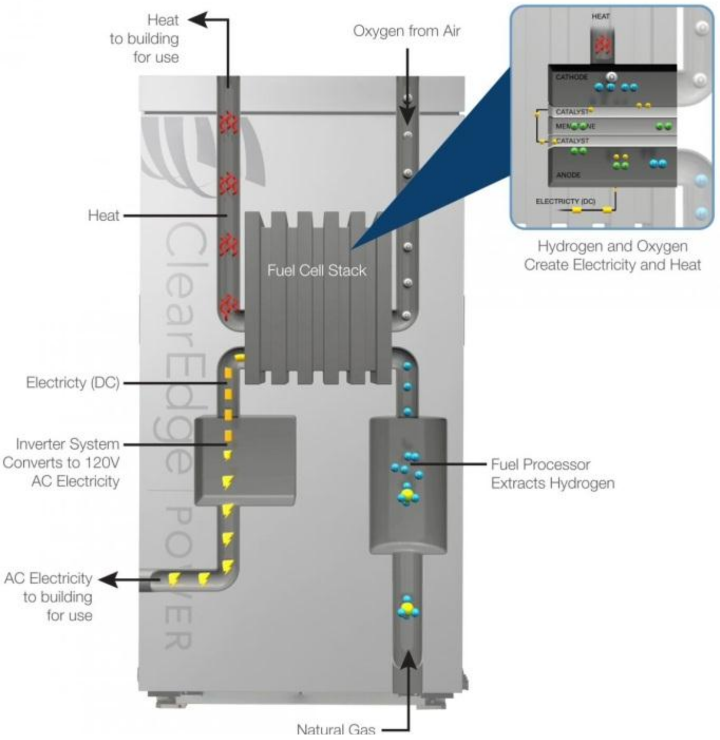
Established in 2003, Oregon-based ClearEdge Power is a clean energy technology company that manufactures and markets a suite of continuous on-site power systems for a wide range of applications. ClearEdge Power systems cleanly convert natural gas into heat and electricity, using PEM technology to produce energy instead of burning fossil fuels. Compared with Bloom Energy and UTC Power, the ClearEdge Power system is available in 5 kW, 10 kW, 15 kW, 20 kW, and 25 kW configurations that scale up to 200kW. This scalable feature is a distinct advantage, and perfect for commercial, institutional, or large residential applications looking for a more cost effective and sustainable energy system. "Investors in ClearEdge are Big Basin Partners LP (early technology company investments), Applied Ventures LLC (venture capital), Southern California Gas Company, and Kohlberg and Company (venture capital). ClearEdge Chief Executive, David Wright has extensive IT sector experience and holds a BS in physics and a minor in mathematics. Board of Directors include the Chairman, Mr James A Kohlberg (also a board member of The New York Times Company), Mr Phil Angelides, President of Riverside Capital Investments (which focuses on clean energy projects and sustainable urban development) and former California State Treasurer. Mr Angelides was also Chairman of the Financial Crisis Inquiry Commission which conducted the US official inquiry into the financial and economic crisis" (ClearEdge). "ClearEdge became the first fuel cell manufacturer to be awarded the Korean Gas Safety Corporation's internationally recognised safety certification, which is mandatory to market fuel cells in Korea, and is recognised throughout Asia, including China, Japan, Thailand, Hong Kong, Singapore, Australia, Russia, and parts of Europe. In 2010, ClearEdge signed a three-year US$40 million distribution agreement with Korean Company LS Industrial Systems, in which LS agreed to purchase more than 800 ClearEdge 5 (5 kW) fuel cell units. In early 2012, ClearEdge Power also entered into a multi-phase US$500 million agreement with Güssing Renewable Energy GmbH of Austria to deliver 8.5 MW of fuel cells to Güssing over 36 months, with the ultimate goal of 50 MW" (FuelCells, 2012).

"About the size of a refrigerator, the ClearEdge5 generates a combined 83,300 kWh of energy per year: 38,800 kWh of electricity and 44,500 kWh (equivalent to 152 MM Btu's per year of heat) of useable thermal energy. This results in an operating cost as low as US$0.7 per kWh, based on US$1.20 per therm for natural gas, when the

ClearEdge5's full electrical and heat output is utilised. Natural gas is cleanly converted into electricity and heat through a five-stage process, as follows.

1. Natural gas is delivered to the system via a standard gas line.
2. The fuel processor extracts hydrogen from the natural gas.
3. The fuel cell stack processes the hydrogen and generates electricity as direct current (DC) power.
4. An inverter system converts DC power into 120-volt alternating current (AC) power.
5. The heat produced during the process is captured using heat exchangers to provide heat for buildings, pools, domestic hot water, and central or radiant-floor space heating" (ClearEdge).

Figure 43: ClearEdge Plus Fuel Cell



Source: ClearEdge Power

6.5 Industry Application of ClearEdge5 Energy System

According to ClearEdge Power, to generate electricity and heat, a fuel cell requires a fuel source containing hydrogen (e.g. natural gas). Once connected to a natural gas source the ClearEdge5 fuel system uses a fuel processor to separate hydrogen from the natural gas by separating it through a series of catalytic reactors. The hydrogen is then fed to the fuel cell stack where the chemical energy is converted directly to electrical energy, creating water and heat as by-products. Since the fuel cell stack, like a battery, generates direct current (DC) power an inverter system is then used to convert the energy into 120 volt alternate current (AC) power and made available for consumption. The heat produced during this process is captured using heat exchangers to provide heat for buildings, pools, domestic hot water and other heating needs. The ClearEdge5 retails for US$56,000 or NZ$68,435 (excluding installation and shipping costs) and has an expected life-cycle of over 20 years.

The average payback is six to eight years. In the U.S. the ClearEdge5 is eligible for US$12,500 in Smart Grid Interoperability Panel (SGIP) incentives, US$5,000 in federal tax credits for homeowners and US$15,000 in federal tax credits for businesses. No such credits or incentives exist in New Zealand. “The ClearEdge5 produces about 43,000 kWh per year in electricity, while a 5 kW solar array will produce about 8,000 kWh per year – roughly five times the annual electricity production. At the same time, the ClearEdge5 will produce about 50,000 kWh per year equivalent in heat when the kWh is converted from Btu’s. The 5 kW solar array will not produce any heat – combined this represents roughly 11 times the energy production of a 5kW solar array. The ClearEdge5 typically emits 1.06 lbs of CO_2 per kilowatt hour or roughly 22 tonnes of CO_2 per year when producing 43 MWh of electricity. An equivalent amount of energy from an efficient natural gas power plant for electricity and burning gas for heating will emit about 8.4 lbs of CO_2 per kWh. The ClearEdge5 system compared to traditional energy generation offers a reduction of 12 tonnes of CO_2 per year for the same amount of energy (22 tonnes vs. 34 tonnes from traditional energy sources). The ClearEdge5 will deliver 5,000 Watts (120/240V or 208V AC/Grid compatible) electricity and up to 20,000 Btu/hour of thermal heat at 150°F. Five ClearEdge5 fuel cell systems or up to 25kW of electricity can be connected to one electricity meter. A facility that has multiple meters could install more than 25kW of systems. The ClearEdge5 will typically be no louder than 60 dB at 3 feet. A normal conversation between two people will be between 60-70dB at 3 feet. When the system is running in normal heat and power mode, it will be quieter than 60 dB" (ClearEdge).

6.6 Levelized Cost of Energy

In considering whether or not to invest in fuel cell technology and natural gas a dairy processing or dairy farm operation would need to weigh-up whether the capital expenditure and value obtained from the technology is going to provide the necessary return on investment. A detailed evaluation would need to be made against the research question, to what degree can the technology (1) reduce operating cost; (2) lower GHG emissions; and (3) minimize exposure to fluctuating energy costs? Two factors include natural gas costs and maximum life of the energy system which is 20 years. The key cost driver for natural gas electricity generation is fuel cost. "The ClearEdge5 appliance will consume approximately 43 therms of natural gas per hour to produce 5 kW of electricity and 20,000 Btu's of thermal heat. If retail gas cost is at US$1.20 per therm (NZ$1.46), the resulting electricity cost is about US$0.10 cents or NZ$0.12 cents per kWh. A therm is a measure of energy use. Typically a customer is billed for the number of therms of natural gas one consumes in a one month period; where one therm of natural gas is the energy equivalent to 100 Cubic feet (1Ccf), or 100,000 Btu of natural gas. From an efficiency perspective the ClearEdge5 generates a combined 94,800 kWh of energy per year: 43,800 kWh of electricity and 51,000 kWh (equivalent to 175 MM Btu's per year of heat) of usable thermal energy" (ClearEdge). According to the manufacturer, the ClearEdge5 consumes about 40% less fuel than power and heat delivered through the gird, reducing carbon footprint by a similar percentage. If the application consumes all of the heat and power, the system can generate electricity at about US$0.06 cents or NZ$0.07 cents per kWh. As with any fuel source cost, if supply and demand constraints or extraction costs change significantly, the share of total electricity generation that natural gas holds, for example, will be dependent on cost fluctuations and the ability to hedge future costs at an attractive price in the present.

Conversely, it may make more sense to take a risk on energy spot rates in order to obtain the most attractive market price for natural gas. The US Energy Information Administration (EIA) expects the Henry Hub natural gas spot price, which averaged US$4.00 (NZ$4.88) per million British thermal units (MMBtu) in 2011, to average US$2.71 (NZ$3.31) per MMBtu in 2012 and US$3.35 (NZ$3.75) per MMBtu in 2013. "We often want to compare the price of a good today with what it was in the past or is likely to be in the future. To make such a comparison meaningful, we need to measure prices relative to an *overall price level.* In absolute terms, the price of a dozen eggs is many times higher today than it was 50 years ago. Relative to prices overall, however, it is actually lower. Therefore, we must be careful to correct for inflation when comparing prices across time. This means measuring prices in *real* rather than *nominal* terms" (Pindyck & Rubinfeld, 2009). Appendix 4 shows the nominal average fuel prices in New Zealand cents per unit for natural gas (1979 – 2011) and electricity (1974 – 2011). The residential cost for natural gas has increased by 566% from the 1979 cost of 1.95 cents per kWh to 12.99 cents per kWh in 2011. Likewise the commercial cost has risen by 615% from 0.86 cents per kWh in 1979 to 6.15 cents per kWh in 2011. Interestingly the wholesale rate, when prices were first recorded in 1990, have increased from 0.90 cents per kWh to 2.57 cents per kWh in 2011, representing a 1.67 cents per kWh increase or a relatively modest 185% increase in comparison.

Turning to the cost of electricity, it is noted that the sales-weighted average of the residential, commercial and industrial prices has increased by a massive 1,298% or 15.77 cents per kWh from 1.20 cents per kWh in 1974 to 16.77 cents per kWh in 2011. "The 2009 Ministerial Review of the components of residential electricity cost (excluding GST) determined prices were made up as follows:

- Energy – the cost of generating electricity: 36%
- Distribution – the cost from lines companies for transporting electricity over local networks between the national grid and your home: 29%
- Retail services – charges relating to providing a high standard of service to customers, including Electricity Authority levies – and margin: 14%
- Transmission – the costs from Transpower, for transporting electricity over the national grid between power stations and local networks: 8%
- Metering – the cost of providing, maintaining and reading electricity meters: 2%" (Contact Energy).

The levelized cost of energy (LCOE) needs to be calculated very carefully. It should take into account the project's total economic cost and total economic benefits – a social cost benefit analysis (SCBA), and the decision to accept or reject the investment using either the net present value (NPV) or internal rate of return (IRR) methods. The decision maker would then either accept or reject the investment proposal based on these and other relevant cost factors. The EIA in its Annual Energy Outlook 2012 states that "Levelized cost is often cited as a convenient summary measure of the overall competitiveness of different generating technologies. It represents the per-kilowatt hour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle.

Key inputs to calculating levelized costs include overnight capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilisation rate for each plant type. The importance of the factors varies among the technologies. For technologies such as solar and wind generation that have no fuel costs and relatively small O&M costs, the levelized cost changes in rough proportion to the estimated overnight capital cost of generation capacity. For technologies with significant fuel cost, both fuel cost and overnight cost estimates significantly affect the levelized cost. The availability of various incentives, including state or federal tax credits, can also impact the calculation of levelized cost. As with any projection, there is uncertainty about all of these factors and their values can vary regionally and across time as technologies evolve" (EIA Annual Energy Outlook, 2012).

The levelized cost shown for each utility-scale generation technology in Appendix 5 provides a convenient summary measure of the overall competitiveness of different generating technologies. It should be noted that the costs shown are calculated based on a 30-year cost recovery period, using a real after tax Weighted Average Cost of Capital (WACC) of 6.8 percent. EIA has also made an arbitrary three percentage point adjustment or increase in the cost of capital when evaluating investments in GHG intensive technologies (e.g. coal).

6.7 Payback Period

The common theme when considering installation of different fuel cell generating technologies is scale. Moreover, the cost differences between the utility supply rates for residential, commercial and industrial natural gas will impact on calculations associated with a payback period for the capital cost of generating units. “The payback period of an investment proposal is the amount of time it will take for the after-tax cash inflows from the project to accumulate to an amount that covers the original investment. There is no adjustment in the payback method for the time value of money. A cash inflow in year 5 is treated the same as a cash inflow in year 1. The following formula defines an investment project’s payback period” (Hilton, 2009).

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Annual after-tax cash inflow}}$$

The variables involved in a payback period calculation are very broad. For example, the return on investment (ROI) is another factor that should be evaluated as part of investment performance when a capital asset is purchased. This formula demonstrates the return or profit generated from the original investment and is expressed in terms of a percentage or ratio.

$$\text{Return on investment (ROI)} = \frac{\text{Income}}{\text{Invested capital}}$$

The formula alerts the decision-maker to the fact that if there is no positive ROI, or if a higher ROI can be obtained from an investment elsewhere, then the investment under consideration should be abandoned. The assumptions involved in calculating a payback period for a SOFC as a sustainable clean energy source for the New Zealand dairy industry are numerous and involve several variables. These include (i) decisions on whether or not grid connection is required, (ii) production costs for electricity from natural gas based on the residential or commercial rates from service providers, (iii) the conversion efficiency percentage of how each system can turn natural gas into electricity; and (iv) the cost of natural gas and whether it is being supplied at rates charged for residential or commercial use. Any one or combination of these variables can impact on the desirability of investing in fuel cell technology. The following return on investment calculation was made by Energy Bulletin for a Bloom Energy Server (capital cost US$800,000) and excludes the cost for grid connection.

“Calculation:

- *Costs per year for 1 million kWh from natural gas from centralised power sources is $100,000.*

- *1,000 cubic foot of natural gas gives 1,034,000 Btu which can be converted at 80% efficiency, hence 827,200 Btu of power which is equivalent to 242 kWh, costing $12 for the fuel. So 12/242 = $0.05 per kWh incorporating fuel costs only. Which amounts to a total fuel cost of $50,000 for 1 million kWh.*

- *At an investment cost of $800,000 it would take approximately 15 years (800,000/50,000) to pay back investments, excluding the costs of connecting to the grid.”* (Energy Bulletin, 2010)

Energy Bulletin states that the calculations for this example were based on residential rates for production costs associated with electricity from natural gas for residential use. However, the Bloom Energy Server is not suitable for meeting the domestic energy needs of consumers as it is designed for large scale application for commercial and industrial markets. Hence the natural gas cost variable utilised in the calculations should ideally be based on commercial as opposed to residential rates in order to obtain a more accurate pay back or ROI indicator. Nevertheless, Figure 44 provides a summary of payback calculation examples for fuel cells in operation from Bloom Energy, ClearEdge, and UTC Power. Together with Appendix 7 it also provides the basis for the reason why a ClearEdge 5 Energy system was chosen as the most suitable application for a dairy farm operation in New Zealand.

Figure 44: Payback Period Comparison

Fireman's Fund – Bloom Energy	
Activity	May 2011 - Installation of 600 kW of Bloom Energy Servers at its two-building campus in Novato, California. The six fuel cells supply 66% of the campus energy needs – about 5.1 million kWh a year.
Benefits	Novato Patch (as cited in Fuel Cells 2000, 2011) found that the company's carbon footprint has been reduced by 15%. By using the fuel cells, Fireman's Fund energy costs have been lowered. Power delivered from the fuel cells will cost less than 10 cents/kWh (the cost of grid power is over 13 cents/kWh). Fireman's Fund estimates that the investment in fuel cells will be paid back in three to five years.
Stone Edge Farm – ClearEdge	
Activity	Stone Edge Farm installed a 5 kW ClearEdge Power fuel cell CHP unit in 2011 on its organic and sustainably managed vineyard estate in Sonoma, California. Waste heat from the system is used to heat an 11,000 gallon lap pool on the vineyard's property.
Benefits	The fuel cell is expected to reduce the vineyard's electricity bill by 49%. 24,000 pounds of CO_2 emissions will be avoided annually. The fuel cell will pay for itself in approximately eight years, much faster than an equivalent sized solar installation. Financial savings will reach $250,000 over 20 years.

Figure 44: Payback Period Comparison (Cont)

Lafayette Hotel – ClearEdge	
Activity	A historic 130-room building in San Diego, California, at the end of 2011 the Lafayett Hotel installed eight ClearEdge5 Power units for a total system size of 40 kW. The fuel cells generate power for the hotel, and waste heat from the units is used to heat the pool, a central feature of the hotel. ClearEdge (as cited in Fuel Cells 2000, 2011) said the fuel cells helped the project qualify for more lucrative rebates and developers saved 42% off the system capital expenditures after rebates and incentives.
Benefits	ClearEdge (as cited in Fuel Cells 2000, 2011) said that the fuel cells are projected to save $29,993 in the first year of operation - $19,556 in net electric savings and $10,377 in net avoided heating costs. The anticipated 10-year savings from the fuel cell is $425,728, with more than $1.2 million in savings on operating expenses expected over 20 years. The hotel will see a 26% energy cost savings. Green Technology (as cited in Fuel Cells 2000, 2011) stated the savings will allow the system to payback the initial investment, with incentives, in 5.8 years, with a projected 20-year internal rate of return of 11.8%. Furthermore, the fuel cells reduce GHG emissions 99.2 tonnes every year, or by 36%.
Becker + Becker – UTC Power	
Activity	In 2010, Becker + Becker installed 400 kW UTC Power fuel cells at two mixed-use buildings, one located on Roosevelt Island, New York City, the other in New Haven, Connecticut.
Benefits	At 360 State Street in New Haven, Connecticut, 65% of the electricity generated by the fuel cell is used to provide power to common and commercial areas. The remainder of the power (excess generation) goes back to the grid with reimbursement. One hundred percent of the fuel cell's waste heat is used for domestic hot water and space heating for 500 apartments, as well as pool heating. The payback period with state and federal incentives is six years, and would be 13 years without incentives. The total investment was $4 million (fuel cell cost was $1.875 million). Financial incentives included a Connecticut Clean Energy Fund (CCEF) grant of $985,000, Federal Tax Credit of $3,000/kW or 30% of install cost ($1.2 million anticipated), Renewable Energy Credit sales of approximately $50,000 per year depending on market pricing, and a distributed generation natural gas rate-discount that forgives distribution charges.

Figure 44: Payback Period Comparison (Cont)

Becker + Becker – ClearEdge	
Benefits	Becker + Becker (as cited in Fuel Cell 2000, 2011) said that at the Octagon, on Roosevelt Island, New York, 100% of electricity generated by the fuel cells powers 500 apartments and common areas. Seventy percent of the fuel cell's waste heat is used for domestic hot water and space heating. The power is sub-metered to tenants, who are charged for their electricity use. Payback period for the installation, with state and federal incentives, is 4.5 years, and 14 years without incentives. Total installed cost was $4 million, of which $2.175 million was for the fuel cell unit, plus installation and existing system tie-in and upgrades. Becker + Becker received $2.2 million in total incentives including a New York State Energy Research and Development Authority (NYSERDA) grant of $1.2 million, and Federal Tax Credit of $3,000/kW or 30% of install cost ($1.2 million anticipated). The fuel cell systems will reduce carbon emissions by 790 metric tons per year per site. Annual energy cost savings at each site are in the range of $350,000 according to Becker + Becker.

Source: Fuel Cells 2000 (2011)

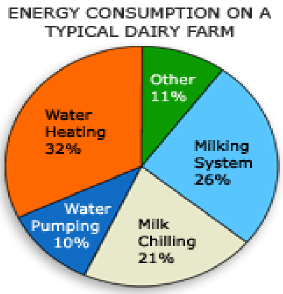
7 FINDINGS ANALYSIS

Much of the findings in this study were gathered from secondary research and while attempts were made to undertake primary research with large dairy processing companies in New Zealand and fuel cell manufacturers in the United States, due to commercial sensitivity this was difficult to undertake in the absence of comprehensive data. Therefore, publically available energy use information was largely replied upon. However, primary research was undertaken through a questionnaire and personal communication (October 18, 2012) with Mr John Gregan, Chief Executive Officer, and Mrs Cara Gregan, Chief Financial Officer of Gregan Dairy and Brookdale Farm in the Hunter Hills, which is located in Waimate District in South Canterbury, New Zealand. From running a total of 7,300 breeding ewes in 2004, the Gregan's decided to convert their business to dairying (Gregan Dairy) in 2008 and Brookdale Farm in 2010. The Gregan's dairy operation is comprised of two non-irrigated farms: Gregan Dairy which is 170 hectares (160 effective) or 420 acres (395 effective) employing 2.5 full-time equivalent (FTE) staff and milking 450 cows. The second farm, Brookdale is 330 hectares (280 effective) or 815 acres (692 effective) employing 3 FTE staff and milking 550 cows. In total this is a 1,000 cow dairy farm operation utilising 500 hectares (440 effective) or 1,235 acres (1,087 effective).

Electricity costs associated with dairy farm irrigation can vary a great deal depending on the depth of the well, how much water is pumped and the type of irrigation system utilised. Gregan Dairy incurs annual electricity costs of $13,000 and some farmers are paying more than $20,000 per month or $120,000 per year in electricity costs for irrigation alone.

Mr Kerry O'Connell and Mrs Carol O'Connell own an irrigated dairy farm in Dunsandel, Canterbury which is leased out. Mr O'Connell (personal communication, October 9, 2012) informed me that their farm is milking 750 cows. As a general guide based on farm advisers figures, electricity costs to run the milking shed are in the vicinity of $25,000 per season and the irrigation cost is approximately $100,000 per season. A season is one year, running from 1 June to 31 May. These costs are commensurate with the operational size of each farm and it should be remembered that the average herd size of a typical New Zealand dairy farm is 386 cows. In North Canterbury, however, where 11.3% of the South Island's 35.8% of dairy cows are located, a herd of 750 cows is now considered an average size farm. The average New Zealand dairy farmer consumes 88,000 kWh of electricity per year (costing around NZ$14,000 excluding lines charges). "Electricity is one of the fastest rising costs in dairy farm operation. Dairy New Zealand reported in 2009, that fuel and electricity prices have increased by 130% and 90% respectively since 2000" (EECA, 2010). Genesis Energy states that the main energy uses on a dairy farm are within the milking shed – hot water heating, milk chilling, the milking system's vacuum pump, and water and effluent pumping. Figure 45 shows the energy consumption on a typical dairy farm in terms of percentage of electricity associated with the main energy uses. Energy consumption figures for Gregan Dairy Farm as contained in the questionnaire in Appendix 6, would need to be utilized in analysing the merits of installing a ClearEdge5 energy system on-site at a dairy farm and to help determine if such a project would be (1) technically feasible, (2) feasible

Figure 45: Dairy Farm Energy Consumption



1. Figures are from Genesis Energy audited farms and are based on a non-irrigated dairy farm.
2. Miscellaneous operations include shed lighting, effluent pump etc.

within the estimated cost, and (3) profitable. Putting aside environmental concerns, the study’s findings indicate that such a proposal should be feasible for a dairy farm that has reticulated natural gas supply availability (i.e. North Island) but possibly not feasible from both a practical and profitability perspective where reticulated natural gas is not currently available (i.e. South Island).

8 CONCLUSION

This study explored a feasible option for lowering GHG emissions and creating future stability in terms of capital and operational cost structures through the adoption of a sustainable clean energy source for the New Zealand dairy industry. The focus was on options associated with combining fuel cell technology to generate electricity from natural gas and the application of a PEM energy system to an average sized dairy farm. The dairy industry in New Zealand is in a phase of significant change and over the next 5 to 10 years will be faced with increased competition from dairy farm operations in emerging countries, the United States and Europe. In the EU alone, “milk production is expected to increase between 55% and 60% in five years following the 2015 EU milk quota abolition” (Astley, 2012). Operating in a geographically isolated country the New Zealand dairy industry must be an efficient producer and remain focused on environmentally sustainable farming practices which incorporate the introduction of innovative clean energy sources.

This will continue to be a challenge while New Zealand is faced with increasing competition from producer countries that continue to heavily subsidise their agricultural sectors, while at the same time having to meet GHG emission restrictions imposed by legislation. As land availability for dairy conversion becomes increasingly constrained, it will be necessary to develop on-farm efficiencies as a means of maximizing growth opportunities. For an innovative industry with over a third of the world’s dairy trade coming from New Zealand dairy exporters, it is possible for the industry to maintain and expand its competitive advantage. While dairy farmers from some countries, particularly in the EU, continue to receive subsidies from their governments which do not help in the creation of an open and competitive market, one mechanism that can help to alleviate this issue is for the New Zealand dairy industry to assist farmers with advice and encouragement to enter the international carbon trading market. If a dairy farm generating electricity with a ClearEdge5 energy system can reduce GHG emissions then the farmer should be able to issue Certified Emission Reduction units (CERs) or similar type instruments. Entering into carbon trading markets will help farmers to off-set or mitigate the capital and installation costs of an energy system. This is essentially a “work-around” solution to competing against subsidized industries, yet an alternative means of generating cash-flow or revenue and reducing the capital cost of an energy system. “CERs are carbon credits issued in relation to Clean Development Mechanism (CDM) projects. The CDM is one of the flexibility mechanisms defined in the Kyoto Protocol. It allows emissions reduction projects in developing countries to be used to assist developed countries (Annex 1 countries) in achieving their commitments under the Kyoto Protocol. Examples of CDM projects for which CERs are generated include:

- Renewable energy: wind farms, hydroelectric power and landfill gas
- Electricity and fuel efficiency for households and industries
- Reducing emissions in industrial and manufacturing processes (e.g. cement production)
- Reducing fugitive emissions from production and consumption of fossil fuels, halocarbons and sulphur hexafluoride.” (Climate Change Information New Zealand, 2012).

Depending on the currency value (e.g. Euro, US$, or NZ$) per CER or per tonne of carbon emission reduction (e.g. 10% to 20%) the payback period on an installed ClearEdge5 energy system could be significantly reduced by utilizing such opportunities as CER or alternative market instruments. It could be an area that Dairy New Zealand or Fonterra may wish to consider acting as a facilitator for dairy farmers to buy and sell carbon credits. For example, farmers could buy credits to meet compliance requirements or voluntary carbon credits to compensate their residual emissions. Likewise, they could sell when the need arises. Dairy New Zealand, for example, could even establish a clearing and settlement division through partnering with an international financial institution such as ANZ Bank to reduce transaction and transfer costs. New Zealand Units (NZUs) are even available under the New Zealand ETS (http://www.anz.com/Markets/Solutions/CarbonTrading.asp).

The study highlights the importance of long-term sustainability, lowering of GHG emissions, and a move toward adopting clean energy technologies to generate electricity from natural gas. The data gathered through primary and secondary research indicates that an average sized dairy farm could benefit from utilising PEM fuel cell technology. For example, the electricity tariff rate for the Gregan Farm is 16.01 cents per kWh and the night tariff rate is 8.3 cents per kWh. A ClearEdge5 energy system appears to be cost competitive with the system able to generate electricity at about 7.0 cents per kWh and consuming about 40% less fuel than power and heat delivered through the grid. The result is a reduction in carbon footprint by a similar percentage which has to be good for the environment and future dairy industry sustainability. But unfortunately the study falls short in a number of areas.

1. There is no reticulated natural gas in the South Island. It would have been preferable to undertake a more detailed analysis of a North Island dairy farm operation that (a) utilizes natural gas; (b) is irrigated; and (c) is willing to release
2. farm and electricity details in order to conduct an in-depth feasibility study on the introduction of a ClearEdge 5 energy system.
3. There exists an opportunity to model the specifics of a ClearEdge5 energy system against the needs of such a dairy farm operation to determine (a) to what extent the system would satisfy those needs; (b) what the cost would be to do so; and (c) how it would compare to the status quo.
4. Due to time constraints, there was no opportunity to conduct an in-depth investigation of feasibility factors in terms of the project's total economic cost including a SCBA.
5. The study highlights that SOFC (Bloom Energy) and PAFC (UTC Power) systems may have significant benefits for large dairy processing operations. It is regrettable that a more detailed analysis of these options could not be undertaken due to the non-availability of required data for a large-scale North Island dairy processing operation and commercial sensitivity concerns of sizeable processing companies involved in the industry.

However, the study has established the basis for the dairy industry or interested parties together with assistance from government agencies (e.g. EECA, MAF) to sponsor a Request for Proposal to undertake an on-farm pilot study. For example, a ClearEdge 5 energy system may be available to import for the purpose of conducting a test case. EECA or Dairy New Zealand may be able to partner with a research university with agricultural interests (e.g. Massey University), a university with a strong engineering history (e.g. Canterbury University), Federated Farmers, and dairy interests (e.g. Fonterra) to complete a comprehensive analysis on a monitor dairy farm as part of an environmental sustainability pilot programme. The pilot study conducted in 2010 as part of the Dairy Energy Action Programme's initiative to help farmers cut their energy costs showed that "46% of farmers will adopt savings technologies if their costs can be recovered within three years" (NZ Energy & Environment Business Week). A ClearEdge5 energy system costs NZ$68,435 (excluding installation and shipping costs) which is not a great deal when compared to the cost of a typical farm tractor which can cost anywhere between approximately NZ$65,000 and NZ$250,000. Furthermore, the payback period is relatively short on a system with an expected life-cycle of over 20 years.

This study recommends that more research and investigation of applicable options is necessary to satisfy dairy farmers and industry producers in terms of financial modelling and whether fuel cell technology is an economically viable option for the New Zealand dairy industry. "While power companies wrestle with supply and demand equations, the oil and gas part of the sector has to assure a wary public that development can go hand-in-hand with environmental protection" (Management, 2012).

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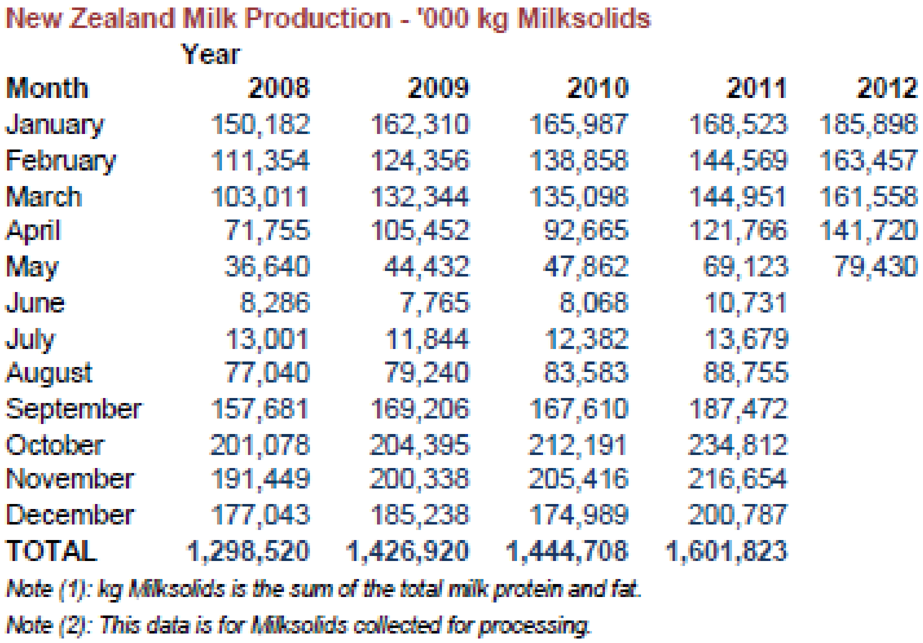
10 APPENDICES

Appendix 1 – New Zealand Milk Production – ‘000 kg Milksolids

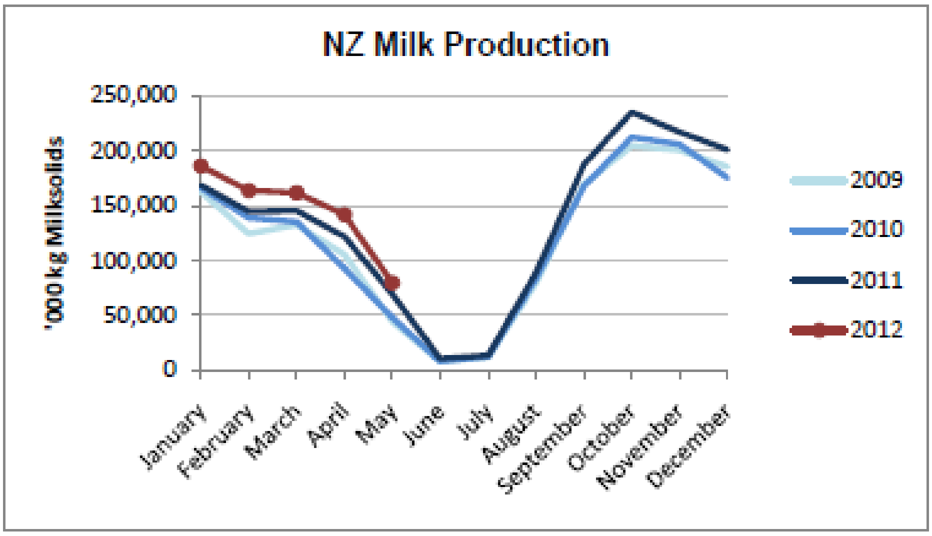


New Zealand Milk Production - '000 kg Milksolids

	Year				
Month	**2008**	**2009**	**2010**	**2011**	**2012**
January	150,182	162,310	165,987	168,523	185,898
February	111,354	124,356	138,858	144,569	163,457
March	103,011	132,344	135,098	144,951	161,558
April	71,755	105,452	92,665	121,766	141,720
May	36,640	44,432	47,862	69,123	79,430
June	8,286	7,765	8,068	10,731	
July	13,001	11,844	12,382	13,679	
August	77,040	79,240	83,583	88,755	
September	157,681	169,206	167,610	187,472	
October	201,078	204,395	212,191	234,812	
November	191,449	200,338	205,416	216,654	
December	177,043	185,238	174,989	200,787	
TOTAL	**1,298,520**	**1,426,920**	**1,444,708**	**1,601,823**	

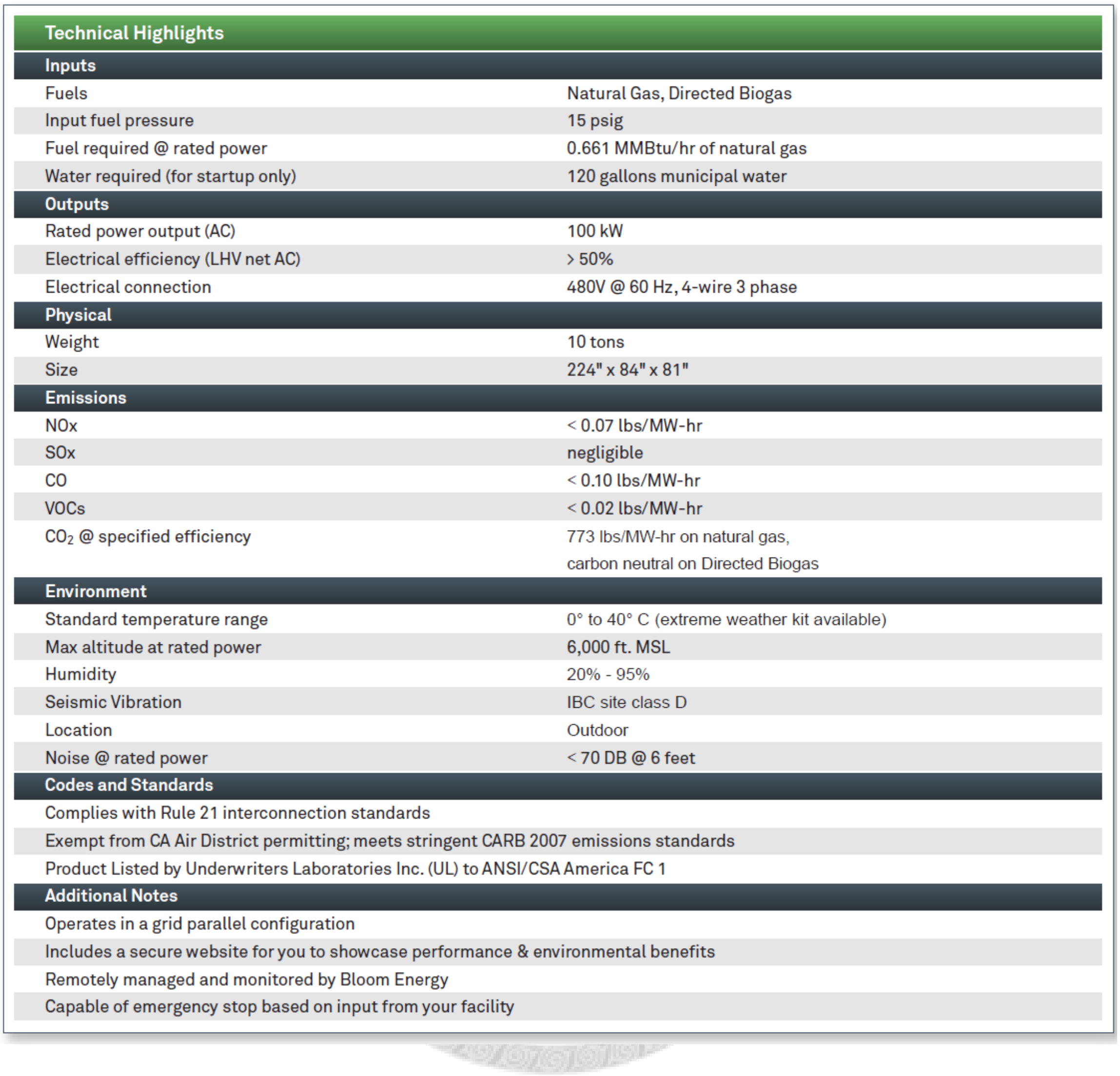
Note (1): kg Milksolids is the sum of the total milk protein and fat.

Note (2): This data is for Milksolids collected for processing.



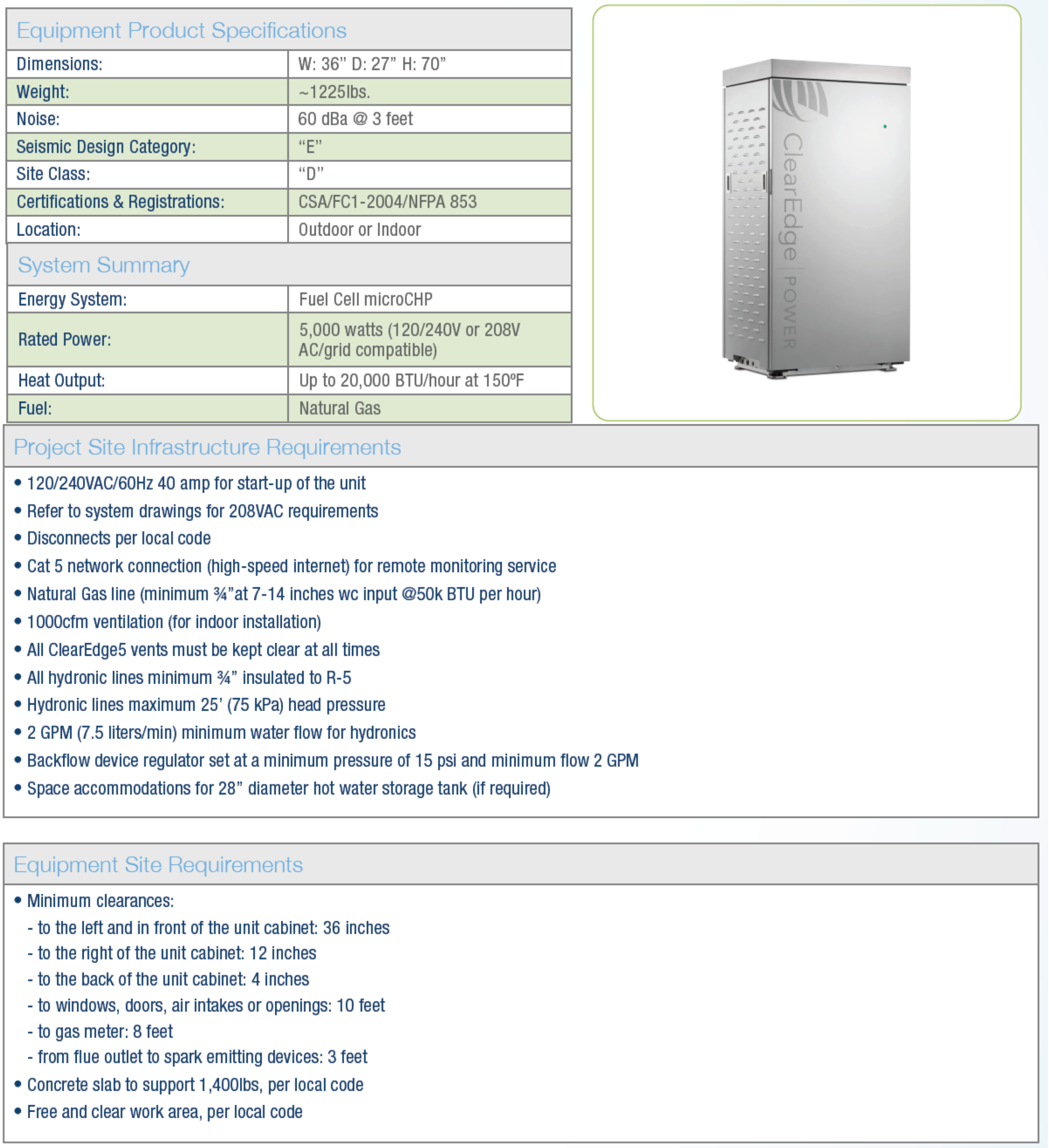
Source: Dairy Companies Association of New Zealand

Appendix 2 – Bloom Energy ES-5400 Energy Server



Technical Highlights	
Inputs	
Fuels	Natural Gas, Directed Biogas
Input fuel pressure	15 psig
Fuel required @ rated power	0.661 MMBtu/hr of natural gas
Water required (for startup only)	120 gallons municipal water
Outputs	
Rated power output (AC)	100 kW
Electrical efficiency (LHV net AC)	> 50%
Electrical connection	480V @ 60 Hz, 4-wire 3 phase
Physical	
Weight	10 tons
Size	224" x 84" x 81"
Emissions	
NOx	< 0.07 lbs/MW-hr
SOx	negligible
CO	< 0.10 lbs/MW-hr
VOCs	< 0.02 lbs/MW-hr
CO_2 @ specified efficiency	773 lbs/MW-hr on natural gas, carbon neutral on Directed Biogas
Environment	
Standard temperature range	0° to 40° C (extreme weather kit available)
Max altitude at rated power	6,000 ft. MSL
Humidity	20% - 95%
Seismic Vibration	IBC site class D
Location	Outdoor
Noise @ rated power	< 70 DB @ 6 feet
Codes and Standards	
Complies with Rule 21 interconnection standards	
Exempt from CA Air District permitting; meets stringent CARB 2007 emissions standards	
Product Listed by Underwriters Laboratories Inc. (UL) to ANSI/CSA America FC 1	
Additional Notes	
Operates in a grid parallel configuration	
Includes a secure website for you to showcase performance & environmental benefits	
Remotely managed and monitored by Bloom Energy	
Capable of emergency stop based on input from your facility	

Appendix 3 – ClearEdgeES-5000 Energy System



Equipment Product Specifications	
Dimensions:	W: 36" D: 27" H: 70"
Weight:	~1225lbs.
Noise:	60 dBa @ 3 feet
Seismic Design Category:	"E"
Site Class:	"D"
Certifications & Registrations:	CSA/FC1-2004/NFPA 853
Location:	Outdoor or Indoor
System Summary	
Energy System:	Fuel Cell microCHP
Rated Power:	5,000 watts (120/240V or 208V AC/grid compatible)
Heat Output:	Up to 20,000 BTU/hour at 150ºF
Fuel:	Natural Gas

Project Site Infrastructure Requirements

- 120/240VAC/60Hz 40 amp for start-up of the unit
- Refer to system drawings for 208VAC requirements
- Disconnects per local code
- Cat 5 network connection (high-speed internet) for remote monitoring service
- Natural Gas line (minimum ¾"at 7-14 inches wc input @50k BTU per hour)
- 1000cfm ventilation (for indoor installation)
- All ClearEdge5 vents must be kept clear at all times
- All hydronic lines minimum ¾" insulated to R-5
- Hydronic lines maximum 25' (75 kPa) head pressure
- 2 GPM (7.5 liters/min) minimum water flow for hydronics
- Backflow device regulator set at a minimum pressure of 15 psi and minimum flow 2 GPM
- Space accommodations for 28" diameter hot water storage tank (if required)

Equipment Site Requirements

- Minimum clearances:
  - to the left and in front of the unit cabinet: 36 inches
  - to the right of the unit cabinet: 12 inches
  - to the back of the unit cabinet: 4 inches
  - to windows, doors, air intakes or openings: 10 feet
  - to gas meter: 8 feet
  - from flue outlet to spark emitting devices: 3 feet
- Concrete slab to support 1,400lbs, per local code
- Free and clear work area, per local code

Appendix 4 (a): New Zealand Nominal Annual Average Natural Gas and Electricity Prices from 1974 to 1979 (NZ cents per kWh)

Year	1974	1975	1976	1977	1978	1979
Natural Gas						
Residential						1.95
Commercial						0.86
Industrial						
Wholesale						
Electricity	**1.20**	**1.24**	**1.63**	**2.21**	**2.52**	**3.33**
Residential	1.15	1.19	1.56	2.15	2.42	3.19
Commercial	2.08	2.13	2.73	3.72	4.22	5.38
Industrial	0.90	0.94	1.25	1.68	1.95	2.63

Source: Ministry of Business, Innovation & Employment

Notes:

1. A sales-weighted average price for natural gas is not given here due to a lack of information on the split between retail and wholesale rates.
2. The electricity price given here is a sales-weighted average of the residential, commercial and industrial prices.
3. Goods and Services Tax (GST) is only included on residential prices for natural gas and electricity. In all other respects GST is not applicable.

Appendix 4 (b): New Zealand Nominal Annual Average Natural Gas and Electricity Prices from 1980 to 1989 (NZ cents per kWh)

Year	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Natural Gas										
Residential	2.24	2.37	2.37	2.37	1.88	2.08	2.82	3.05	2.72	3.32
Commercial	1.29	1.33	1.33	1.33	1.49	1.77	2.04	2.64	2.38	2.47
Industrial										
Wholesale										
Electricity	**3.83**	**4.21**	**4.74**	**4.82**	**4.92**	**5.76**	**6.64**	**7.43**	**7.96**	**8.17**
Residential	3.69	4.05	4.56	4.69	4.80	5.62	6.71	7.89	8.71	9.03
Commercial	6.08	6.61	7.33	7.53	7.70	8.87	9.94	10.98	11.52	11.71
Industrial	3.05	3.34	3.78	3.80	3.88	4.55	5.13	5.47	5.73	5.78

Source: Ministry of Business, Innovation & Employment

Notes:

1. A sales-weighted average price for natural gas is not given here due to a lack of information on the split between retail and wholesale rates.
2. The electricity price given here is a sales-weighted average of the residential, commercial and industrial prices.
3. Goods and Services Tax (GST) is only included on residential prices for natural gas and electricity. In all other respects GST is not applicable.

Appendix 4 (c): New Zealand Nominal Annual Average Natural Gas and Electricity Prices from 1990 to 1999 (NZ cents per kWh)

Year	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**
Natural Gas										
Residential	3.39	3.78	3.84	4.15	4.40	4.90	5.49	5.97	6.14	5.88
Commercial	2.47	2.63	2.63	2.58	2.64	2.68	2.73	3.28	3.36	4.26
Industrial										1.76
Wholesale	0.90	0.92	0.95	0.98	1.01	1.04	1.07	1.10	1.13	1.01
Electricity	**8.23**	**8.40**	**8.62**	**8.68**	**8.75**	**9.04**	**9.36**	**9.56**	**9.72**	**9.44**
Residential	9.22	9.81	10.27	10.78	11.37	11.93	12.68	13.41	13.19	13.28
Commercial	11.72	11.59	11.49	11.15	10.90	10.72	10.92	10.91	10.56	10.20
Industrial	5.73	5.78	6.00	6.01	5.88	6.21	6.17	6.11	6.64	6.17

Source: Ministry of Business, Innovation & Employment

Notes:

1. A sales-weighted average price for natural gas is not given here due to a lack of information on the split between retail and wholesale rates.
2. The electricity price given here is a sales-weighted average of the residential, commercial and industrial prices.
3. Goods and Services Tax (GST) is only included on residential prices for natural gas and electricity. In all other respects GST is not applicable.

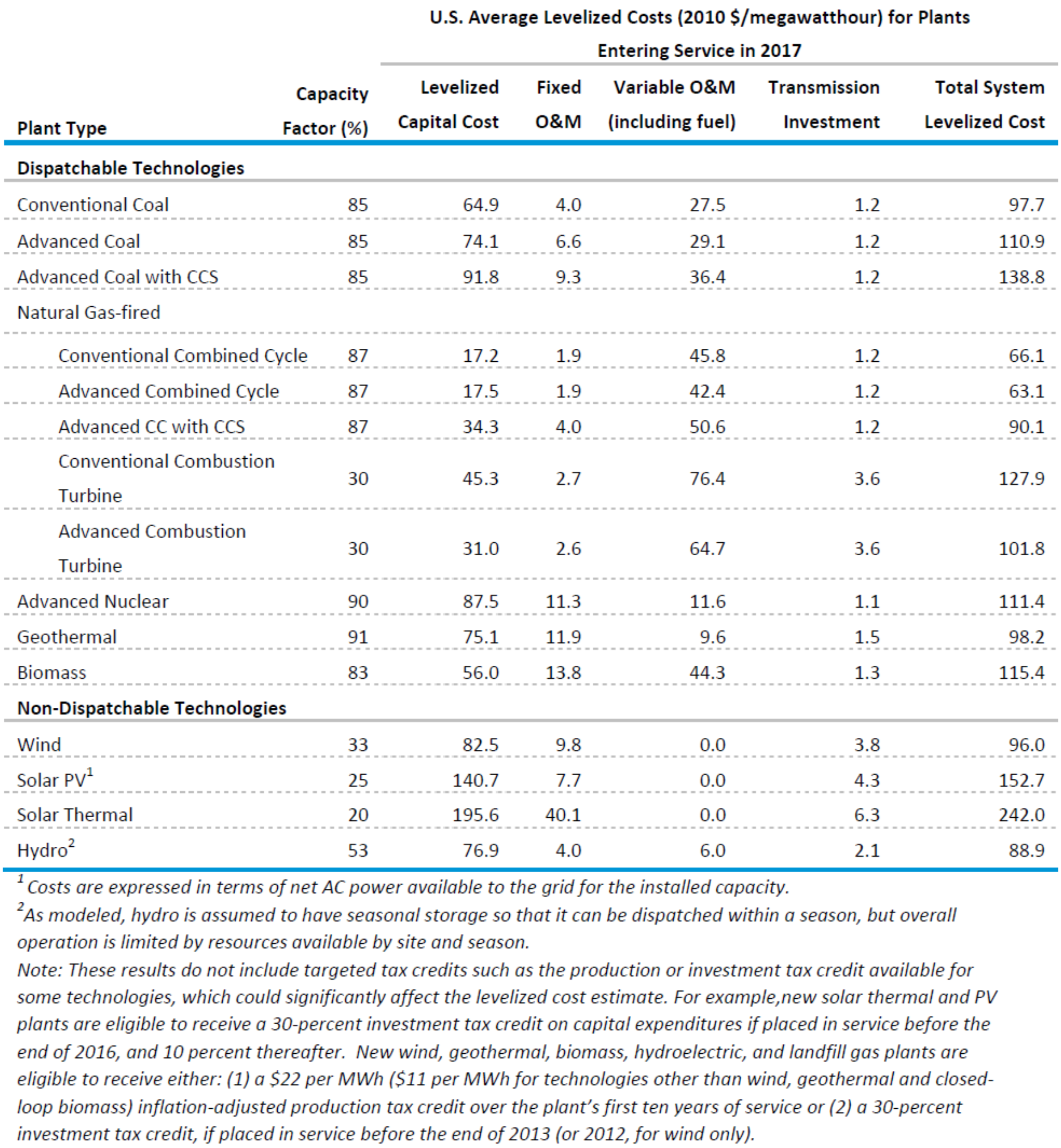
Appendix 4 (d): New Zealand Nominal Annual Average Natural Gas and Electricity Prices from 2000 to 2011 (NZ cents per kWh)

Year	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Natural Gas												
Residential	4.64	4.71	4.80	6.60	8.76	10.13	9.83	12.57	14.29	11.83	11.94	12.99
Commercial	3.23	3.18	3.35	3.71	3.46	4.25	5.14	5.82	6.02	5.62	5.72	6.15
Industrial	1.59	1.63	1.74	2.08	2.28	2.71	3.17	3.22	2.99	3.16	2.89	2.83
Wholesale	0.98	1.02	1.06	1.16	1.38	1.37	1.74	1.96	2.01	2.51	2.65	2.57
Electricity	**9.45**	**10.06**	**10.68**	**11.60**	**12.28**	**13.32**	**14.06**	**14.79**	**15.99**	**16.28**	**16.33**	**16.77**
Residential	13.26	14.17	15.28	16.42	17.96	19.19	20.56	22.10	23.28	24.13	25.34	26.22
Commercial	10.26	10.49	10.73	11.69	12.27	13.25	13.85	14.14	14.94	15.09	15.39	15.85
Industrial	6.23	6.62	7.12	7.91	8.00	9.05	9.30	9.79	10.87	10.40	9.61	9.35

Source: Ministry of Business, Innovation & Employment

1. A sales-weighted average price for natural gas is not given here due to a lack of information on the split between retail and wholesale rates.
2. The electricity price given here is a sales-weighted average of the residential, commercial and industrial prices.
3. Goods and Services Tax (GST) is only included on residential prices for natural gas and electricity. In all other respects GST is not applicable.

Appendix 5 – Estimated Levelized Cost of New Generation Resources, 2017



		U.S. Average Levelized Costs (2010 $/megawatthour) for Plants Entering Service in 2017				
Plant Type	**Capacity Factor (%)**	**Levelized Capital Cost**	**Fixed O&M**	**Variable O&M (including fuel)**	**Transmission Investment**	**Total System Levelized Cost**
Dispatchable Technologies						
Conventional Coal	85	64.9	4.0	27.5	1.2	97.7
Advanced Coal	85	74.1	6.6	29.1	1.2	110.9
Advanced Coal with CCS	85	91.8	9.3	36.4	1.2	138.8
Natural Gas-fired						
Conventional Combined Cycle	87	17.2	1.9	45.8	1.2	66.1
Advanced Combined Cycle	87	17.5	1.9	42.4	1.2	63.1
Advanced CC with CCS	87	34.3	4.0	50.6	1.2	90.1
Conventional Combustion Turbine	30	45.3	2.7	76.4	3.6	127.9
Advanced Combustion Turbine	30	31.0	2.6	64.7	3.6	101.8
Advanced Nuclear	90	87.5	11.3	11.6	1.1	111.4
Geothermal	91	75.1	11.9	9.6	1.5	98.2
Biomass	83	56.0	13.8	44.3	1.3	115.4
Non-Dispatchable Technologies						
Wind	33	82.5	9.8	0.0	3.8	96.0
Solar PV[1]	25	140.7	7.7	0.0	4.3	152.7
Solar Thermal	20	195.6	40.1	0.0	6.3	242.0
Hydro[2]	53	76.9	4.0	6.0	2.1	88.9

[1] *Costs are expressed in terms of net AC power available to the grid for the installed capacity.*

[2] *As modeled, hydro is assumed to have seasonal storage so that it can be dispatched within a season, but overall operation is limited by resources available by site and season.*

Note: These results do not include targeted tax credits such as the production or investment tax credit available for some technologies, which could significantly affect the levelized cost estimate. For example,new solar thermal and PV plants are eligible to receive a 30-percent investment tax credit on capital expenditures if placed in service before the end of 2016, and 10 percent thereafter. New wind, geothermal, biomass, hydroelectric, and landfill gas plants are eligible to receive either: (1) a $22 per MWh ($11 per MWh for technologies other than wind, geothermal and closed-loop biomass) inflation-adjusted production tax credit over the plant's first ten years of service or (2) a 30-percent investment tax credit, if placed in service before the end of 2013 (or 2012, for wind only).

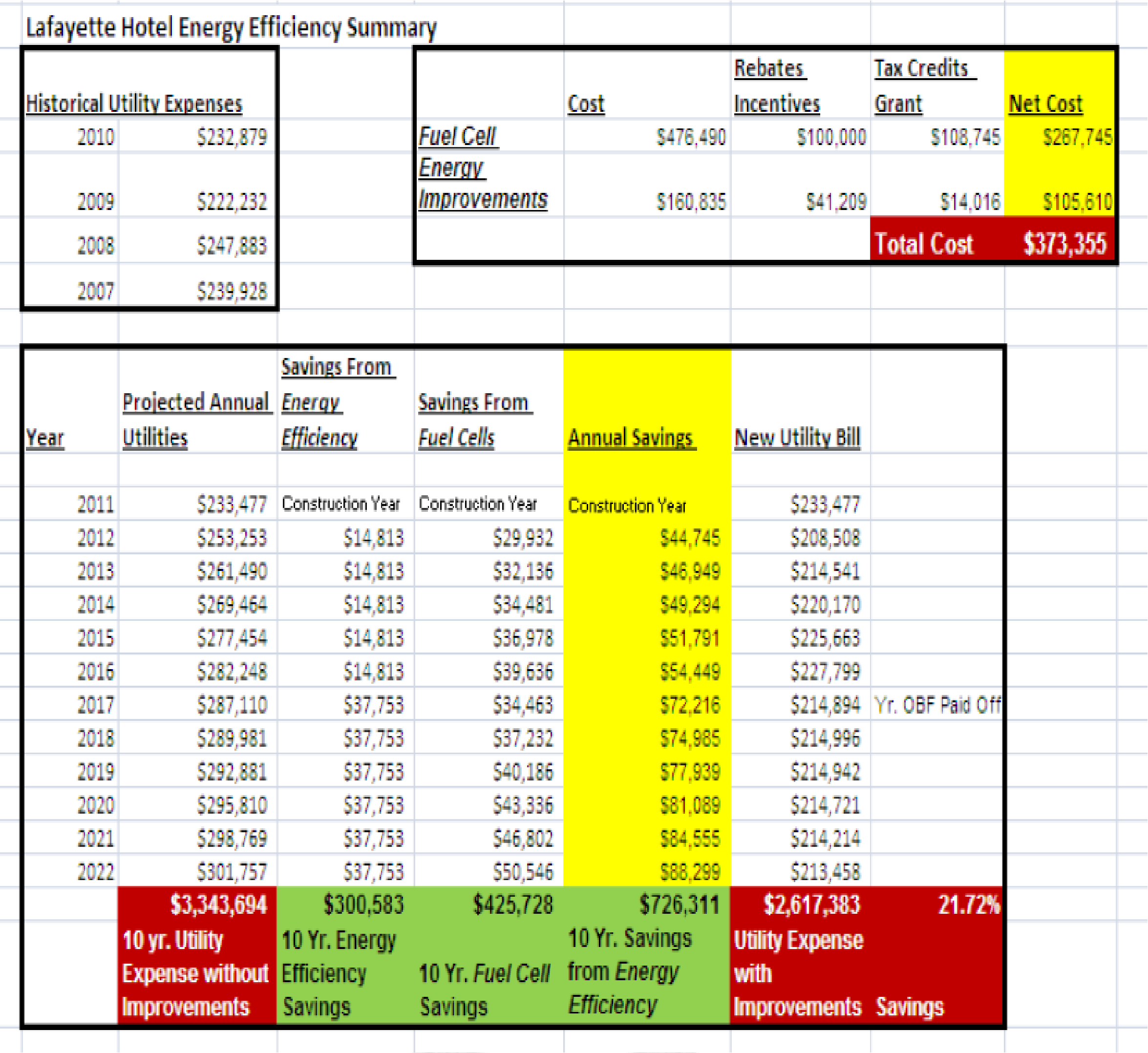
Source: U.S. Energy Information Administration, Annual Energy Outlook 2012, June 2012, DOE/EIA-0383 (2012)

Appendix 6 – Gregan Farm - Dairy Shed Electricity Costs

Farm and Electricity Account Inputs	Input Details and Rates – GST exclusive	Comments
Number of cows being milked	450	
Milking days per year	275	
Day/Night metering	Yes	
If yes for day/night, percentage of night use	20%	% = (night use / [night use + day use]) x 100
Do you have a specific Hot Water/Control meter	No	
Anytime/General tariff	Cents/kWh	If time of use (TOU) meter, use average of variable (cents/kWh) energy and line rates
Day tariff	16.01 cents/kWh	
Night tariff	8.3 cents/kWh	
Hot Water/Control tariff	cents/kWh	
Prompt payment discount applicable	4%	0%, 5%, 10%, 15%, 20%
Hot Water Inputs		
Equipment wash – hot water volume per wash	350 litres	Convert gallons to litres by multiplying by 4.5
Number of equipment washes per week	2	
Vat wash – hot water volume per wash	350 litres	
Number of vat washes per week	6	
Hot water temperature in cylinder	85°C	Usually 85°C
Average water supply temperature to cylinders	10°C	Temperature can vary between summer and winter
Refrigerant in milk refrigeration unit	R404	Usually found on milk cooling refrigeration unit e.g. R12 or R22
Output water temperature from pre-cooler	28°C	
Milk cooling refrigeration motor size	25 kW or 10 hp	
Milk Cooling Inputs		
Milk vat size	18,000 litres	
Milk vat location	Outside	
Is milk vat insulated	No	
Is there a milk pre-cooler	Yes	
Milk temperature into vat (usually after pre-cooler)	18°C	Regulations are for 18°C
Target milk temperature in vat	5°C	
Is milk cooled by an ice bank or a chilled water system	Yes – chilled water	
Volume of milk per cow per day (average)	20 Litres	
Milk Vacuum Pump Inputs		
Time take for morning milk	100 minutes or 1 hr 40 mins	This is the average time milking equipment is switched on e.g. vacuum pump
Time taken for evening milk	90 minutes or 1 hr 30 mins	
Number of vacuum pumps	1	
Vacuum pump motor size	11 kW	
Variable Speed Drive currently installed	Yes	This would be installed on the vacuum pump

Source: Questionnaire - Genesis Energy (Efficiency Calculator Table)

Appendix 7 – Payback Period for ClearEdge5 Energy System



Lafayette Hotel Energy Efficiency Summary

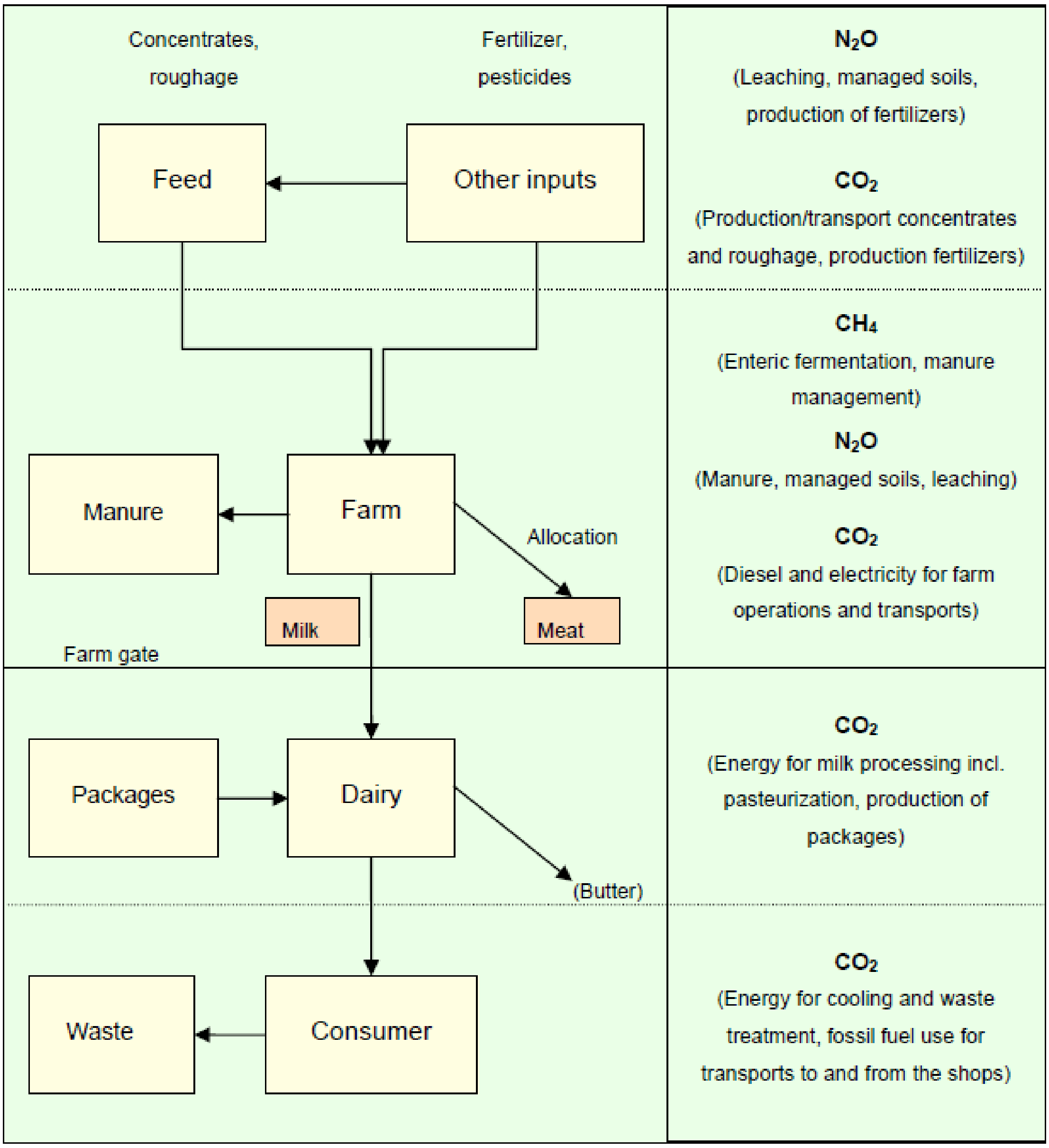
Historical Utility Expenses	
2010	$232,879
2009	$222,232
2008	$247,883
2007	$239,928

	Cost	Rebates Incentives	Tax Credits Grant	Net Cost
Fuel Cell	$476,490	$100,000	$108,745	$267,745
Energy Improvements	$160,835	$41,209	$14,016	$105,610
			Total Cost	$373,355

Year	Projected Annual Utilities	Savings From *Energy Efficiency*	Savings From *Fuel Cells*	Annual Savings	New Utility Bill	
2011	$233,477	Construction Year	Construction Year	Construction Year	$233,477	
2012	$253,253	$14,813	$29,932	$44,745	$208,508	
2013	$261,490	$14,813	$32,136	$46,949	$214,541	
2014	$269,464	$14,813	$34,481	$49,294	$220,170	
2015	$277,454	$14,813	$36,978	$51,791	$225,663	
2016	$282,248	$14,813	$39,636	$54,449	$227,799	
2017	$287,110	$37,753	$34,463	$72,216	$214,894	Yr. OBF Paid Off
2018	$289,981	$37,753	$37,232	$74,985	$214,996	
2019	$292,881	$37,753	$40,186	$77,939	$214,942	
2020	$295,810	$37,753	$43,336	$81,089	$214,721	
2021	$298,769	$37,753	$46,802	$84,555	$214,214	
2022	$301,757	$37,753	$50,546	$88,299	$213,458	
	$3,343,694	**$300,583**	**$425,728**	**$726,311**	**$2,617,383**	**21.72%**
	10 yr. Utility Expense without Improvements	10 Yr. Energy Efficiency Savings	10 Yr. *Fuel Cell* Savings	10 Yr. Savings from *Energy Efficiency*	**Utility Expense with Improvements**	**Savings**

Source: Historic Consultants Inc

Appendix 8 – Flowchart of the Milk Life Cycle and the Associated GHG Emissions



Source: European Dairy Association, A sustainable dairy sector – global, regional and life cycle facts and figures on greenhouse gas emissions, 2008.