Building a Sustainable Ōtaki Community

ENERGY USE PATTERNS AND SCOPING OF RENEWABLE TECHNOLOGY OPTIONS FOR ŌTAKI

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ENERGY USE & ALTERNATIVE TECHNOLOGY OPTIONS

EXECUTIVE SUMMARY

Purpose of Study

The study of energy use patterns and scoping of potential technologies that might contribute to the Ōtaki area becoming a sustainable community has been undertaken as a component of the Kapiti Coast District Council's strategy for economic and social renewal of the Ōtaki community and economy. 'Energise Ōtaki' is the Council's long term initiative to make the Greater Ōtaki area a net exporter of clean energy. The report sets out an estimate of energy consumption and effective energy output of resident farms, households and businesses. This identifies the dominant role of households in the area's energy use, and the key demands of transport fuels and household electric power.

A suggested technology road map (TRM) has been prepared from the energy use patterns and potential technologies that might take advantage of the renewable energy resources available within the Ōtaki area.

Base-Line Findings

The base-line study for the Ōtaki area has identified the current use of only one renewable energy resource available from within the area – wood. Wood supplied 6.5% of the total area energy intake in 2007, the latest date for which data on the total energy intake is available. Some of this wood is used in open fires for space heating of residences, one of the lowest efficiency energy uses available.

The consequence of the low energy generation from within the area is that for it to be a net exporter of clean energy, the Ōtaki residential, farming and business community has to generate energy savings and source new energy supplies from within the area equivalent to 93.5% of its total energy intake. This is a major challenge, and it is not likely that the area's resources can provide a mix of energy types similar to the demand profile. Thus, the area will need to trade energy with external districts to secure the energy profile that it requires, and still secure a "net energy generator" status.

The first step in achieving the goal must be to secure energy reduction through conservation and to improve the efficiency of energy use within the area. The potential for these strategies is explored in subsequent sections.

Energy Efficiency

The base line case suggests that there are a number of avenues whereby the Ōtaki area and its households in particular, can significantly improve the energy efficiency of their community. One aspect is insulation, and another is home heating technologies. Penetration of energy efficient space heating technologies is presently low.

New forms of lighting – residential, commercial and street – have come available in the form of LED lighting. The capital cost of this technology has fallen to more affordable levels for installation.

Home appliance energy efficiency continues to improve.

Nevertheless, improved efficiency will not make the Ōtaki area a net exporter of renewable energy. Given the area's reliance upon purchases of energy from external sources, substantial investment in generating technologies will be required to meet the vision of Energise Ōtaki. The potential alternatives for this investment were given an initial review.

Technologies

Technologies that may be applicable to the community in the achievement of the goal of becoming a net exporter of renewable energy are set out in Chapters 9 – 12.

> Chapter 9 looks at renewable energy generation across a number of forms, including electric power, biogases and liquid biofuels.
>
> Chapter 10 undertakes a preliminary survey of energy storage options, with particular reference to electric power.
>
> Chapter 11 investigates road transport and allied hybrid and short term storage technologies.
>
> Chapter 12 looks at community scale options, including a preliminary review of a local smart energy network.

A major feature of today's energy markets is the very rapid rate of technological innovation taking place in all fields of renewable energy. This pace is accelerating as advances in nano technology start to enter the domain, and as competition for energy productivity intensifies. Some of these developments offer elegant, simplified solutions, such as PSA Motor Groups' new "Hybrid Air" system which delivers regenerative breaking without the need for battery storage or an additional electric motor. Similarly, new breakthroughs in energy storage are finally competing with the traditional medium of hydro lake storage.

Importantly, the high capital cost of many of the new alternatives has begun to fall sharply, even without allowance for enhanced productivity. For example, prices for Solar PV panels have declined by 85% over the last few years, making solar PV an economic electricity generating technology in its own right. In the all-electric vehicle market, pricing has become sharper as production volumes have risen, and many more marques entered the field, including high performance cars. In NZ, pricing for the new Holden Volt late in 2012, and the indicative pricing for the mid-2013 release of the Mitsubishi Outlander PHEV sharply reduce the premium previously placed upon electric vehicles. At the same time, the single charge range of the vehicles is steadily being increased. It is clear that electric vehicles are now becoming a mainstream technology and electric drive technologies are becoming simpler & cheaper. A particular market vector, especially in cities, is becoming understood.

On balance, the overall energy outlook points to a reduction in demand for energy from private buildings, especially for heating, coupled with an intensification in the use of (high energy efficiency) electric appliances. In the road transport sector, fuel efficiency is finally being applied to reduced energy consumption rather than more powerful vehicle performance.

A sequence of new technologies is cascading through the transport sector, with all electric vehicles already a mainstream technology, and hydrogen and methane power following. Last, but possibly the fastest moving, is the use of compressed air for both motive power and for energy storage.

Analysis

Examples of community-scale initiatives are explored in Chapter 12. It is clear that for Ōtaki, the development of a smart local electricity network is a key asset for de-risking and lifting the productivity of any area energy initiative. While the local electricity lines company Electra has protocols in place for distributed generation and local energy storage, the scale of Energise Ōtaki's goals will require direct collaboration with Electra for an effective configuration to be developed.

Chapter 13 highlights some trends in market conditions, and notes that any investment into renewable energy in Ōtaki, whether on an individual or a community scale, should be subject to appropriate due diligence. This study and report is only a scoping study, and should not be relied upon for investment purposes.

Technology Road Map

Should the Ōtaki community decide that it wishes to invest in renewable energy systems, even in the light of the market outlook and the uncertainties involved in dealing with new technology, a draft technology road map (TRM) is set out in Chapter 14. It is for negotiation & confirmation within the Ōtaki community. The adaptation of the Ōtaki sub-station lines network into a smart network is noted as a key element for any significant investment in renewable power generation. Coupled with that, Ōtaki is recommended to seriously investigate community-level power storage to reduce economic risk in renewable power investments.

Solar thermal & PV are the first renewable energy technologies recommended to be explored. Solar is a very strong relative resource endowment for Ōtaki. The solar PV installation can include more expansive installations on individual premises - beyond the needs of the occupants. It could also include a community scale solar PV farm to enable participation by those unable to install their own PV capacity whether by reason of site's orientation or non-ownership of an Ōtaki property.

The second area to be explored is that of a viable power equation for the treatment of bio waste streams. New technologies offer much improved economic performance, with shorter process times, smaller plant and cheaper operating costs. They also offer a clean water output that could be used within the area.

In the field of motive energy (fuels) the rate of innovation is particularly high at the present time.

There has been a long standing effort to generate bio fuels such as ethanol & biodiesel. Ethanol is well established in Brazil, but elsewhere has often continued to rely upon subsidies.

The game may have changed with the recent commercial scale up of the microorganism technology of Joule Unlimited.

This US based company uses modified microorganisms that directly secrete ethanol, diesel, and as of April 2013, gasoline and jet fuel. The technology uses sunlight, non-potable water and waste CO_2 to feed the microorganisms in a series of tube reactors.

The system delivers very high hydrocarbon production volumes at a cost ex their plants well below the equivalent of US$100/ barrel. The target is to get the delivered price to US$50/ barrel. This is a radically new low price point for bio drop-in fossil fuel replacements.

The cheapest unit of energy is the unit that doesn't have to be generated. Ōtaki must start with improving its energy efficiency, including the upgrading of existing infrastructure and equipment. Solar energy forms are the place for Ōtaki to commence its investment. The reasons are the new (wholesale) price competitiveness of solar technologies combined with Ōtaki's sunny location. A community scale generation site is recommended, accompanied by an electricity storage facility, and then wind turbine generation. Biomass generation of methane using waste materials is a major area for consideration. Motive energy for transport is a major demand vector in Ōtaki. Several areas to move the community towards motive energy efficiency are noted.

A number of alternative technologies are fast rising renewable energy competitors for motive power, including hydrogen fuel cells and compressed air power. Both electric vehicles and its competitors are rapidly advancing their technology and economic performance. It is expected that electric vehicles will be a medium term leader, together with drop-in replacement bio fuels, but that compressed air technologies which have an even simpler drive mechanism will ultimately take a larger role than these because of their exceptionally low capital & running costs.

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INTRODUCTION

This study was commissioned by the Kapiti Coast District Council (KCDC) as the first stage of a project to establish whether or not, using renewable energy only, the Ōtaki area could become an energy self-sufficient community, and if so, how? This report was prepared to provide a benchmark as to the present energy situation. It is also a scoping study to assess whether or not a self-sufficient vision is practical, and if so to indicate which technology choices available to Ōtaki might best fit its resource endowment and energy use patterns. Finally could a zero carbon footprint community attract new economic activity to the area?

KCDC has undertaken a number of initiatives in pursuit of this potential goal – it has established a Clean Technology Centre and Clean Technology Trust in Ōtaki. It has established a small solar PV demonstration unit at the Ōtaki library. In 2013 it procured an all-electric waste truck.

This study will prepare an energy use profile using existing data available from Statistics NZ and other reliable sources to establish a base line by which all measures to substitute fossil fuels with energy savings, improved energy efficiency and installation of renewable generation can be gauged. A preliminary overview will be made of the renewable technology options that might be available for Ōtaki. A few offerings within the different technology areas will be profiled, however, independent due diligence must be carried out before any investment is made, as the profiled providers are not the only candidates capable of providing a cost-effective solution in any particular energy form. In addition, there is a very fast pace of innovation in the renewable energy and intelligent efficiency markets. Combined with the excess capacity in a number of technology areas and the flow through to market prices, there appears to be a significant investment risk at present, however risk assessment is outside the scope of this study.

Technology options are to be reviewed in 3 timeframes – those commercially available now, those which will be commercial within a 2-year time frame, and those beyond this time dimension. Within the 2-year frame, there are a large number of options for moving Ōtaki towards being a net energy exporter. A few communities of similar size overseas have already achieved this goal, albeit with incentives and subsidies not available in NZ. These achievements will be briefly reviewed.

A Technology Road Map (TRM) will be prepared as a preliminary guide for Ōtaki policy-makers to consider in relation to developing an energy self-sufficient community. The TRM will largely focus on technologies available now or expected to be commercialised within 2 years and will identify the policy, network, generation, bio-energy and motive energy options which will most likely meet the requirements of the goal of becoming a net exporter of clean energy.

1 THE ŌTAKI AREA - ENERGY USE PROFILE

1.1 THE ŌTAKI AREA

Ōtaki is a small community of around 8,500 people within the Kapiti Coast District in Aotearoa New Zealand. Ōtaki lies on the West coast of the North Island, north-west of the capital city, Wellington. It has a long indigenous community history, most recently concerned with the displacement of the incumbent Rangitane and Muaupoko people by the Ngati Raukawa, Ngati Toarangatira & Te Ati Awa iwi under the leadership of chief Te Rauparaha from around 1819. Ōtaki has a nationally recognised treasure in its Maori marae, Raukawa and one of the nation's oldest & finest churches, Rangiatea.

The area is bounded by the Tararua ranges in the east and the Tasman Sea in the west, facing Kapiti Island. It is drained by the Ōtaki River. It is predominantly a farming and residential community.

The town has a population of 5,600. It is divided into 3 parts;

1. Ōtaki Beach, which is largely residential, part of it holiday properties
2. Ōtaki Township, inland from the beach, containing shops & residential areas, plus the Maori tertiary educational institution, Te Wananga o Raukawa
3. Ōtaki Railway, further inland, located on the North Island Main Trunk railway line & State Highway 1. Major transport fuel outlets and a sizable retail activity are located here.

The rural area made up of Ōtaki Forks, Te Horo and Kaitawa has a population of 2,900. Farming in Ōtaki has a strong component of market gardening for supply of fresh produce to the Greater Wellington urban area. A small industrial area is located on the banks of the Ōtaki River, to the south of the town. This area almost links the southern edges of Ōtaki Railway and Ōtaki Town.

The Ōtaki area thus has a population of 8,500, which makes up about 17% of the total population of the Kapiti Coast District – see Table 1.1 below. It is a ward within the Kapiti Coast District Council (KCDC), and is served by its own electric power substation as part of a wider district electric power lines network operated by Electra Ltd. Electra is a community owned company.

Table 1.1 Population of the Greater Ōtaki Area

	Ōtaki Area Unit	Ōtaki Forks Area	Te Horo Area Unit	Kaitawa Area Unit	Greater Ōtaki Region	Kapiti Coast TLA	Ōtaki/KC
2006 population	5,634	1,452	669	507	8,262	46,200	18%
2010 est	*5,638*	*1,543*	*717*	*580*	*8,478*	*49,400*	17%
2031 forecast	*6,485*	*1,338*	*807*	*561*	*9,191*	*60,900*	15%
no. households (occupied dwellings)	2,381	555	289	179	3,404	19,110	17%
av. Household size (#people)	2.3	2.6	2.3	2.7	2.46	2.3	

Source: Statistics NZ

1.2 ECONOMIC CHANGE

The Ōtaki Area has suffered some economic setbacks in recent times. Ōtaki's dairy factory closed some decades ago. A significant poultry processing plant has closed. More recently, a newly upgraded export abattoir closed. Partly offsetting these closures has been the establishment of Te Wananga o Raukawa, and some new primary processing industries including a winery, lavender & olive oil processors, a large cool storage/logistics facility and an acclaimed cooking school. Ōtaki Railway has established itself as the regional direct factory outlet for clothing & fashion manufacturers & distributors.

Overall, Ōtaki has seen a shift in its industrial structure from primary processing to specialty foods and service-based employment. A new threat is the proposed Ōtaki by-pass of the state highway.

The changing economic circumstances of the Ōtaki area have prompted the KCDC to undertake some initiatives to further the renewal & development of the local economy. These include:

1. Establishment of a Clean Technology Centre (CTC) in the riverside industrial estate with a local property developer
2. Trial installation of solar PV panels on the local library
3. Development of solar heating and other energy-saving initiatives at the swimming pool;
4. Establishment in 2011 of a local action group, Energise Ōtaki, to explore the potential role of renewable energy technologies in providing a new economic dimension for the community. This has translated into a goal of making the Ōtaki area a net exporter of (renewable) energy.
5. The formation of a Clean Technology Trust to form a technology incubator and revolving investment fund for businesses scaling up new clean technologies
6. Ordering an electric powered waste collection truck from a member firm of the CTC.
7. Initiating a project to replace street lighting with new LED lighting technology to reduce the energy and maintenance requirements of street lighting.

Transition Town Ōtaki, a community-led network has also formed to focus the area on revitalising the local economy and make the shift to lower energy lifestyles. Their aim is to build a healthier, more resourceful, more self-reliant community.

1.3 ENERGY USE IN ŌTAKI

Energy is typically measured in joules (J). Electric power is measured in terms of watts (W) supplied over a time period, hours (h). Thus the standard electric unit, kWh is a measure of the amount of power being used and the time period of use. A 100kW electric motor operating for 1 hour consumes 100 kWh, and for 2 hours, 200 kWh. Quantities are measured in powers of 10, with:

kilo	k	thousand	10^3	kilowatt	kW
mega	M	million	10^6	megajoule	MJ
giga	G	billion	10^9	gigawatt hours	GWh
tera	T	trillion	10^{12}	terajoule	TJ
peta	P	quadrillion	10^{15}	petajoule	PJ

Energy delivered to resident households, farms & businesses in Ōtaki in 2007 is estimated to have totalled 596 TJ. This supply generated 222 TJ of effective energy for these customers. The energy supplied by type is set out in Table 1.2 below.

Most consumers do not deal in energy measured in joules, so they have little awareness of the economic value of energy measured on this scale. In order to provide a ready relationship with market values, we have converted all units into watts. Thus, Ōtaki residents received 161.0 GWh of energy on the equivalent power measure, and secured 60.1 GWh of effective energy use.

Expressing energy in kWh equivalents is not typical industry practice, but all measures of energy in the text will also have the joule equivalent presented. For purposes of conversion;

1 kWh	3.6×10^{6} J	or	3.6MJ
1 TWh	3.6×10^{15} J		3.6PJ
1 litre of petrol (L)			32.0MJ
1 cubic metre of natural gas	1 m^3 @ standard temperature & pressure		34.0MJ

Table 1.2 Ōtaki Area
Estimated Composition of Energy Supply & Effective Use, 2007
GWh equivalents

Energy type	Quantity supplied	Effective use	Efficiency	% Supplied	% Used
Coal	4.62	2.43	52.6%	2.9	4.0
Diesel	30.96	4.85	15.7%	19.2	8.1
Electricity	40.50	31.26	77.2%	25.1	52.1
Fuel oil	0.15	0.09	60.0%	0.1	0.1
LPG	2.81	1.42	50.5%	1.7	2.4
Natural gas	15.75	10.19	64.7%	9.8	17.0
Petroleum	55.57	6.86	12.3%	34.6	11.4
Solar photo voltaic	..	..			
Solar thermal	0.14	0.14	100.0%	0.1	0.2
Wind turbine	..	..			
Wood	10.47	2.82	26.9%	6.5	4.7
Total	**160.98**	**60.05**	**(Avg) 37.3%**	**100.0**	**100.0**

Note: Effective energy use is defined as end-use energy available as a proportion of energy delivered.
The equivalent measures in joules for energy supplied & effectively used are 596 and 222 TJ.

Sources:
Statistics NZ, various household & business surveys.
Ministry of Economic Development, Energy Data File.
Energy Efficiency & Conservation Authority, databases.
Green Chip, area estimates & reconciliations.

Four energy sources dominate the Ōtaki area energy usage profile – petrol, electricity, diesel & natural gas. Collectively, these 4 sources provide 89% of effective energy delivered. A solid energy, wood for home heating, is the next largest (only 6.5%).

The energy profile for Ōtaki shows a high dependency upon fossil fuels. Ōtaki sourced 68% of its energy from fossil fuels in 2007. The other major energy source is electricity, providing 25% of the total intake. Electricity is supplied from the national grid via the local line company, Electra. In New Zealand, electricity is predominantly generated from renewable energy sources, including hydro, geothermal & wind turbines.

It is interesting to note that, while considered a mainstream power technology today, wind turbine generation did not register as an energy source within the Ōtaki area in 2007. The area is exposed to the north westerly weather pattern and does have some possibly viable sites. These issues are canvassed further in the technology profiles discussed below in Chapter 4.

Similarly, while solar thermal heating was becoming established, albeit as the smallest energy source for the Ōtaki area, solar PV also did not register as an energy source in 2007. Project on site visits do not identify a significant investment in solar PV even in late 2012, when local installers were reporting a real 8% return on investment for the technology.

Table 1.2 also highlights the significant utilisation wedge that exists for transport fuels. There is a very low capture of effective use of some fuels, especially diesel & petrol at 15.7% & 12.3% respectively. The efficiency of conversion through internal combustion engines is very low, with much of the energy input being lost through heat generation & its ineffective transfer to the environment. Significant advances have been made in the energy efficiency of internal combustion engines since 2007, but this application would remain the most significant source of energy loss in Ōtaki along with wood fuelled open fires for home space heating.

In total, the low efficiency of transport fuels transforms the composition of effective energy use within the Ōtaki area. Electricity provides the majority of effective energy use – 52%. The other significant energy types effectively used were natural gas (17%) and petrol (11%).

In part the average energy efficiency within the Ōtaki area (37%) reflects the current residential population and the limited commercial & industrial activity in the area. A consolidated profile of effective energy use by major sector in Ōtaki is set out in Table 1.3 below. The same data is set out in Figure 1.1, including the proportions for energy supplied.

Table 1.3 Ōtaki Area
Energy Intake by Major Sector, 2007

Sector	% of total
Primary sector total	4
Industrial & trade sector total	35
Services sector (public & private)	5
Households	56
TOTAL, Ōtaki	**100**

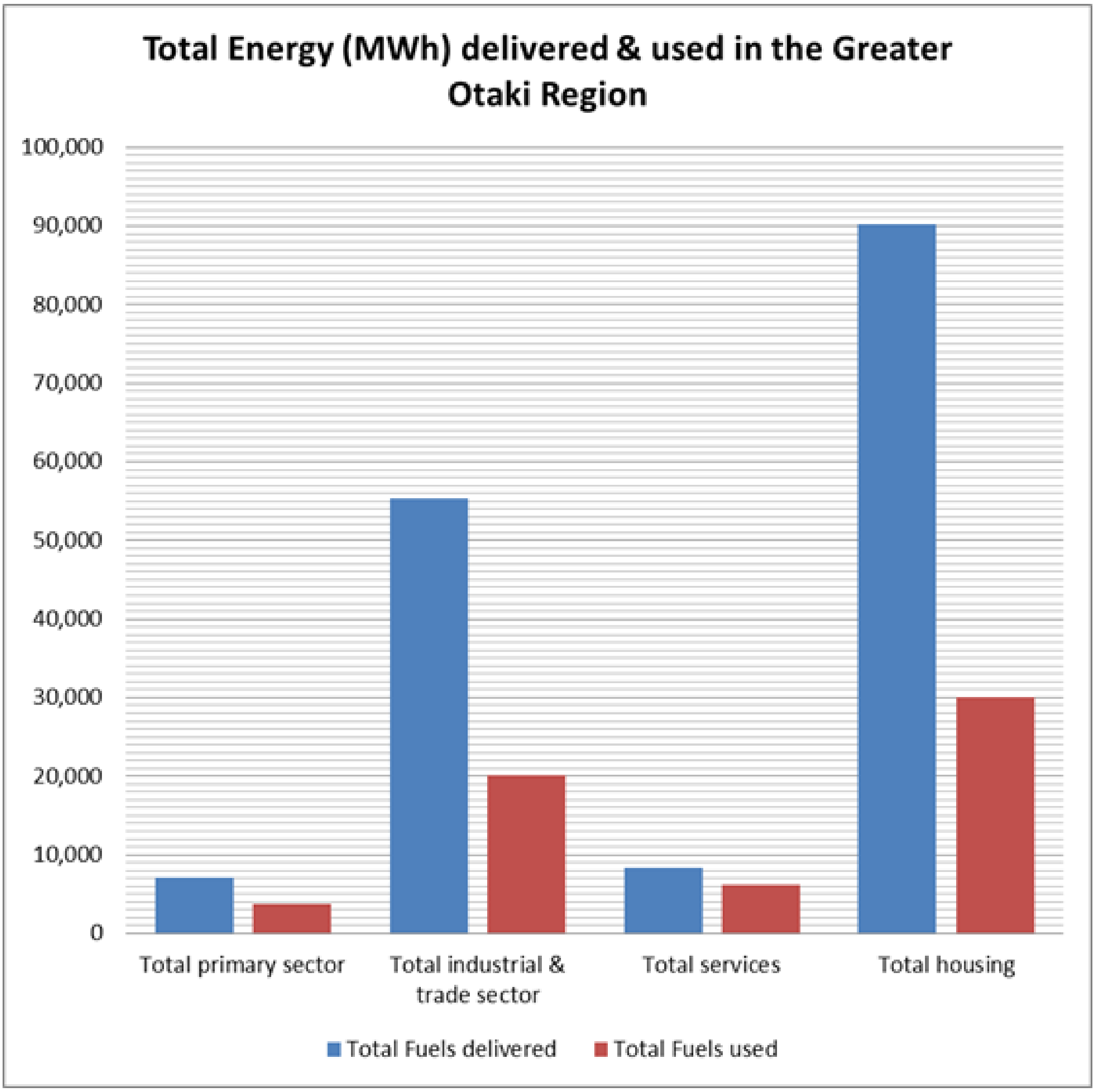
Notes & sources – refer to Table 1.2 above.

More detailed data on energy use patterns is provided in Table 1.4 & Figure 1.2 below. The major features of this material are:

1. Households take 56% of all energy used in the region and are the largest group-user of electricity (58%). The majority of household energy use is liquid fuels for private transport.
   i. Transport fuels account for 63% of household energy use.
   ii. Electricity provides 26% of household energy use, and of that, the majority (one third) is used for water heating.
   iii. Only 27 Ōtaki dwellings used solar thermal for water heating in 2007. The predominant use of coal & wood is for space heating in open fires and wood burners.
2. Industrial & Trade Sectors: This sector is the second largest user of energy in Ōtaki, taking 35%. Manufacturing is the largest, accounting for 15% of the area total. Manufacturing is the largest user of natural gas, with 46% being used in boilers and burners.
3. Services: The services sector uses a minor proportion of the area's energy use – 5%. Education, finance/real estate and local government are the major users, and electricity and natural gas the predominant fuels.
4. Primary: Again, primary is a small part of the area's energy profile at 4%. Of significance is indoor cropping, which accounts for 50% of the primary sector energy use (sourced from coal and natural gas).

Figure 1.1 highlights again the wide wedge between energy supplied and effective end use. The largest source of energy loss is the household sector, where efficiency is only 33%. In part, this reflects the heavy reliance upon private vehicles for transport within the Ōtaki community. In turn, that reflects the design of the urban space, community lifestyles and the limited availability of public transport in the area. However, the operation of a viable public transport service is difficult in an area such as Ōtaki, which has a relatively small population, and a wide geographic residential footprint.

Figure 1.1 Ōtaki Area
Comparison of Energy Supplied & Effective Use, by Major Sector, 2007



Notes & sources – refer to Table 1.2

Another factor is the demand for home heating. In large part, Ōtaki has an elderly housing stock, and such units are not well insulated for low winter temperatures. Retrofitting such capacity is relatively capital intensive. Raising the necessary capital to pay for refits and upgrades is not easily secured for many households in the Ōtaki area, even where the lifetime economics of the investment is strongly positive.

Table 1.4 Ōtaki Area
Efficiency of Energy Use by Type & Major Sector, 2007

% of energy delivered

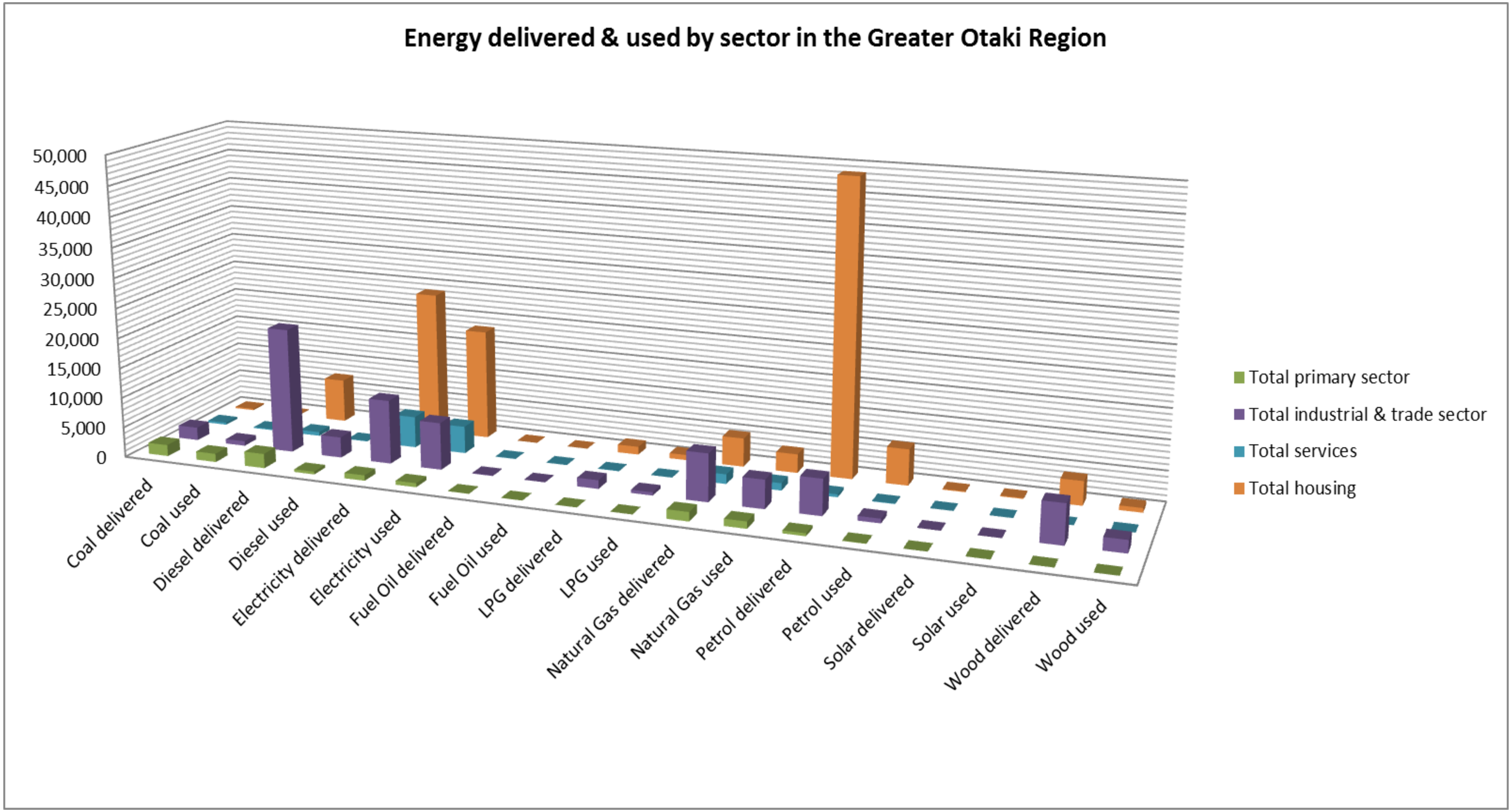
Energy type	Primary	Industry & Trade	Services	Households	**Total**
Coal	75	36	53	33	**59**
Wood		32		19	**27**
Fuel oil	68	48	69		**59**
Diesel	19	17	16	12	**16**
Petroleum	14	13	15	12	**12**
LPG		37	28	66	**50**
Natural gas	76	60	76	65	**66**
Solar thermal				100	**100**
Electricity	75	74	87	77	**77**
AVERAGE	**52**	**36**	**73**	**33**	**37**

Notes & sources – refer to Table 1.2.

The data in Table 1.4 gives greater detail on the efficiency of different energy types as deployed in the Ōtaki Area. Of the major energy types, electricity and natural gas are the standouts in efficiency terms, at 77% & 66% respectively. The next most efficient are the heavy fossil fuels – coal & fuel oil at 59%.

In contrast, transport fuels registered very low efficiency levels in effective use terms – under 20%. Savings in private transport, and facilitating the take up of alternative, more efficient transport technologies must therefore become a key element in the development of an energy strategy for the Ōtaki area.

Figure 1.2 Ōtaki Area
Type of Energy Delivered & Effective Use by Major Sector, 2007



Notes & sources – refer to Table 1.2

Table 1.5 Electra Ltd
Electric Power Supplied through the Ōtaki Sub-Station & Network, 2005 – 2012

	2005	2006	2007	2008	2009	2010	2011	2012
GWh supplied to Ōtaki area	38.8	38.5	40.6	40.3	39.9	41.6	41.1	41.3
Max demand, MW	91	92	98	97	90	94	94	104
Avg Sales per Consumer, KWh	9,731	9,513	9,934	9,698	9,561	9,859	9,667	9,701

Source: Electra Ltd, Annual Reports. Ōtaki area 10% of total Electra network.

Electricity supplied to clients in the Ōtaki area through the Electra lines network is not growing. Total supply peaked in 2010 at 41.6 GWh. Average supply per consumer is the same at the end of the 8 year period as it was at the beginning in 2005. At the same time, maximum demand in this network has increased steadily, from 91 to 104 MW. This data indicates an increasing effort by clients to manage their electricity demand.

Table 1.6 Ōtaki Area Dwellings
Fuel Sources Utilised, 2007

	No of dwellings	% of dwellings
Electricity	3,391	99.6
Mains Gas	1,189	34.9
Bottled Gas	937	27.5
Wood	1,395	41.0
Coal	168	4.9
Solar Power (thermal)	34	1.0
Other Fuel(s)	54	1.6
No Fuels Used in this Dwelling	72	2.1
Not Elsewhere Included	162	4.8
Total dwellings	**3,404**	

Source: Statistics NZ, Kapiti Coast District Council, MED survey.

Private occupied dwellings in which more than one fuel type was used have been counted in each stated category. Therefore the total number of responses in the table is greater than the total number of private occupied dwellings.

Not Elsewhere Included includes Response Unidentifiable and Not Stated.

Electricity is the dominant energy source for Ōtaki area dwellings, being supplied to nearly all dwellings in 2007. The next largest energy source was wood at 41%, and mains gas 35%.

Bottled gas is the other major energy source utilised by the community. The informal energy sources and nil returns indicate that a significant holiday home element remains a feature of the area.

Table 1.7 below explores energy use patterns within the region in further detail with respect to appliances & heating.

Table 1.7 Otaki Area & Households
Estimated Composition of Energy Use by Technology, 2007
MWh equivalents

	Total Ōtaki Area		**Households**	
Technology type	**Intake**	**Efficiency**	**Intake**	**Efficiency**
Burner (Direct Heat)	5289.7	66%	4,251.7	64%
Clothes Dryer	440.4	25%	440.4	25%
Cooking Elements	15.3	44%		
Cooking Ovens	2,862.2	35%	2340.7	37%
Electric Furnace	250.0	58%		
Electric Motor	4,977.1	75%	165.0	75%
Electronics	5,178.0	92%	4,280.0	90%
Furnace/Kiln	5,633.1	43%		
Heat Pump Cooling)	668.5	185%	14.1	200%
Heat Pump (Heating)	1,065.1	200%	330.6	200%
Hot Water Cylinder	11,353.3	84%	10,338.0	84%
Industrial Ovens	181.9	52%		
Internal Combustion (Lawnmower)	734.6	30%	734.6	30%
Internal Combustion Engine (Land Transport)	85,532.0	13%	55,495.3	12%
Lights	5,470.1	9%	2,884.1	7%
Open Fire	2,456.1	11%	2456.1	11%
Open Fire, with Wetback	291.8	40%	291.8	40%
Pump Systems (for Fluids, etc.)	1,789.5	75%		
Refrigeration Systems	6,070.2	80%	3,674.4	85%
Resistance Heater	3,979.8	100%	2,463.9	100%
Stationary Engine	827.9	29%		
Total (MWh)	**160,976**	**(Avg) 37%**	**90,161**	**(Avg) 33%**

Notes & sources – refer to Table 1.2.

The standout feature of Table 1.7 is again the dominance of energy intake for internal combustion engines in the Ōtaki area's energy mix, and the private household's dominant share of that. Households consume 65% of liquid transport fuels. Combined with its very low energy efficiency, private motoring must be a central part of the area's response to its energy goals.

The second major energy use is electric power for hot water cylinders, accounting for 7% of the total energy intake. Again, households are the dominant user, in this case representing more than 90% of this energy demand.

Lighting accounts for 14% of the region's power consumption with 5,470MWh used annually. However, only 9% is used. The rest is lost as heat. There is approximately 80kW of installed streetlight load in Greater Otaki and approximately 1000 street lights

Table 1.8 Otaki Area Lighting

Total Lighting (MWH/yr)	retail	households	street	Industrial & trade
5470	479*	2884	520	284
	9%	53%	10%	5%

* Retail strip on SH1 consumes 370MWh/yr

Notes & sources – refer to Table 1.2 &

KCDC correspondence

Quinten Heap, 2011, "Opportunities in Otaki for improved energy efficiency in retail lighting and its offsetting through renewable Resource"

The other significant energy demands are for residential space heating 5%, and refrigeration 4% of energy intake in 2007. Electronic equipment such as TV's, computers etc was the other material use, at 3%.

2 ENERGY ISSUES FOR A SELF-RELIANT ŌTAKI COMMUNITY

2.1 CHALLENGES & PRIORITIES

The data from the tables in Section (1) show that the Ōtaki area only has a single source of energy generation from its own resources – wood. This comes in the form of informal woodlots on some of the area's farms and lifestyle blocks, and some from commercial suppliers from plantation forests. Table 1.2 shows that wood supplied 6.5% of the areas total energy intake in 2007.

KCDC's vision for a sustainable Ōtaki therefore involves a 93.5% reduction/ own production target.

A target of this magnitude poses significant challenges. In 2007, electricity was the major effective energy use within the area (52%) and a heavy reliance upon private transport for travel saw the community source a high proportion of its energy supply from inefficient use of fossil fuels.

Households are the largest energy users in Ōtaki – 57% of the total. Thus, realising the vision will require engagement with the residential community, an activity already commenced with the establishment of the Energise Ōtaki process. This relationship could provide a vital contribution to the Council's implementation of its vision.

In 2007, Ōtaki was not producing significant amounts of energy from within its residential & business communities. As the data indicates, the challenge then is to first adopt minimisation strategies such as conservation (eg insulation of existing homes). Then, the potential to replace/improve energy use with new technologies should be explored, especially those relating to household and transport fuels, plus the equally inefficient use of open fires for residence space heating.

It is possible for KCDC to continue with its pioneering role in the introduction and demonstration of new technologies and practices in energy management. KCDC has already shown this leadership in the actions taken to date. The Council's own purchasing practices and infrastructure provision may be particularly significant.

At this stage of the project, the 93.5% reduction/ own production target is a high challenge in relation to the area's resources. Even if Ōtaki could produce energy equivalent to its own demand or greater, it seems unlikely that the mix of resource endowments of Ōtaki would enable it to match the profile of its energy supply needs. Therefore, the community could concentrate on a few technologies, and trade surplus output for other energy forms, such as electricity, that it could import from elsewhere, whether or not it has met the 95% target.

Table 2.1 below summarises these target areas and reasons for choosing them. Sections 6, 7 & 8 will explore the potential alternatives to address these issues in more detail.

Table 2.1 Priority areas for reducing the Ōtaki area's energy net intake

Target	Options to address
Electricity	Whilst electricity is relatively efficient, to become sustainable, Ōtaki must seek to reduce electrical demand in areas where energy demand is high, such as space & water heating & appliance use.
Liquid Transport fuels	Petrol and diesel use comprises the majority of fossil fuel demand (78%). This is predominantly used for local transport which has the lowest utilisation efficiencies.
Wood	Wood was primarily used in space heating, providing 6.5% of energy intake in the Ōtaki area. Wood was utilised by 32% of Ōtaki residences. While wood-fired burners offer high efficiency (<75%) the efficiency of wood in open fires is very low at 15%[1].
Bio waste to gas &/ or liquid fuels	The Ōtaki community generates a significant amount of bio waste that could be processed into energy, if economics warranted. The bio streams include human effluent; reject horticultural produce and forest harvest waste.

2.2 ENDOWMENT FOR GENERATION OF RENEWABLE ENERGY

Ōtaki's primary renewable energy resource endowment is solar. The area is located within the – Nelson/ Marlborough/ Kapiti/ Wairarapa climate zone, the sunniest in NZ. This provides a decided orientation towards solar PV and solar thermal technologies, neither of which had made any significant market penetration within the Ōtaki area in 2007.

There are a number of new energy start ups that are utilising sunlight and CO_2 to generate biomass for processing into energy. A new one, Joule Unlimited, has announced the direct production of fuels from sunlight, CO2 & non-potable water. Here again, Ōtaki's sunny location would give it a strong advantage, provided that there are sites available that have limited food production potential. Ōtaki does have some low fertility land that could be a candidate for such use.

Despite its west coast location between 2 of NZ's windiest cities, Palmerston North & Wellington, Ōtaki does not have the same high wind energy potential rating, as it lies in the wind shadow of Kapiti Island. Thus it will be more difficult to find economic sites for the deployment of wind turbine energy than in other areas of NZ.

Ōtaki has a relatively long coast line, but again lies in the protective shadow of Kapiti Island. This limits wave energy for the area. The coastal geography provides little potential capturing the energy of tidal currents.

A second strong resource for renewable energy in the Ōtaki area is bio mass. The area has some plantation forests and woodlots that offer firewood and wood pellet opportunities. Ōtaki is a major

[1] Retrofit interventions to enable healthy living conditions in existing New Zealand houses, July 2009, University of Otago. http://www.energywise.govt.nz/sites/all/files/retrofit-interventions-report-07-09.pdf

market gardening area, with the potential for recovery of biomass waste streams for energy production. There is also the potential for the treatment animal and human effluent for biogas generation and recovery of clean water.

3 INTERNATIONAL INITIATIVES FOR SUSTAINABLE ENERGY COMMUNITIES

3.1 AUSTRALIA

Australia has a good renewable energy endowment with extended seasons of long sunshine hours in most states, a huge, lightly populated hinterland and good wind sites, especially in the south and west. The nation is becoming increasingly aware and responsive to the case for a green economy and the contribution that renewable energy can make to that. Responding to government incentives and onerous energy pricing, Australia now has more than 1 million solar PV installations.

3.2 AUSTRIA

Austrian town Gussing, population 4,000, created international attention with its decision in 1992 to stop all civic buildings from purchasing fossil fuels. At the time, the town was under financial stress, economically challenged, and losing its young people. Located on the border with Eastern Europe, its trade had been badly curtailed. The measure was taken in order to reduce the town's cost structure and its economic outlook.

Payments for deliveries of fossil fuel of €6m pa were seen as a major external payment that was a significant handicap to the prosperity of the town & the region. Could the region produce replacement energy and sell it to its own users?

Energy use in Gussing was optimised, and expenditure on fossil fuel fell by 50%. Then energy efficiency and low carbon energy initiatives followed:

1. a district home heating plant for 27 homes burning chipped local wood
2. a rapeseed processing plant producing car fuel
3. a wood gasifier to fire an electricity generator and feed the 'waste' heat into the district hot water system. The plant achieved an energy efficiency of 85%.

The investments have continued, and Gussing County now has 27 decentralised generating plants and an energy "turnover" in excess of €14m. The technologies in the county include biogas generation, a solar cell manufacturer and a green biomass gasification plant. Wood harvest for local generation is less than half of the annual of the annual forest growth. The area has enjoyed the establishment of more than 50 enterprises and the creation of more than 1,000 new jobs, direct & indirect. So successful has Gussing's strategy been that it is now referred to as the "Gussing model".

The success of the county has been such that a related industry has emerged – eco-tourism. The accommodation sector has moved to adopt renewable energy sources. The town also became the base for the European Centre for Renewable Energy, which was formed in 1996.

3.2 DENMARK

Denmark generates 20% of its electricity from wind turbines. This capacity was built in response to substantial tax credits, which are now being phased out. As a first mover in wind generating strategies, Denmark has been able to build a significant international market in wind turbine technology. Its leading company, Vestas, supplies around 33% of the world's wind turbines.

On stormy days, Denmark can meet all of its power demand from wind and more. The improving performance and durability of wind turbines combined with increased efficiency means that turbine shut downs are now only needed for extreme storm conditions.

3.2.1 Samsoe

Samsoe is a Danish island with a population of 4,200. Traditionally it was 100% dependent upon petroleum and coal-fired electricity from the Danish grid. Starting from a bench line of 11 tonnes of CO_2 emission to the atmosphere per person pa in 1998, Samsoe became carbon neutral in 2005, and by 2012 they were carbon negative – exporting more energy than they consumed.

The technologies exploited to secure this massive turn around were:

1. home insulation
2. new windows
3. 11 1-MW wind turbines plus many household turbines, mostly cooperatively owned
4. another 10 large 2.3-MW wind turbines built at sea to provide a carbon offset for gas & diesel fuels used in farming
5. solar panels
6. closed wood burners
7. biomethane produced from anaerobic biodigesters.

The island is also participating in Government programmes to switch transportation to electric vehicles, including the building of a network of charging stations.

3.2.2 Bornholm

Borhnholm is another Danish island in the Baltic Sea. It has a population of 13,900, and has significant wind turbine and biomethane production capacity.

Bornholm is leading an experiment in "vehicle-to-grid" power storage. Parked electric vehicles will act as a storage device for excess electricity produced on the island. When the weather is calm & no wind energy is being generated, electricity flows back into the grid, reducing the need for coal-fired power. Denmark estimates that it would need only 400,000 electric vehicles used in this manner to provide backup storage for its 5,200 wind turbines.

3.2.3 Copenhagen

Copenhagen is one of many cities globally that is using district heating generation facilities in order to exploit the advantages of combined heat & power generation. It aims to supply heat to virtually all its homes by 2025. Copenhagen intends that these plants will be fired by biomass.

3.3 GERMANY

3.3.1 Schönau, Germany – A Community Led Initiative

Schönau is a town in the Black Forest region of Germany. It has a population of 2,441 (2008) in a 14.7 km² area. In 1986 (just after Chernobyl nuclear disaster and the clean up from the fall-out in Germany), the residents of Schönau began an anti-nuclear movement – Parents for a Nuclear Free Future – a club to replace nuclear power in their town. While initially focusing upon energy efficiency through energy saving contests eg (the lowest power bill), the civic action group realised that energy production was the key step for eliminating nuclear energy purchases. They commenced negotiations with KWR, the regional energy monopoly and the town's energy supplier and network owner. The group wanted to finance and install renewable energy generating capacity in their district, hoping to use the local lines network to feed the renewable energy to Schönau's citizens.

KWR's 20 year license to supply Schönau was due for renewal in 1991, and it did not share the renewable energy aspirations of the local people, and worked to frustrate them. It tried to entice the town to conclude an early renewal of the 20 year supply contract in 1990 - without any environmental provisions - by offering a 100,000 deutschmark incentive for a quick deal. In order to keep the city from signing the contract, the citizens decided to raise the same money themselves. They raised 100,000 deutschmarks within just a few weeks, with a lot of support from outside the district.

This was the beginning of a battle with local and central government and KWR, to purchase their local electricity distribution network plus the contract to the grid. Schönau Power Supply (Elektrizitätswerke Schönau or EWS) was established in 1994 as an independent, decentralized, locally owned energy supply coop company for Schönau with 650 members. In 1999, EWS began the nationwide promotion of environmentally and sustainable electric power generation across Germany.

Based on the financial records of KWR, EWS estimated the value of the Schönau network at 4m deutschmarks, but KWR valued them at a staggering 8.7m marks and challenged EWS to find the money. In the face of national vitriol, KWR revised the price to 5.7m marks. Rather than appeal the purchase price and risk getting held up in court for another 10 years, EWS paid the revised amount. Four million marks came from 650 citizens (now the cooperative owners) backed by a supportive local bank. The "Schönau energy fund" raised a further 2 million marks through a spectacularly successful nationwide fundraising campaign. Major environmental groups such as Greenpeace, WWF and the Association for the Environment and Nature Conservation called for donations. Newspapers published free ads and private parties waived gifts in favour of donations for EWS. It only took a few months to get the additional needed money together.

EWS believes the future of electricity generation and distribution is a key social role**.** They therefore buy exclusively from independent producers, either locally owned small power generation plants or large ecologically oriented hydro power plants ***provided that*** they have **no equity stakes in nuclear power plant operations** or their subsidiaries.

Ecology is EWS' prime driver. Thus, avoiding harmful emissions is a critical goal. EWS' current energy mix therefore also contains **no coal fired electric power**. EWS is committed to a responsible use of energy and support efficient power generation and energy-efficient consumption technologies. Initial generation was with micro hydro schemes, wind turbines and combined heat and power plants.

EWS is a cooperative, owned exclusively by residents of the town. A Supervisory Board oversees the guidelines and objectives for the operating companies of EWS. These are divided into four legally independent companies:

1. The Elektrizitätswerke Schönau Vertriebs GmbH, responsible for electricity and gas distribution
2. Electricity Networks Schönau GmbH which operates the Schönauer electricity and gas network and other networks outside the local area Schönau
3. The Elektrizitätswerke Schönau Direkt GmbH, responsible for the marketing of electricity from renewable energy plants,
4. Schönau Energy for the construction and operation of power generation facilities.

Thanks to attractive feed-in tariffs and civic commitment, the closed EWS network was created.

The majority of EWS power is derived from solar energy. The largest community facility is on the roof of the Protestant church, with a generating capacity of 51.5 kW (known as the "Schonauer creation window"). There are also PV systems on the roof of the high school, generating 9.66KW.

EWS originally provided 1m kWh to 1,700 local customers. Today it has 1,830 shareholders, supplies 400m kWh to 130,000 electricity customers throughout Germany and gas to 8,300 customers in southern Germany.

Table 3.1 Schönau Energy Production

Energy Type	No of Plants	Production (kW)
Solar Photo Voltaics	116	922
Combined heat and power	13	95
Hydropower	5	370
Wind	1	2,000
Sewage	1	50

EWS actively promotes the establishment of new ecological power generation plants through the raising of Sonnencents, or sun cents. Included in the tariff that EWS customers pay, the sun cents finance new renewable energy capacity in Germany, including wind turbines & solar PV – known in Germany as "rebel power stations". EWS also assists other communities to form cooperatives to purchase and operate their local lines networks according to their renewable energy conviction.

Policy Environment

In 1998, EU requirements were implemented in German deregulating the electricity market. Each electricity customer in Germany had the right to decide where s/he gets their power. In 2000 feed-in tariffs were introduced, subsidising green energy generation. Tens of thousands of homes and hundreds of companies switched to the EWS.

Today, more and more people in Germany are opting away from nuclear-energy (8 of the 16 nuclear plants have shut down) towards ecological energy supply. At a national level, there were periods of daylight last summer when over 50% of Germany's power output was solar-generated.

3.3.2 Munich

The city of Munich plans to meet all of its electricity for renewables by 2025. It will meet this by building local generating capacity and supplementing it by out-of-city capacity ownership. The local capacity will be a mix of hydro, solar PV, geothermal, biomass, biofuels, and biogas. Munich also aims to participate in German solar PV farms in Saxony and Bavaria, plus Spain, and in wind farms in the North Sea.

3.4 ITALY

3.4.1 Green Mountain Communities

Lifestyle changes in Italy have seen the population of mountain communities decline, despite the efforts of their citizens, provinces, regions and the state. Further, even where the properties are occupied, people are reluctant to live in them through the winter snows. As their power lines age, the cost of renewal is no longer viable given the low base load and wide variation in use between summer and winter. The communities must find a new solution for their energy.

Adding to the communities' challenges are rising standards for water discharge & quality. Run off from farming is leading to poor downstream water conditions. The communities are now being challenged to improve their farm practices and animal husbandry from an ecological as well as an animal health perspective.

The response to these challenges has been to form an association to research the technology options available to enable these communities to become self sufficient for energy and to provide a framework for the installation, management and servicing of the plant. Care was taken to ensure that a full range of technologists were enrolled and skilled in these activities. State sponsored projects to benchmark the villages and their energy use, and to trial alternative solutions are now in progress.

3.4.2 Biomethane Transport Fuel

Italy has been a leader in the use of biomethane in transport. It was the first to authorise its use, and its methane/ natural gas fleet represents some 50% of all such vehicles in Europe. Italian biogas plants and output have accelerated sharply since 2006/07. The country now has over 900 CNG filling stations, more than any other country.

Italian car manufacturer Fiat is an acknowledged global leader in the manufacture of CNG & biomethane fuelled cars. In 2012, Italy sold some 160,000 natural gas vehicles, compared with around 30,000 in Sweden and 20,000 in the US.

Fuel cost savings for natural gas are very large in Italy, being 60% compared with an equivalent petrol engine and 33% compared with the diesel version. This reflects the much lower taxes on natural gas fuels.

3.5 JAPAN SMART ENERGY POLICY

Japan is developing a national "Green Energy Policy". It envisages a phasing out of nuclear power and a 30% share of renewables power generation by 2030, although the new government is expressing concerns as to the affordability of this. The largest contributor to the renewable energy generation by 2020 will be solar PV (33GW capacity, or 68% of total renewables). The city of Fukushima is targeting 100% renewable power generation by 2040.

As part of its plans, Japan is moving to ensure that every home has a smart meter that will permit the development and management of a smart national grid and an intelligent household demand response regime. Smart community demonstration projects are in progress in Yokohama, Toyota, Keihanna & Kitakyushu.

The International Energy Agency is working with the Tohoku region in the re-build after the 2011 earthquake & tsunami. The building of solar farms and co-generation sites is intended to act as an exemplar for the nation. The plans include the goal of energy self sufficiency and makes provision for power back-up. It is planned that the community will incorporate biofuels & the recovery of industrial waste heat in its smart city design.

3.6 NETHERLANDS

The Netherlands has long promoted the concept of bicycles for travel & recreation. With its flat topography, this has become a feature of the lifestyle. The rejuvenation of cycling is discussed further in the following chapter.

Amsterdam has just directed that all new building developments form 2015 be "energy neutral". This reflects a new trend in local government and city planning away from the traditional focus upon "percentage savings" goals for efficient buildings to goals of "near-zero" & "net-zero". The equation includes on-site renewable energy generation.

3.7 SWEDEN - A BIOMETHANE-NATURAL GAS CONFIGURATION

Sweden is regarded as the European champion in biomethane technology. It commenced production of biogas from waste water treatment plants in the 1960s, originally in an attempt to reduce sludge volumes. The first oil price shock of the early 1970s led to a change in thinking towards reducing dependency upon oil, and also towards reducing environmental impacts. Sugar refineries and pulp mills started to use anaerobic digestion in the 1970s, for waste water purification and adoption of the technology continued in subsequent decades.

The Swedish Biogas Association reports that biogases are largely used at the production site in Sweden. A combined heat & power installation is the most profitable configuration if the heat & electricity can be used on site. Upgrading biogas to vehicle fuel quality requires relatively large investments, but the demand for such gas is rising steadily.

Swedish sewage treatment plants are at a scale where such upgrading is economically viable. This is easier done if the feedstock sewage is not contaminated by heavy metals, or residues of medicines & pesticides.

Sweden has more than 150 public fuelling stations on its highways, and more than a dozen cities where the bus fleets operate solely upon biomethane. Biogas, with the CO_2 removed to achieve a methane content of 97% can be used as a vehicle fuel alternative to petrol & diesel in modified gasoline or diesel engines. German & Swedish companies now offer "dual fuel engines" which can use either or both diesel & gas. The CO_2 can be removed by a water wash or cryogenic separation. Sweden has more than 40 plants doing this. Sweden is now pioneering the large scale production of biomethane from forest industry waste.

The standout feature of the Swedish system is the integration of natural gas and biomethane into a single natural gas grid. Remote sites are supplied with tank trailers, with full tanks of liquid natural gas being exchanged for empties. Biomethane now accounts for 60% of all natural gas used by the Swedish vehicle fleet.

Swedish motor vehicle manufacturer Volvo offers natural gas powered buses, and Volvo trucks now offers diesel-methane powered trucks with both CNG & LNG filling. Volvo ceased production of CNG cars in 2007, but renewed production in 2009 through a contract partner.

3.8 UNITED KINGDOM

3.8.1 Cambridge 2030

Cambridge 2030 is a grass roots initiative established in 2010. It is comprised of concerned citizens who have aspirations for the building of a vibrant regional community and rural & urban space over the coming 20 years. It is a voluntary group comprised of active professionals and advisors who have selected expertise to bring to the conversation. The goal is to synthesise an easily understood and integrated vision for the region to form the basis of informed and complementary action.
http://cambridgeppf.org/vision/about.shtml

Cambridge city has a population of around 130,000 and is located 80km north of London. The city's university, established in 1209, has international renown. The central city area is a key tourist destination in the UK, with many university colleges, fields and the river Cam. The central city retains a human scale dimension with lanes and parks and cycle trails, but population & urban expansion place this environment under pressure. A second university is based in Cambridge today, Anglia Ruskin University (previously Anglia Polytech).

In recent decades a high technology industrial activity has established itself around the city specialising in bioscience and IT technologies. The city now has a respected role as a centre of successful innovation. As a result of its academic and industrial growth, the region faces increasing population pressures and urban encroachment into rural areas. Cambridge's road network is now highly congested.

In response to these pressures, the city council has installed a guided bus way with a separate right of way/ corridor. There are 5 park and ride stations on the periphery to prevent the bringing of visitors' & commuters' cars into the city. This system operates 7 days per week. It has been very successful, requiring successive expansion. The service has now been extended to include services between Cambridge and St Ives & Huntingdon. In 2012, the Cambridgeshire Guided Busway won the National Transport Awards as the Most Innovative Transport Project in the UK.

Cambridge 2030 is tackling a number of topics to prepare the way for developing an integrated vision. It is conducted within a national target of reducing carbon emissions by 80% by 2050. The theme is: "**What kind of place do we wish the Cambridge sub-region to be in twenty years time?**

- an area of continuous growth with a dynamic high-tech economy and vibrant service sector?
- an area of economic growth with a more diverse economy and with greater local integration?
- an area that seeks to sustain the present economy and social environment but without further significant growth?
- an area that seeks to exploit local advantage for national and international gain?

These options and many more require thought if we are not to stumble forward unwittingly. Isn't it time we started debating these issues now?"

The issues canvassed so far are set out in Table 3.5.1 below. The process involves a 2-workshop programme, commencing with a panel of invited specialists and some with wider viewpoints. The programme consists of pre-notified questions, 3-4 presentations on the topic, plus 2 facilitated discussion groups which debate the issues and questions.

Table 3.5.1 Cambridge 2030, Topics Considered to 2012

2011	2012
Economics & technology	Land use
Housing 2030	Social cohesion
Education & skills	Culture, leisure & sport
Retail & business	Transport
Agriculture & green spaces	Energy, water & waste

The second workshop brings together a wider group of participants including those from residential associations, local government councillors & officers, and business people. Following brief introductory talks, participants divide into facilitated groups of 10 to debate questions provided by the organisers. Between the two workshops, the topic is also debated by community interest groups promoting the arts, science, community and commerce & industry. This feedback is available to the participants of the second workshop.

Each workshop concludes with the publication of a 1-page statement of the main conclusions, available on the website. Materials from presenters & other sources are also published there. A strong cultural and lifestyle demand is an underpinning theme from the work to date.

3.8.2 Factors identified in Cambridge 2030 Applicable to the Ōtaki Area

1. Housing:
   - Slow rate of housing replacement - the energy inefficiencies of the existing housing stock is the key challenge.
   - Financial capacity - the capacity and willingness of homeowners to invest in energy efficient measures in their home is a vital element in improving the sustainability of the Cambridge community.
   - Uncertainty - owners are uncertain regarding running costs & payback periods for energy efficiency investments.
   - Supply chain coordination – is not acting in a coordinated fashion for thermally efficient retrofitting. Gains of scale and synergies are not being realised.
   - Contextual recognition – recognition of the impact of household lifestyles on greenhouse gas emissions & the environment are low.
   - Challenge is underestimated – a shift from driving & recycling to walking & cycling does not go far enough. Homeowners must invest in retrofitting (eg insulation, heat pumps). Local retrofit zones and a revolving fund could make a big difference.
2. Agriculture and Green Spaces:
   - Food, soils, water & fuel – how much local self sufficiency in food production do we need to go with energy self sufficiency?
   - Open spaces – access for townspeople provides a major health and social advantage for the region.
   - Valuing open space and the environment – current political debate does not have a ready measure for valuing the utility of open space and a clean environment.
   - Land management & farms – a need for sustainable greater production must be matched by sustainable production of the sward, naturally storing & releasing water, and preserving wet lands. Can farms become energy centres for the sub-region?
   - Green infrastructure – it will be necessary to have an integrated strategy for agriculture, urban development & nature conservation. http://www.cambridgeshirehorizons.co.uk/our_challenge/default.aspx
   - Learning – given the pressures on the green infrastructure, there is a major role for education to identify the new knowledge & technologies needed for a successful community lifestyle & economy, and to train young people in the insights & skills required to succeed in it.

3. Economics and Technology:
    - Quality of life – this is the key to attract talented people to reside in the region.
    - Location of economic activity – should not focus simply on Cambridge city. Include other 'nodes' (Te Horo). The location of employment should receive the same level of attention as housing in planning.
    - Finer settlements & settings – the region's key natural assets should be recognised, protected & celebrated.
    - Improved people-focused transport system – movement within the town & within the region must be improved for pedestrian and cycle routes with more public transport. Increased cycle parking and better control of car speeds is also recommended.
    - Public spaces, including cultural & entertainment – this is a critical issue for the community. People, both old and young, need the stimulation of meeting in both formal & informal contexts
4. Social Cohesion
    - Demographic change – the population is enjoying a longer, active life. There is potential here for a great contribution to the community.
    - Isolation and loneliness – some parts of the region have become isolated with small, elderly populations. In all of the communities, loneliness is a big killer. Face-to-face engagement is important.
    - Schooling – a need for greater community engagement with curriculum and schools.
    - Local services – strong preference for local (residential) delivery of public services such as vicar, head teacher, police officers, community nurses ...
5. Culture, leisure and sport:
    - Good health – strong need for physical stimulation for good health, and reduction in ill-health demands on the public finances. Need for more recreation grounds. Aim for long-term good health, energy and excitement.
    - Culture – build on a combination of traditional and modern culture, and seek a distinctive regional identity.
6. Business and retail:
    - Quality of life – considered to be declining and under threat from poorly planned growth.
    - Fiscal devolution - could local government and business combine to take risks together funded from a local growth dividend (a form of tax increment financing).
    - Retail and tourism – avoid being a 'clone' city swamped by short-stay low-spend tourists

3.8.3 Scottish Community Energy Generation

Scotland has been a leading player in the field of renewable energy. It has a formidable endowment in terms of hydro power (1.3 GW installed), marine (tide & wave – potentials of 14 GW & 7.5 GW respectively) and in wind (a potential of 36.5 GW). By 2012, 39% of Scotland's electricity came from renewables, led by large increases in wind power. So strong has been the growth that the country has lifted its goal for renewable generation of its electricity by 2020 from 50% to 100%.

Wind turbines in Europe typically generate power for 25% of the time. This is also true in Scotland. At times, generation can fall as low as 2% of installed turbine capacity. However, Scotland has some special sites on its west & northern coasts where generation is much higher. In 2005, a wind farm in the Shetland Islands set a world record of 58% of capacity.

The Scottish Government has promoted community ownership of renewable energy generating schemes. Nevertheless, where major schemes are planned for exporting power to Scotland's population centres, debate can be fierce. Despite opposition, government proceeded with the Beauly-Denny high voltage power line to deliver power from the western isles.
http://www.scottishrenewables.com

3.9 UNITED STATES

The US has long had groups promoting the case for renewable energy and limiting the emission of green house gases. Meeting since 1975, an informal group of Congressional House members formed the Environmental and Energy Study Institute in 1982, aimed at promoting environmentally sustainable societies. It grew to include a large number of representatives & Senators. The separate body enabled it to seek additional funding resources.

In recent times, the Obama administration has reopened the National Energy Research Lab, and the Department of Energy has become proactive in sponsoring new technologies, including the provision of loan guarantees for commercial scale up. Renewable energy technologies were a feature in the 2009 American Recovery & Reinvestment Act.

The recent expansion in shale gas production has led to a fall in gas prices, and the substitution of this fossil fuel for coal. This has led the major US power companies to pressure states to remove/ reduce mandates for renewable energy production (which displace the less expensive fossil fuel feedstocks). Already, investment in renewable energy capacity has been falling as government incentives are wound back. Bloomberg estimates that investment in renewables in 2012 fell to $4.5b, a fall of 54% from 2011, and predicts further falls.

3.9.1 A Renewable Energy Infrastructure for New York State?

A much debated paper was presented by Jacobson, Howarth, Delucchi and others in February. It investigated a plan to convert the State of New York's energy for all purposes (electricity, transport, heating/ cooling and industry to fully renewable sources. Described as a "wind, water & sunlight" or WWS generating plan, it envisaged that, by 2030, the State's energy could be derived from:

10% - onshore wind turbines (5MW scale)
40% - offshore wind turbines (5MW scale)
10% - concentrated solar (100MW plants)
10% - solar PV in 50MW plants
6% - residential rooftop solar PV in 5 million 5kW systems
12% - commercial & government rooftop solar PV in 100kW systems
5% - geothermal
5.5% - hydroelectric
1.5% - wave & tidal.

The major technologies in the plan are wind turbines (50%), solar PV (28%) and concentrated solar (10%). The researchers estimated that the new mix of generation would drop the State's end-use power demand by around 37%. As the technologies are all renewable, there would be no fuel costs.

It is interesting to note that the study takes no account of biomass waste streams for bioenergy, nor of solar thermal energy for space and water heating/ air conditioning.

3.9.2 Rural Utility Cooperatives

Community cooperatives have been a feature of the US national infrastructure since the "New Deal" policies of President FD Roosevelt. The costs of a full scale roll out of telecommunications and electricity infrastructure into rural areas was considered too large to be borne by investor-owned utilities who were concerned that the capital cost of installations would not be repaid from potential revenues. Thus, the strategy was to enable citizens to form their own organisations that could interconnect at the city hubs. This was sponsored by the establishment of the Rural Energy Administration.

Today, there are some 900 rural electricity cooperatives in 47 US states. They serve 42m clients, and work through the National Rural Electric Cooperative Association. Owned by the customers they serve, they come in 2 forms;

1. distribution coops, filling a role similar to the NZ Lines companies
2. generation & transmission coops, formed by groups of the distribution coops as wholesale power generators and deliverers.

The coops not only serve residential members, but have 18.5 million businesses, schools, farms, irrigation schemes and other establishments. The coops are still typically in lightly populated areas, with low numbers of consumers per mile of power line. This is only 15% of the customers that publicly-owned utilities service per mile of line.

Coops have some distinguishing characteristics, including voluntary & open membership, equal financial contribution and voting, and community focus. In NZ, a number of lines companies have similar community ownership & focus through community trusts. The largest is Vector, 75% owned by the Auckland Energy Consumer Trust. In Kapiti, the shares of the lines company Electra are held by the Horowhenua Energy Trust.

3.9.3 Community Choice Aggregation

Community Choice Aggregation (CCA) is a system created by several US states to allow cities and counties to aggregate the buying power of individual customers within a defined area in order to secure alternative energy supply contracts. The legal form is neither a company nor an organisation. First formed in Massachusetts in 1997, the CCAs have established a reputation for proactive and transparent energy efficiency programmes. They have become major champions of renewable energy, distributed generation, and of the switch from coal fired power generation to the less harmful natural gas.

CCAs now represent the leading positive outcome from the power market deregulation in the US. They have been able to raise funds through their municipal affiliations. In conservation minded California, legislation empowering the formation of CCAs was enacted in 2002, and some 40 communities are implementing local schemes.

There has been a push back from investor-owned power generators, but in turn there has been a countervailing response from local communities. Recently, the 2010 Proposition 16 in California limiting communities' ability to form CCAs was heavily promoted by Pacific Gas & Electric, yet was turned down by voters.

4 LIFESTYLE & TECHNOLOGY CHANGE

4.1 MOVE TO LOW CARBON FOOTPRINT LIFESTYLES

Cheap energy has been a feature of the NZ lifestyle for many decades. NZ's industrialisation was initially highly distributed and water driven (wind mills also featured). These technologies quickly gave way to steam power, from cheap coal, and then to hydro-electric power. The rise of the internal combustion engine was predicated upon the ready availability of cheap, high density (fossil) liquid hydro carbon fuels.

The dominance of fossil fuels came to be questioned by the oil price shock of 1974, and subsequent market volatility. Recently, the price of coal (for power generation and steel making) underwent a boom & bust cycle on the rising demand for energy and construction materials from large, fast growing economies such as India, China & Korea. Over the same period, the world has seen its urban population overtake the size of the rural population. Urban communities bring with them higher population densities, higher demands for the transport of goods & services, especially food, and a concentration and specialisation of industry in city environs.

Low power prices have led to a change in life style. Rising incomes have led to households demanding appliances for refrigeration, clothes washing, dish washing and cooking. Comfortable temperatures are an important 'need 'of the middle class, demanding energy for air conditioning and heating. Households in developed countries have become multi-car sites, and also acquired other motorised recreational assets such as boats, light aircraft and performance vehicles. These vehicles have high "specs" which often include energy consuming services such as electric windows & seat adjustment, electric steering, seat heating in addition to electronic management & entertainment systems.

Hand tools are no longer manually powered – they are either electrically or pneumatically driven. Gardening now includes motor mowers and chain saws and other powered equipment. Life has become busy; time highly valued and powered machinery a key to squaring off these conflicting lifestyle demands. We drive our cars to do errands with ridiculously short distances. In some sense, we have become self-indulgent.

A counter revolution has begun to develop, most recently present in the Occupy Wall Street movement. Alarmed at trends of global warming, evident environmental pollution and indifference from business & political leadership, questions are being asked. New global and local leadership hubs have formed. Can we slow down? Can we care more about neighbours, colleagues, family & friends? Can we better care for our environment on which all life depends?

One technology that has been a massive empowering for the population – until overtaken by the motor car – is the bicycle or push bike. Invented in Scotland in 1839, it is a human-powered, 2 wheeled (in tandem formation) single frame machine with a chain drive that today incorporates sophisticated gearing systems. Developed from an 1817 walking machine (wooden framed, no pedals) the original designs (with the crank on the front wheel) were 3 times more energy efficient as walking and 3-4 times as fast. The push bike then went through many transformations - including the development of roller ball bearings, a crank drive (front wheel) with pedals in France in the early 1880s, the chain rear wheel drive in the late 1860s, and then connecting the cranks to the bike's frame & finally the seat tube – creating the diamond shape of today's bicycle frame.

There followed several waves of innovation and market penetration:

1. 1870s – Progress in metallurgy provides strong, lightweight parts that enable the first all-metal bike to be built. Solid rubber tyres introduced. Front wheels increase in size as the larger the diameter, the faster the bike can go
2. 1888 – John Dunlop introduced the first practical pneumatic tyre – it quickly becomes a universal design
3. late 1880s – Successful re-design of the free wheel (enabling coasting, removing the need to keep pedalling all the time)
4. 1889 –Coaster brake developed in the US, building upon the freewheel technology
5. 1924 – French develop the gear shifting bicycle
6. 1970s – Mountain biking emerges to become a major recreational sport. This is followed by the emergence of cyclo-touring. Protective gear developed, including helmets
7. 1990s – Bikes emerge as a form of commuter transport, including the use of foldable bikes. In the Netherlands, 26% of all trips are made on bikes. In Denmark the figure is 18%, and it is around 10% in a number of other European countries including Belgium, Germany, Sweden & Finland. Traffic lights adjusted for the rhythm of bikes, not cars
8. Mid-1990s – bike sharing schemes launched in Copenhagen, and have since spread to many cities, most notably Paris, with its 20,000 bikes and more recently London. These schemes have even appeared in cities in the automobile-centric US, including Boston, Minneapolis, San Francisco & Washington.
9. Late 1990s – the bicycle parking lot, some now quite high tech. The aim is to improve security from theft, and increase capacity.
10. 2000's – cycle "superhighways" develop. These combine bike paths with bike lanes on regular streets to give cycle commuters a smooth route from suburb to town & city. London opened 4 in 2010. Copenhagen is planning to install 26 routes keeping cyclists and motorists as separate as is possible.
11. 2000s – e-bikes or pedelecs recover their lost status. First developed in the early 1900s, these bikes are fitted with a small electric motor powered by a rechargeable battery. China has taken to this development with alacrity, with a fleet of more than 100million. Sales growth has also been strong in Europe, especially in Germany & the Netherlands, where 20% of new bikes are e-bikes.

The bike is ideal for short distance travel and has recently become a major recreational vehicle. Cycling also provides health benefits through the exercise that it requires for its operation. The first major modern resurgence in cycling was 'mountain biking', a sport of off-pathway cycling. This has stimulated a demand for cycle-ways from a much larger public, creating a demand for new trails to be developed in unused (typically rail) corridors. In many modern cities, bikes have become a significant portion of commuter travel, and special facilities are being created for cyclists and their bikes, including secure stands, cycle ways in urban centres & country cycle trails.

One element in the resurgence of cycling has been the conflict in corridor use between motor vehicles (roads) pedestrians (footpaths) and cyclists, who have only recently been given an independent corridor in NZ & many other countries. Without separate corridors, cyclists are exposed to danger on roads, while they can infringe the safety & enjoyment of pedestrians. Separate corridors for all 3 forms of mobility are optimal.

Many urban centres are closing off their central areas to motor vehicles, restricting use to pedestrians and cyclists only. In addition, many are restricting inner city traffic to speeds of 30 km/hour to provide a safer environment for pedestrians & cyclists, as has happened in Wellington and the new speed restrictions around NZ schools. Feedback from these initiatives in the UK (Brake and British Cycling) is that they increase walking and cycling by 20%, reduce the accident rate by 5% for each 1 mph cut in motor traffic speed, and engender a greater feeling of security within the community. This has lead to the "GO 20" campaign, a pledge not to exceed 20mph (30 kph), and for civic authorities to greatly expand the 20 mph limit throughout the UK.

Bicycles offer a major opportunity for rolling back Ōtaki's demand for private transport fuels. Dedicated, safe cycle trails enables substitution of human power for mechanical and other energy demands.

4.2 RENEWAL OF URBAN INFRASTRUCTURE FOR NEW LIFESTYLES

Growth in the size of urban centres, transport needs of people and goods has collectively led to heavy use of roads and congestion at peak commuting and holiday times. Congestion, plus the increased cost of liquid fuels has created a renaissance in public transport and the emergence of cyclist commuters. Internationally, passenger numbers on rail and tram services have grown rapidly, necessitating increased investment in modern public transport vehicles and infrastructure. As private road vehicles have clogged inner city centres, streets have become restricted to pedestrians & cyclists. Buses have received dedicated road lanes & corridors.

These trends are not a feature of everyday life in Ōtaki, apart from the congestion on state highway 1 at Ōtaki railway. Nevertheless, Ōtaki could assess these developments and apply modified versions for the advantage of its community lifestyle. Some aspects for consideration include:

1. Provision of "people and pedestrian" space within the urban hubs of the area
2. Provision of dedicated cycle lanes in key corridors for commuting within the area, especially to schools and civic amenities
3. Facilities for secure cycle storage at certain hubs
4. Lighting to enhance night time security & safety.

International experience indicates that dedicated corridors have a significant impact upon use. This is true even for such things as dedicated bus corridors – some of which now include guided buses. Daimler Benz pioneered this type of service in Essen, and it also now used in Cambridge. In NZ, the North Shore bus lane has been a success in attracting strong patronage.

5 PUBLIC SERVICES & ENERGY CONSERVATION

5.1 STREET, TOWNSHIP & PUBLIC LIGHTING

The cheapest unit of energy is the unit that is saved. An early opportunity for energy conservation is the deployment of light-emitting diode (LED) illumination for roads and public spaces, such as car parks & malls. Although LEDs have a high up-front capital cost, they consume less than 15% of the energy of traditional incandescent lights. Technical advances in LED technology, including in the lenses, has improved their cost: performance ratio at a strong rate.

Dutch lighting major, Philips, has just announced a new range of LED products that will replace is entire existing LED range. These LED bulbs will consume only 8.5% of the energy per lumen of traditional incandescent light bulbs. US competitor has also announced LED technology breakthroughs for buildings

LED performance has now reached the point where their performance already warrants their installation in interior public and commercial spaces such as libraries, reception areas, recreational facilities, foyers and areas requiring spot lights, including retail displays & signage. In these areas, the owner is using their lights for several hours per day, and the pay-back period can be well less than 1 year. Also, these organisations have ongoing capital budgets and investment analysis well able to identify the total life cycle savings and fund the initial capital cost.

5.2 TRAFFIC PLANNING & ENGINEERING

The upcoming main highway by-pass for Ōtaki offers new challenges and opportunities. The roundabout and shopping precinct on state highway 1 are undoubtedly a traffic bottleneck, especially in peak travel and holiday times. Nevertheless, that precinct serves as a major commercial facility. It is the factory outlet location for the Wellington region. It attracts numerous visitors expressly for this type of shopping. However, a good proportion of those shoppers are casual, in the sense that their stops are unplanned and opportunistic in response to displays and other visit incentives promoted in the precinct by the outlets. The precinct also creates a flow-on benefit for other travel related businesses in Ōtaki, such as fresh produce, food and fuel outlets. Could the railway outlet precinct survive the by-pass?

The answer to that question is undoubtedly being researched. In part the answer will be determined by how readily access can be made to the precinct. Could the precinct be re-engineered into a more visitor friendly destination? Could it enhance the experience of a visit for pedestrians? Would the existing outlets cooperate to support such an initiative? Could it be designed to attract ancillary businesses that could replace the loss of the fuel outlets?

Energise Ōtaki might be one way of contributing to such a solution. If Ōtaki could gain a leading regional reputation as the place for seeing renewable energy technologies for households and businesses demonstrated, and for accessing professional services related to the use of these technologies, then Ōtaki could create a second draw card for visitors to travel to it, and get out of their vehicles. In so doing, those visitors too would add to the business traffic of the community's ancillary businesses.

Tranzit NZ does not include economic factors other than those directly related to transport in its design calculations. If Ōtaki wants to create this sort of space in response to a deliberate change in traffic patterns, it has to advocate for them through consultation and planning channels. This is a role that KCDC could lead.

5.3 PUBLIC BUILDINGS

Local & educational buildings are often large. They are operated by bodies that have a large budget, and can take a longer term investment horizon than private building owners can, especially the majority of households who live on tight budgets. A longer term investment horizon enables total life cycle analysis to be analysed, and investments planned accordingly. These bodies also have the financial reputation and resources to undertake capital projects which have a multi-year horizon.

The case for LED lighting in public buildings has been noted above. These buildings also have space and water heating installations, and may have the ability to benefit from a move to renewable and more efficient technologies. If their site is compatible, they can be a good candidate for solar energy installations for space & water heating, and even for solar PV electric power generation.

In many instances, the owners of these buildings have a maintenance cycle. Appropriate reviews for the improvement of energy efficiency can be incorporated into these cycles.

One role that public buildings can play is to be an early adopter of new energy efficiency technologies associated with the smart grid (see Chapter 12 below for some more details). As communication technologies, sensors, software and the ability for intelligent automation advance, public buildings can provide an early point of introduction to the wider populace and businesses. As people ask questions as to "why was that done", the message of new energy efficient technologies and what they do and how is conveyed more quickly within the community. There is further discussion of some of these options in the following chapters.

6 INDIVIDUAL & RESIDENTIAL ENERGY CONSERVATION

6.1 SETTING PRIORITIES

In light of the base line of energy supply and effective use set out in Chapter (2) above, both households and transport fuels need to be the focus of the energy component of KCDC's sustainable Ōtaki strategy. Three areas are identified as important elements:

1. Household energy infrastructure & management:
   i. Passive design for new dwellings and major renovations & extensions
   ii. Retrofitting of existing housing stock
      – Targeting insulation of dwellings, especially those built before 1979.
      – Installing more efficient (low emission)s wood burner or pellet fire or installing a heat pump
      – Improving water heating performance by making better use of pre-heating systems,
      – Upgrading household appliances, and retiring old, poorly performing units (eg old fridges used for beverage cooling).
2. Encouraging a more energy efficient set of fuel technologies, especially towards fuels that can be viably produced locally.
3. Improving the management of the household as a network to reduce peak power demand, and improve efficiency aware energy management.

Energy demand in residences is dominated by heating – for cooking, space heating/ cooling, and water heating. Internationally the average is around 80% of total energy. In winter, lighting becomes a significant demand as well. Often the focus of solar energy is upon generating electricity, but the thermal heat of the sun is a very important component of renewable energy generation. The requirement for thermal energy can be reduced with effective insulation and ventilations systems.

6.2 PASSIVE BUILDINGS

Passive design is the control of ventilation and temperature without using any products that consume energy or other resources. The aim is to avoid the use of heaters, dehumidifiers or fires.

Good passive design includes:

- House orientation – positioning the house to allow maximum sun in the winter and coolness in the summer. This includes careful assessment of which rooms should be the sunniest.
- Solar energy – using solar panels for water heating and possibly electric power generation.
- Use of shading elements – for example, wide eaves protect from the sun in summer and provide increased weather protection in winter.

- Placement and glazing of windows – the larger windows should face the sun to capture the warmth, use double glazing to stop heat escaping, and have shading to limit summer overheating.
- Ventilation – using window joinery that allows ventilation, such as security catches allowing windows to remain partially open, or vents in the joinery.
- Effective Thermal Envelope – an extension to the traditional concept of insulation - to reduce heat loss & energy demand. Must be accompanied with excellent ventilation.
- Thermal Mass – using heavy building materials to store solar energy and limit overheating during the day but then release energy during the night to provide heating. Eg. Earth buildings (adobe, rammed, pressed, poured, straw bale & cob), floating concrete floors.

This concept can be extended to sustainable environmental construction - the creation of energy efficient, solar passive and sustainable homes. The sustainable home embraces the concept of the smart use of sustainable resources in new buildings and alterations/ extensions. Renewable materials include products such as Douglas Fir, New Zealand wool and efficient design & orientation of buildings to harness the energy of the sun.

Upper Hut based Enviro Homes is active in this field. www.envirohomes.co.nz

See also:

Ecobob	http://www.ecobob.co.nz
ebodə	http://www.ebode.co.nz/eco%20features.html
Hybrid Homes	http://hybridhomes.co.nz
Homestar	http://homestar.org.nz
Powered Living	http://www.poweredliving.co.nz

Little Greenie

Little Greenie is a NZ building system based upon the principles of German passive solar building design. It features a strategic orientation of the home to the sun, the deployment of thermal mass to collect & store the sun's heat, the elimination of heat and energy leaks (including cold bridging) and a comprehensive solar hot water system. The installation includes dimming LED lighting.

High energy efficiency has been secured through the use of a simple rectangular design and high quality components. The footprint is modest. Roof design avoids all unnecessary angles. As a result of these features, the building is almost maintenance free. Little Greenie is already working with KCDC.

6.3 WISE LIFESTYLE FOR LOWER POWER CONSUMPTION

6.3.1 A Lifestyle Check List

Genesis Energy has provided guidance for wise management of domestic energy including the following:

- Use natural warmth from the sun as much as possible to dry clothes instead of the dryer. SAVE $40* every year.

- Washing powders are so effective in cold water these days, there's really no need to do hot washes. SAVE $60* each year.
- Got a beer fridge? If you only turn it on at the weekend and keep it switched off during the week, you'll SAVE $100* every year.
- Check that your hot water is no more than 55 degrees C at the tap. Every 10 degrees C higher than that, and you're spending a hefty 10% more than you need to. SAVE $30* every year.
- Like your towels warm and dry? Your heated towel rail can do the job in just a couple of hours - then flick it off and you'll SAVE $100* each year.
- Phase out standby mode altogether. It's not just the obvious culprits like TVs, stereos and electronic equipment. Washing machines, dryers, and phone chargers left on at the wall can also drain a lot of unnecessary energy. Switch everything off at the wall and you'll SAVE $75* a year.
- Try and reduce the amount of time spent in the shower. By limiting your showers to 5 minutes you could SAVE $100* per year.

*: These are indicative savings only obtained from http://www.genesisenergy.co.nz All the above savings also represent reductions in energy demand from the Otaki community.

Finally, if your home incorporates internal access from your garage, and is built above it, ensure that insulation is in place, including the garage door, and on internal walls & floors that interface with the garage.

6.3.2 Electricity Monitors

Real-time feedback to users is a very important part of being self-aware and being able to make ecologically friendly lifestyle choices. Electricity monitors/ dashboards are devices which determine how efficient (or wasteful) the patterns of use of electronic appliances really are. They help find out which appliances (& members) are the energy abusers in the house, and help users optimize their consumption. They monitor the kilowatt hour consumption of an item to learn how much it costs to run. They will also determine the electrical expenses by day, week, or month.

Advanced meters can enable the home owner to become proactive in the management of their electrical appliances and timing their use of them. The key is sustainable 2-way communication, and links into both the network of home appliances & equipment, and interaction with the external lines network. The system needs to be able to empower the consumer as well as the power providers/ distributors.

6.3.3 Thermo Mapping

Another excellent and effective information feedback system is thermal mapping of a building. These services have become available in recent years. The maps show the thermal leakage or transmission of heat from the heated home to the colder external environment, or the reverse in an air conditioning situation – the absorption of heat from the warmer external surroundings.

6.4 RETROFITTING EXISTING BUILDINGS

6.4.1 Insulation

Otaki Households use 23% of their energy on heating. Inadequate insulation wastes heat – with parts of the house acting as a radiator to the external environment. Improving a home's ability to retain heat combined with the smart use of clean, efficient heating systems will reduce the amount of energy needed for heating, and thereby decrease the area's energy demand.

The industry's recommended order of priority for insulating a home should be:

1. ceiling
2. under floor
3. walls
4. windows

In Otaki with its relatively high proportion of older dwellings, the strategy should be to target and assist homes built before 1979 improve their insulation.

6.4.2 Higher Efficiency Lighting Technologies

There are several technologies which offer much greater efficiency than traditional incandescent light bulbs, including (tungsten) halogen, compact fluorescent lamps (CFLs) and light emitting diodes (LEDs). All offer superior efficiency to what most households have been using until very recent times.

Halogen Lamps

A halogen lamp is an advanced form of incandescent lamp in which a small amount of a halogen has been added (typically bromine or iodine) at pressure. The glass tube is made of fused quartz or high silica glass. The combination of the halogen gas with the tungsten filament produces a chemical reaction which re-deposits evaporated tungsten back on the filament. This regenerative reaction enables a halogen lamp to operate at a higher temperature than normal gas-filled incandescent lamps.

Halogen lamps offer the advantages of small size, lightweight, longer life & low production cost. They are more efficient than standard incandescent lamps because of the regenerative tungsten cycle. They are dimmable, and do not use mercury. However, they run at very hot temperatures, are sensitive to any oil left on the glass, and can fragment.

Compact Fluorescent Lamps (CFLs)

The CFL lamp is a tube in design, although it may be made in a helical shape. The CFL is emitted from a mix of phosphors within the tube. It uses 20 – 33% of the power of a traditional incandescent lamp for the same amount of visible light, while having a life span 8 – 15 times greater. CFLs have a higher initial cost, but over their life offer major energy savings that recover the extra cost many fold. China has become a major manufacturer of the helical design. CFLs have been designed for both AC and DC current applications.

Light Emitting Diode Lights (LEDs)

Lighting product manufacturers have been supplying high efficiency LED lamps for some time. The technology has steadily improved, and the cost of the bulbs has fallen – from around US$40 a few years ago to around $15 now, $10 later this year, and still falling (towards a floor of $5 each?). At the same time, the efficiency of LED lights in terms of lumens per watt is continuing to improve.

The advantages for consumers are:

1. high energy efficiency
2. long life cycle – up to 20 years
3. can handle multiple short use cycles unlike compact fluorescent bulbs which need to heat up, and burn out if on/ off cycles are too many and too short
4. good light
5. chips in the LEDs can incorporate wireless connectivity, permitting users to control light colour and the lighting schedule from a smart phone. Apple already has such an app. See http://www.technologyreview.com/view/506556/apple-sells-philips-color-shifting-wireless-lights

Traditionally, householders have measured the strength of a light bulb by its wattage. However, this is no longer a satisfactory guide to light bulb performance. Factors must now be taken into account:

1. light emission measured in lumens
2. what spectrum of light (LED lights can be 'tuned' to the full spectrum of colours)
3. quality of the colour, measured by a colour rendering index (CRI), typically today around 80, but many are available with CRIs of up to 93
4. heat sink design, which moves heat away from the micro semi conductor. Some designs are not acceptable for public show
5. operating heat (determines its suitability for tight spaces)
6. initial cost

6.4.3 Higher Efficiency Heating Technologies

The data of household technology use presented in Tables 1.6 & 1.7 show that there is substantial room for moving space heating in Ōtaki households from open fires to more efficient wood burners and heat pumps. Options for these migrations are set out below in Chapter 9.

7 FARMS & ORCHARDS

7.1 OVERVIEW & FARM MANAGEMENT

Farms, market gardens, orchards and vineyards have a lot of machinery and equipment. Today, most of it uses energy. Key items are tractors & powered field plant and electric pumps for irrigation. If not regularly maintained and replaced, this equipment can incur a significant & avoidable excess energy use cost. In dairying market gardens, there is also the cost of chilling the milk & produce and generating hot water.

There has been a lot of innovation in the energy and motor industries in recent years. In addition, farming has generally become more intensive. Property sizes change. Owners & managers need to ensure that the equipment on the property is still the right size for the farming operation. Do energy efficiencies now offer a high return on investment?

Farm buildings benefit from energy efficiency initiatives, including lighting, insulation & controlled ventilation. Dairying, with its early milking hours, can also capture efficiencies and cost savings from new LED lighting technologies. Building technologies are explored in Chapters 9, 11, & 12.

A major farm-market garden-orchard cost is fertiliser, and in the case of dairying, effluent treatment & water discharge. Land use rotation, green crops and integrated pest management offer areas for savings. Use of GPS systems to facilitate precision applications of fertiliser and seeds can also be utilised to avoid wasted resources.

7.2 MACHINERY

Motive power is an important component of modern day faming, market gardening and orcharding in NZ. Typically, motors are an important opportunity for energy savings. Diesel has been the preferred mode of energy for carrying materials and produce, planting, tending & harvesting. Farm vehicles have many powered implements that are driven from a power off-take.

Diesel engines are around 50% more efficient than similar sized petrol (gasoline) engines, and modern diesel designs now meet exhaust standards. Diesel engines have a life double that of a petrol engine, and are more readily able to use biofuels. NZ now has low sulphur content diesel fuel.

Farm practice can be ordered so as to limit energy use, including through farm management decisions. Suggested check-lists from organisations such as the US Institute for Energy and the Environment include:

1. minimise the number of trips for tillage & seedbed preparation
2. are nil-till planting systems , such as the NZ-invented seed + fertiliser drills, appropriate
3. if using mulch, reduce the depth of tillage in seedbed preparation
4. combine across-field trips including for fertilisation & for herbicides
5. is it appropriate to combine fertiliser & herbicides at planting
6. use post-emergence herbicides for weed & annual grass control

7. minimise use of the cultivator
8. is field equipment matched to the appropriate sized tractor (fuel efficiency declines sharply if excess tractor horsepower is used)? Match gears & throttle speeds to the work at hand – avoid overloading the engine. Use appropriate equipment balance with machinery
9. prepare and execute a general tractor and equipment maintenance programme. Include air line & fuel system filters
10. trips to town: is the pick-up the most appropriate? – this is one of the major uses of US farm fuel. Is a vehicle of that size needed? Is a trip necessary, or can the business be conducted by telephone or over the internet. Can a pick-up trip be organised to include the collection of goods from several suppliers.

Vehicle weight is an important consideration in agriculture, as heavy tractors & vehicles can compact soil and thereby weaken its structure and fertility. Inflate tyres to the proper pressure – over-inflation can create ruts in soft soil. University of California identified that incorrect tyre inflation creates a 25% excess of fuel consumption.

7.2 MOTOR EQUIPMENT & PUMPS

The initial purchase price of an electric motor is now around 2% of total lifetime operating cost of the motor in US farming. NZ costs are likely similar. Thus, electrical machinery, especially pumps, offers a strong case as the place to start in search of farm energy efficiency. US research has identified that motors offer savings of up to 30% if general and application-specific measures are adopted. A study of irrigation performance on farms in Wyoming, Nebraska & Colorado identified that on average, 25% of energy used for irrigation was wasted due to pump & motor inefficiency. Particular targets should be pumps, compressors, fans & blowers. Some specific items for check lists include:

1. maintenance & regular servicing of irrigation engines & motors. Upgrade when necessary
2. electric motors, switches & control panels - free of dirt, insects or bird nests
3. electric connections – tight, and all moving parts lubricated.
4. regular inspections of sprinkler/irrigators-stop leaks, replace warn nozzles & trim impellors
5. avoid over-watering. Use irrigation schedules. Measure the amount of water being applied. Irrigate before soils become completely dry. Consider irrigation methods for periods with limited water availability
6. avoid patchy water distribution and inadequate pressure
7. for dairy farms, issues relating to refrigeration need additional attention, including:
    i. refrigeration heat recovery units to pre-heat hot water
    ii. consider scroll compressor refrigeration, as part-load capability is now available
    iii. heat exchangers (plate pre-coolers) to pre-cool milk before vacuum cooling
    iv. variable speed drives on vacuum pumps for milking
    v. is insulation of milk vats efficient and un-damaged
    vi. are hot & cold pipes insulated
    vii. are there any hot water leaks, eg from valves & pumps
    viii. are flow check valves needed to prevent feed-back of heated water?

8 OTHER BUSINESSES & INTELLIGENT ENERGY EFFICIENCY

8.1 COMMERCIAL LIGHTING

In US commercial buildings, lighting makes up 21% of all energy use (Energy Information Administration). It can make up 20 – 35% of all electricity consumption in industrial plants. Retrofitting with solid state LED technologies offers a means to secure a major reduction in this use of energy. If the installation is programmable, the site's entire lighting system can be monitored and become a real time managed application. This involves layers of software, building controls and high performance lighting all operating together, sometimes with their own computing platform.

In November, Osram Sylvania began shipping LED lights equivalent to 100-watt incandescent bulbs. Significantly, these strong bulbs give off light in all directions, a break from the previous omni-directional performance of LED bulbs. Philips commenced shipping its A21 bulb the following month.

In April 2013, Philips announced that it had improved the performance of its LED equivalent of the fluorescent light tube. Widely used for large area overhead lighting, the new LED version produces 200 lumens of light with 1 watt of power, twice the efficiency of current LED technology. Development engineers at Philips have already achieved well over 200 lumens/ watt – suitable for outdoor situations. The breakthrough has come from tuning the light the LED lamp gives off.

Philips proposes to launch a full range of LED light bulbs & tubes in 2015. It will retrofit its entire lighting products line, including consumer bulbs. An LED replacement for a traditional 60-watt bulb would then be using 5 watts.

8.2 MOTION SENSING LIGHT SWITCHES

In many buildings, the use of motion switches has been adopted to ensure that lighting is turned off if there is no occupant active in the area for a given period of time. These switches have been important for incandescent illumination, but may be less useful for new systems such as with LED lighting, where power consumption is lower, and maintaining the heat of the bulb important.

8.3 DAYLIGHT SENSITIVE LIGHTING

Lighting can be adjusted so that illumination is switched on only when natural lighting conditions are inadequate for the activity within the premises. Modern systems offer a step dimming capability so that the sensing "eye" can fine tune the light to the standards set for the location, often using adjustable fade rates for better adjustment on the part of the occupants.

In addition, 2-way communications enable the settings to be managed from a central control point. With remote wireless communications, these systems no longer require dedicated wiring, greatly increasing the flexibility of installation and operation.

8.4 IMPROVING ENERGY EFFICIENCY OF OCCUPANTS

Real time fee back on energy use and efficiency can lead to significant improvements in the energy behaviour of building users. The feedback can include such elements as:

1. providing the real time price of the energy used in the building at the point of decision, with dash board displays etc, including
    i. electrical plug loads
    ii. electrical lighting loads
    iii. electrical equipment power consumption when not in use (eg, switching off computers)
    iv. timing of use of phone chargers etc
    v. reduced demand for energy for comfort by encouraging more appropriate clothing & exercise
2. use of smart meters & displays to provide total building energy consumption to occupants
3. encouraging the use of stairs rather than elevators for trips up/ down small numbers of floors

All these measures can be further enhanced by ensuring that all energy related plant & equipment is fully maintained, serviced and updated.

8.5 BUILDING HEATING & VENTILATION

A significant area of energy efficiency is the matter of proactive energy management, especially relating to waste heat recovery from air conditioning chillers & space heating systems. Energy for these applications consumes almost 50% of all energy used in US buildings. Some buildings such as data centres have particularly high demands for cooling.

New energy management systems and technologies offer the opportunity for significant savings. These include variable speed motors for the dynamic alignment of energy with occupancy; smart thermostats that can manage HVAC settings & operations; seamless remote monitoring; and demand-controlled ventilation adjusted in real time for occupancy levels. US HVAC firms consider most buildings to be consistently over-ventilated at huge excess cost.

Smaller buildings have limited access to intelligent HVAC automation. Regen Energy is working with Carrier to provide an automated energy management system for commercial rooftop units. Such systems enable smaller building owners to participate in demand response management to shift load from peak points. By smoothing out peaks, the systems offer energy savings of 15 – 30%, giving a payback period of around 2 years in the US excluding incentives. Other providers of the systems are EnTouch, SCL Elements, & Retroficiency.

Buildings can also use automated blinds for solar protection to minimise air conditioning demand, or to enable solar warmth to be captured for space heating. Similarly, office buildings can deploy solar thermal technologies for both space and water heating, and absorption chillers for cooling.

8.6 ON-SITE ENERGY GENERATION & STORAGE

In the same way that sensors & analytics are turning "passive" lighting & HVAC systems into dynamic, responsive installations, they can also insert intelligence into on-site renewable energy generation and storage. These can also extend to electric vehicle fleets and combined heat & power systems. Collectively, all these systems can be combined into an integrated, intelligent energy management system.

8.7 REGENERATIVE LIFT DRIVES

Lift drive systems can be installed which capture the kinetic energy of braking the car in descent for use in ascent. This is similar to regenerative braking that we are now familiar with in motor cars. Companies such as FIAM are supplementing these systems with power storage systems, which extend the role of back-up and safety capacity.

8.8 INTELLIGENT ENERGY EFFICIENCY

Most of the discussion above relates to discrete improvements in energy consuming devices or improved design. While a wide array of advances are being made in these "hardware" areas, they are now only one part of the total resources available for improving energy efficiency. A new dimension in energy efficiency has arrived with modern ICT technologies and especially 2-way communications between energy generators and users.

This new dimension is information-driven. New sensors, which enable real time web-based monitoring, predictive algorithms and smart energy using equipment are transforming energy use. Users can manage their own use profile, in effect being able to take control of their use profile and insert their own ripple control over their total energy demand. Now, an energy user, residential, farm, commercial, industrial or government can take control of their own energy demand. They can respond to the energy market situation of the moment. In so doing, they can respond to peak pricing models of the energy retail companies. In turn, this enables energy suppliers to provide market pricing which prices for peak demand, and thereby to incentivise the market to alter its behaviour on a dynamic basis. Major system savings in terms of little used peak stand-by capacity are therefore made available.

Building owners are now in the process of being able to establish their own "smart micro grid". For a commercial building as discussed above, it will have the sensors, communications and software algorithms to provide the most efficient energy demand from the alternatives available to it. In the case of space heating, it may use blind adjustments and stored hot water from the solar thermal system to smooth out the HVAC energy demand profile.

In total, we now are moving towards a situation where the action is dynamic, holistic and decision taking is system-wide, not generator driven. The advances within the IT industry and electronics underpin this new status. Supplemented with new algorithms, every item in a user site can be individually monitored for its performance, energy demand, accorded a priority status on the site that may alter across the day & week, and is all managed in real time.

Renewable energy is largely a distributed generation technology. It too can be monitored and managed in real time. Matching intelligent use with intelligent distributed generation creates a new dimension for efficiency at the system-wide level. This dimension is dynamic, and it is possible for it to work in an holistic way. US discussion calls this new dimension "intelligent efficiency." A number of leading energy and management strategy companies have modelled the potential of intelligent efficiency.

McKinsey's 2009 study into Energy Efficiency estimated that US$520b economy-wide investments in intelligent energy efficiency, with then-known technologies could save 23% of projected US energy demand by 2020, giving a financial return of 2.3 X the necessary investment. Similar, more recent studies by organisations such as Deutsche Bank Climate Advisors & the Rocky Mountain Institute, indicate higher the savings, and better financial and ecological returns from investment.

Key players in the new intelligent efficiency world are the facilities managers and plant operating managers. Traditionally, they did not have access to real time data nor did they have the authority to make key energy contractual decisions. Typically, other management roles have assumed these contractual authorities, most often (central) finance. Today, real time data collection, data mining/ analytics, energy assessments and feedback systems all create a new level of energy efficiency that was previously unobtainable. The decision is no longer a simple energy supply contract – energy savings through intelligent facilities management is now just as important.

In the power sector, a smart grid, able to facilitate the necessary action between the suppliers and users, is a critical element of intelligent efficiency – discussed further below.

Some of NZ's major generators have been installing "smart meters" in customers' premises. Genesis Energy has installed over 300,000, which record energy use in half hour blocks. These meters enable remote meter reading, but also facilitate time-of-day pricing. With feedback systems to the users, discretionary power use is then able to be managed by the user for off-peak times, including re-charging of electric vehicles. Genesis has conducted customer trials in Waitemata & Christchurch with a 3-part tariff – peak, shoulder and off-peak. Wi-fi enabled power boards enable users to programme their own energy use patterns, including pre-setting times for washers, dryers & re-charging.

Imaginative variations of these feedback and management schemes are available overseas. One is the "energy orb" in the US, which glows different colours to display real time energy use & corresponding electricity tariff. This device is leading to savings of up to 40% in peak period energy usage. Competitors include the "Wattson", a digital display that looks similar to a digital clock, and is also able to display when cheap energy is being generated. Sweden has the Power-Aware Cord, which uses coloured light to signal when an appliance is on and how much energy is being drawn. In Finland, the use of these feedback technologies has seen large decreases in power consumption.

Championing the access to and use of such devices is a potential role for Energise Ōtaki, for all power user groups. It would quickly cut the power demand in the area from existing installations, and enable technology transitions to electric powered technologies such as heat pumps and electric vehicles (including bikes) to be made with minimised infrastructure investment.

9 ŌTAKI - RENEWABLE ENERGY GENERATION CANDIDATES

9.1 OVERVIEW

9.1.1 International Perspective

Globally, renewable energy capacity has risen sharply over the last decade in response to concerns about resource sustainability and the emission of greenhouse gases (GHG) and the spill over into climate change. In this context, the United Nations has established a new global initiative – Sustainable Energy for All. The initiative has three interlinked goals:

- Universal access to modern energy services
- Improved rates of energy efficiency
- Expanded use of sustainable energy sources.

The renewable Energy Policy Network for the 21st Century (REN21) recently published a "Global Status Report on Renewables 2012". REN21 estimates that renewable energy sources supplied 16.7% of total global energy in 2010. Modern renewable energy accounted for 8.2%, a share that has continued to increase over recent years. Traditional biomass (wood for open fire space & hot water heating and cooking) accounted for 8.5%.

Table 9.1 Global Renewable Energy Capacity & Bio Fuel Production, 2011

Energy type	Added in 2011	% Growth	Year end Capacity
Power Generation (GW)		%	
Biomass generated power	6	9.1	72
Geothermal power	+	0.1	11
Hydro power	25	2.6	970
Ocean power	+	150.0	1
Solar photovoltaic (PV)	30	75.0	70
Concentrating solar thermal power (CSP)	1	38.5	2
Wind power	40	20.2	238
Hot Water & Heating (GW_{th})			
Modern biomass heating	10	3.6	290
Geothermal heating (Incl industrial)	7	13.7	58
Solar collectors, hot water + space heating	>49	26.8	232
Transport Fuels (billion litres)			
Biodiesel production	3	15.7	21
Ethanol production	-	-0.5	86

Note: Figures rounded

Source: Table R1, Renewables 2012 Global Status Report; REN21, Paris

Highlights of the report include:

1. Electric Power

   Renewables accounted for 20% of global electricity generation in 2011, and more than 25% of generating capacity. The difference reflects the intermittent nature and variability of some renewable energy sources such as wind and solar.

   Hydro power is the largest source of renewable energy globally, but is growing modestly. Non-hydropower renewable capacity grew by 24% in 2011. There has been a sharp increase in concentrating solar thermal power (CSP) in 2011 from very low activity levels, and several more very large projects are in construction.

2. Heating & Cooling

   The heating and cooling sector is considered to have a largely untapped potential for renewable energy deployment.

3. Transport Fuels

   Gaseous and liquid biofuels are the renewable energies most deployed in the transport sector, although electric propulsion is a major element in railway, subway and light rail traction, and an emerging technology in the automotive sector.

   Liquid biofuels provided 3% of global road transport fuels in 2011. Ethanol production is flattening out.

4. Solar Energy's Rise

   Solar energy has surged to become the major growth node of renewable energy over the period 2006-11. Combined, solar collectors for hot water & space heating and solar PV are now the second largest form of global renewable energy capacity after hydro. Including CSP, the solar technologies added twice the capacity of wind turbines in 2011.

5. Geographic View of Renewables

   In 2011, renewables provided 12.2% of Germany's final energy consumption. Italy's investment in renewables has stepped up sharply over the last few years, especially in solar PV. In the US, all renewables increased to 11.8% of primary energy production in 2011 on the back of a 57% increase in investment on 2010. China has the largest installed renewable energy capacity of any nation, and is targeting that renewables supply 11.5% of the county's primary energy by 2015, and 15% by 2020.

6. Renewables Equipment & Investment

   In 2011, solar PV and on-shore wind power equipment prices fell sharply. This cost reduction has helped accelerate the penetration of these technologies into new geographic markets. In the face of the global financial crisis, many support policies for renewable energy adoption have been rolled back, especially preferential feed-in-tariffs. Many of these policies were aimed at establishing a leading position in the manufacture of new forms of energy plant & equipment.

   Total employment in the renewables industry globally is estimated by REN21 to be 5 million and to have substantial growth potential.

Total investment in renewable capacity in 2011 rose by 17% to US$ 257b, twice the total of 2007, the last pre-financial crisis year. Investment in renewables was some US$ 40b higher than investment in fossil fuel capacity.

7. Energy Efficiency & Renewables
   Fossil fuels supply 85% of current global primary energy. Analysts Jacobson and Delucchi (Energy Policy vol 39 (2011) pp1154-69), also Scientific American, November 2009, "A Path to Sustainable Energy by 2030", have calculated that a full conversion to today's renewable energy technologies (wind, water & solar) would lower the demand for primary energy by 30%. Von Weisacker and colleagues (Factor 5, Earthscan, 2009) estimated that technologies already in existence today require less than 20% of the primary energy used in most circumstances today. Moves towards greater use of renewable technologies would greatly reduce the environmental, social and security issues related to current energy demand.

   Lighting has been a major source of end-use energy efficiency in recent years. Compact fluorescent lamps provide the same amount of light (lumens) as traditional incandescent bulbs with one quarter the electricity. More recently, the performance of light-emitting diodes for lighting has been improving rapidly, as already discussed.

   The European Union has a system of constant upgrading and abandonment of the least efficient category of home appliances. As these and North American standards are introduced, significant energy efficiency gains are made. Similarly, the EU, California & Japan have applied fuel economy standards to motor vehicles. Between 1980 & 2006, fuel economy improved by 60% but the majority of this was utilised in increased vehicle weight and engine performance, leaving only a 15% improvement in distance per volume of fuel. However, REN21 reports that this trend in the use of economy gains reversed in 2006 in response to rising fuel prices.

9.1.2 New Zealand's Renewable Energy Situation

The NZ Energy Data File of the Ministry of Economic Development (MED) shows that New Zealand generated 77% of its electric power from renewables in 2011, primarily from hydro. In total renewables provided 39% of NZ's primary energy supply in 2011, a new record and second only to Iceland. In part, this reflects a displacement of fossil fuel power generation by renewables. Total Consumer Energy (primary energy less used in energy transformation) supplied by renewables was 32.3%.

Hydro Electric Power

Hydro electric power is the backbone of NZ's electric power generation system. It was pioneered by the gold industry in 1886 at Bullendale, near Queenstown. The first municipal electric power network was established in the West Coast mining town of Reefton in 1888.

Geothermal power

NZ was the 2nd nation after Italy to use geothermal power for the generation of electricity. The Wairakei plant came on stream in 1958. This was followed by further exploitation of geothermal power for industrial use, especially in the pulp & paper industry in the North Island. In the last decade, several new geothermal electric power generation plants have been constructed.

Wind power

There have been no feed-in-tariff incentives in NZ for renewable energy power generation such as has been used frequently overseas. Nevertheless, as the size of wind turbines has increased, and the scale of wind power farms grown, the amount of wind turbine energy generated in NZ has expanded. Wind energy generation has been economic for two reasons. First, NZ's occupies a favourable location in the westerly wind belt of Southern Ocean. Second, NZ's large amount of hydro storage and generation capacity enables the wind and hydro facilities to be coupled into a complementary electric power configuration, with the hydro storage lakes providing critical energy storage capacity with a quick response time to changes in wind generated power.

Typically, wind turbines fall into 2 dimensions, large and small. Large turbines, which are often located in big wind farms. Ōtaki's climate, being in the shadow of Kapiti Island for the prevailing north westerly winds, does not rate as a candidate for one of these large installations. Smaller scale technologies are discussed below.

9.2 ŌTAKI - ENERGY GENERATION POSSIBILITIES

The energy situation in Ōtaki is that around 45% of effective energy used is sourced from renewables (using the 2011 coefficients of MED with the 2007 data in Table 1.2 above). This reflects the high proportion of electric power used in the area. However, nearly all of Ōtaki's energy – around 95% - is brought into the area.

Table 1.2 estimated that half of Ōtaki's energy use was provided by electric power, with an efficiency factor of 77.2%. The other major energy use was liquid fuels for motor vehicle internal combustion engines. Here the efficiency is only around 13%, and a large opportunity is available for cutting the intake of the area's energy by a reduction of this use, and a switch to other more efficient technologies.

The section below investigates technologies that might build Ōtaki's capacity to become a net exporter of energy.

Note: any power generation system rated at 10 kW capacity or greater requires approval by the local lines network company (Electra in Ōtaki's case).

Parameters for Consideration of Technology Options

Two principal criteria are used for the identification of technologies which might have the potential to achieve Ōtaki's goal of being a net exporter of energy:

1. Size
    - individual house/ car
    - neighbourhood/ street
    - town
    - area (all of Ōtaki + rural components)
    - district (eg KCDC)
    - region (eg greater Wellington) + regional groupings
    - national

2. Technology's commercial & technical status
    - prototype completed, process calibrated & plant successfully operated
    - field tests of prototype completed, performance data available
    - prototype tested in situ within value chain
    - commercial production prototype completed
    - commercial availability scheduled for 2015 (>2 years)
    - client-hosted installation available for inspection and technical performance data of commercial plant available.

Value Chains & Technologies

Renewable energy comes in several forms and with different applications. For the purposes of the Ōtaki assessment, we have used the following map in Diagram 9.1. Three core streams of energy generation are explored – electric power, biomass and thermal energy. We then explore some specific issues relating to the storage of energy, particularly important for some renewable energy forms. The work then looks at motive power, and the rapid rate of technological innovation occurring there. Finally we address the question, does Ōtaki's situation & resource endowment enable it to realistically pursue Energise Ōtaki's goal of becoming a net exporter of energy.

9.3 ELECTRIC POWER

Electric power is able to be transferred very readily, and is an efficient energy form. Lighting was the first publicly available application in the form of the incandescent light bulb in the 1870s. This replaced the former gas lighting technology. Electric motors, which exploit the electromagnetic properties of electricity, deliver an efficient, controllable and clean means of motive power. These properties have been widely exploited in domestic appliances, hand tools, industrial machinery and motive power for railways, buses and trams. Electricity can be used for space & water heating, refrigeration and air conditioning.

In many countries, electric power is generated by means of thermal plants using fossil fuels such as coal and natural gas. In NZ, with its generous hydro endowment, generation of electric power from these sources is limited, and today restricted largely to peak power capacity. In a number of countries, especially France, nuclear fuels are a major source of electric power generation. Nuclear fuel is not in contention as an energy source in NZ. In any event, plants are too large & complex for consideration in Ōtaki. NZ has only minimal ocean power generating capacity (tidal).

9.3.1 Hydro Electricity

Micro scale hydro power systems are now on the agenda for small and isolated communities as the economics of replacing aging 110KV distribution lines to these user groups is no longer considered necessary nor economic.

NZ home appliance manufacturer Fisher & Paykel pioneered the application of direct drive electric motors in washing machines, and then in dish washers using fine computer controls & sensors. Trade marked as the "SmartDrive" motor, other NZ engineers started reconditioning these motors from disused appliances and converting them into micro hydro generators.

Powerhouse Wind is using direct drive technology in its small scale wind turbine. The major advantage is that the technology avoids the need for a gear box, eliminating cost and weight.

Micro hydro may be applicable to the circumstances of some rural properties in the Ōtaki area, but will be unable to make a material contribution to Energise Ōtaki's goals of becoming a net energy exporter using renewable energy technologies.

9.3.2 Solar Photovoltaic

Solar energy is a major source of power for plant life on earth, and is increasingly being exploited by humankind for electric power and heat generation as noted in Section 9.1 above. Some of the solar technologies, such as concentrating solar thermal, require a large scale investment and land resource, and are not considered to be appropriate for the small Ōtaki area.

Two characteristics of sunlight are exploited in different ways. One is the thermal heat in the sun's rays, which can be captured and concentrated for heating. This is discussed below. The second uses the photoelectric effect of sunlight to create electric power (solar PV). Both forms of solar energy have the characteristics of zero variable costs, but high up-front capital investment.

A number of new technological breakthroughs are being reported in the technical literature. Many apply to solar PV. Many of these technologies are a part of the entrance of nanotechnologies into many industries. The nano technologies are lifting the energy efficiency of these systems into the mid-20% range.

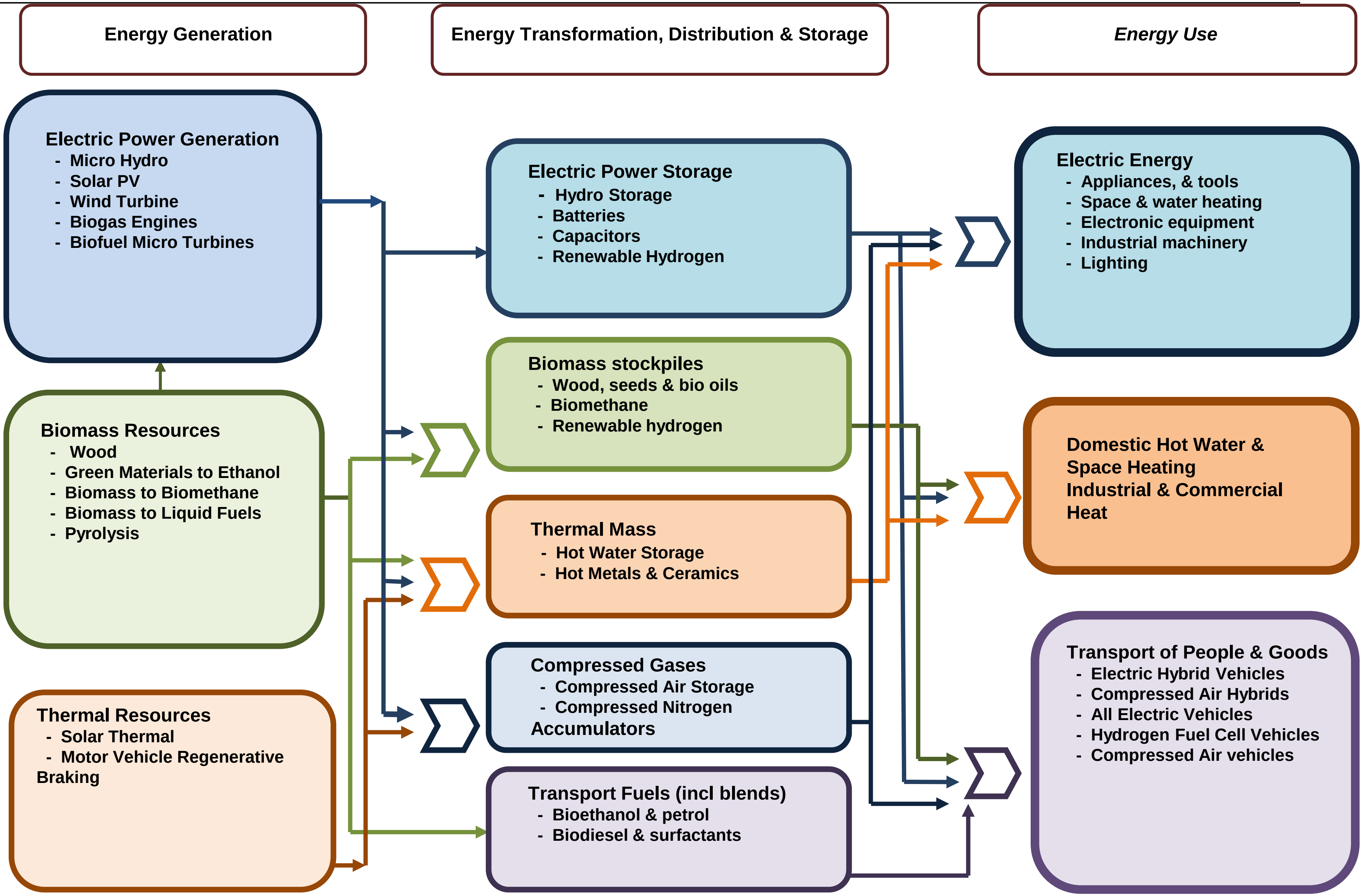
Photovoltaics use semiconductor materials, principally silicon, to convert sunlight directly into electricity. The installations range in scale from residential through commercial to electric utility (grid). Solar PV is a modular technology, and therefore well-suited to distributed energy generation. Utility scale installations, including solar farms with *concentrated* PV are not explored further in this study, because their scale is beyond that of a small area such as Ōtaki.

There are several versions of solar PV technology:

1. Silicon wafers, based on silicon semi-conductors.
   These cells are typically sliced from ingots, electrically connected and packed into modules, or flat panels. Panels have an energy conversion efficiency of 15-18%. There has been a steady improvement in efficiency of the wafers over an extended period.

   Specialised units can have conversion efficiencies as high as 24%, with a corresponding 1-3x variance in cost/kWh, depending on crystal type and construction of the panel. At this time, silicon-based flat panels continue to dominate the global PV market, accounting for nearly 90% of 2011 sales of photovoltaic products. Annual production of Si-based PV in 2011 reached more than 15 gigawatts—an order of magnitude higher than other PV technologies.

Diagram 9.1 Ōtaki Energy Technology Options



2. Thin-film cells, a challenger technology.

   Made from micron-thick layers deposited on an inert rigid or flexible substrate, PV cells come in many forms, but most typically as flexible laminated panels and, increasingly as building-integrated photovoltaics (BIPV). These range from window coverings to roofing products to cladding.

   There are two dominant types of thin-film technology: Cadmium-Telluride (CdTe) and Copper-Indium-Gallium-Selenide (CIGS). CdTe is currently the most commercially prominent thin-film technology, whereas CIGS technology leads in conversion efficiency.

   Thin-film cells absorb more light than silicon wafers, but have a lower conversion efficiency of around 6-11%. However, thin films have a number offsetting advantages that bode well for their future vis-a-vis flat panel PV, including

   i. Utilisation of less expensive materials in much smaller amounts;
   ii. Potential for application to (or integration with) almost any light-receiving man-made surface. The films can be flexibly integrated with building surfaces, vehicle coachwork and many exterior products;
   iii. Light-weight enables application of solar PV capacity where the weight of PV panels cannot be carried by the structure (eg roofs)
   iv. Near-ubiquitous deployment possibilities that dwarf the potential for purpose-built flat panel systems.
   v. The capital intensity of manufacturing plants for thin film are also significantly less than for silicon wafers, though in a heavily oversupplied market, this factor is less significant at present.
   vi. Research-level conversion results of 17% for CdTe and 20% for CIGS PV units suggest significantly higher conversion efficiencies will be commercially available in the future.

       In April 2013, First Solar announced NREL confirmed results of 16.1% for its version of CdTe thin film modules (the previous record was 14.4%). First Solar also announced a new record for open circuit voltage, the first advance in the technology in over 10 years.

       First Solar also advised financial markets that it was projecting that it's manufacturing cost will be US$0.63 - $0.66 per watt in 2013, and that cost will plunge to $0.40/ watt by 2017. Cost per watt in late 2011 was $0.69. http://www.firstsolar.com

3. Concentrated PV (CPV) technologies involve the use of mirrors or lenses to focus a large amount of light on a small, very densely-populated photovoltaic cell. Due to substantially higher capital costs, CPV technology is almost exclusively intended for large scale solar farms generating 1 megawatt or more.

CPV-based installations require more land area and have critical tracking and cooling requirements that are optional or unnecessary with flat panel equipment. A major advantage is the ability to store energy in heat form, and therefore better match demand with available supply. The Solana power plant in Arizona is a good example of this technology, and of its scale.

http://www.abengoasolar.com/web/en/nuestras_plantas/plantas_en_construccion/estados_unidos/#seccion_1

CPV technologies are most appropriate for near-cloudless climates because the slightest cloud cover reduces output to zero – whereas the output from a flat panel device corresponds with the amount of light reaching the surface. Additionally, the extremely precise, multi-axis tracking systems required for CPV system are particularly vulnerable to even moderate winds. These characteristics render current CPV technologies less suitable than others in most NZ environs.

4. Next generation PV technologies are in development, using even less expensive materials and working for higher efficiencies. A number of new technological breakthroughs are being reported in the technical literature, including thin c-Si by epitaxial growth, crystallized polysilicon layers, and nanoscale Si. Nano scale materials in particular appear to offer the prospect of a paradigm shift in cost and performance levels. However, upward migration of incremental technical innovations that are not coupled to substantial production cost savings will be largely forestalled until global oversupply and demand reach equilibrium.

INDUSTRY ECONOMICS

The cost of solar PV has fallen steadily over several decades; with a sharp fall in recent years as the industry moved into a position of heavy over capacity from 2009 (some estimate this to be of the order of 2 times market off-take at present). Solar PV panels are a capital intensive industry, and overcapacity hurts industry participants badly.

Chinese industry expansion has been frenetic over the period from 2007, as the country moved to increase the proportion of renewable energy in its total energy production. Solar equipment production capacity grew tenfold in China between 2008 and 2012. Capacity continued to be added in China in 2010, 2011, & 2012 despite the oversupplied market conditions.

As a result, according to industry executive Brad Mattson in California, solar PV panel prices fell by 85% over the last 4 years. By January this year, the average selling price per watt of solar modules was well below US$0.70. Solar PV prices are now at a level where solar PV is a competitive energy generating source, but new technology developments cannot be introduced because the extremely low margins prevent an economic return on investment being made.

Industry consolidation naturally follows the descent of prices to levels below some firms' costs of production.

There have been more than 20 solar panel manufacturer closures in Europe & the US over the last few years. In China, the Wuxi (& main) manufacturing subsidiary of market behemoth, Suntech Power, declared insolvency and commenced a restructuring of its business on 20 March 2013. It owed US$1.1b to a Chinese banking consortium. This is a very significant event in Chinese corporate & banking affairs, and for the solar PV market.

The disruption is not limited to financial impacts. Often the companies with the most promising new technologies are most vulnerable to downward pricing trends. The mature commodity-oriented companies with lower debt exposure and R&D investment are left standing, while less capitalized firms with nothing to leverage except untried technologies and unsustainable production costs fall by the wayside.

The lesson is that the global market does not necessarily promote (or even allow) "linear" adoption of the most efficient or potentially cost-effective technologies. Irrespective of any technical superiority, promising innovations that have not reached a competitive scale can be substantially delayed or stifled altogether following a global price collapse. The short term advantages of a precipitous fall in flat panel prices may, to an unpredictable degree, be offset by the inevitable resultant delays in new technology adoption.

END USER ECONOMICS

Differences between low, medium and higher efficiency panels don't translate simply as lesser-to-superior choices, but rather as a range of equipment options that can all be appropriate under different circumstances. Panel price and the variable land and equipment costs of deployment have to be factored carefully against operating efficiency.

Installation costs are a significant cost item in PV facilities, and with central inverters (which connect the solar panels' electricity and convert it from DC current to grid compliant AC) there are issues with regard to the impact on system performance of shading/ mal performance of any panel. Recently, micro inverters have been released onto the market in a plug and play form, greatly simplifying installation and eliminating the performance degrading arising from single panel malfunction or shading – see Enphase & its competitors, including Enecsys & SolarEdge. http://enphase.com http://www.enecsys.com http://www.solaredge.com

Solar panel PV is a highly modular energy system, enabling almost any sunny site to generate its own power. While solar PV will run appliances and equipment when the sun is shining, many users, especially households, have their peak demand in periods outside the strongest sunlight hours. Thus, a system of energy storage is needed to match use with the energy supply.

In NZ, the energy storage role is typically fulfilled by the large power generation companies offering a supply and buy back agreement, purchasing unused solar PV power during the day, and supplying power from the grid when the solar PV generation is not functioning.

One company, Meridian Energy, has been offering a 1 to 1 price for these transactions, and absorbing the line & transmission costs of its supply. It is modifying this arrangement for purchases above 5kWh/ day (where Meridian's purchase price is more than halved).

Note that electrical distribution service in regions that include a significant concentration of PV-based feed-in connections can be challenged by the sudden and transient on/off cycle as daylight intensity changes when cloud cover sweeps across an area and systems react accordingly.

In April 2013, Swedish start up Sol Voltaics announced a nano wire layer technology that can be added to a solar panel, creating another absorptive layer. The layer generates another 4-5% of energy, lifting total efficiency from around 18% to over 22%.

http://www.solvoltaics.com

Table 9.2 Solar PV Energy

Proprietor:	Several imported systems widely available in NZ with a well established installation industry.
Value Chain:	Electric power
Application:	Highly distributed power generation, for off-grid situations or self generation with grid interface for use/ generation balancing.
Status of Technology:	Fully commercial. Client-sourced technical performance data readily available. Strong price competition with arrival of new manufacturers, especially from China and new thin film. .
Technical Performance Characteristics:	***Solarzone*** figures for the Wellington Region. Life guarantee, 25 years, likely life <40 years. Performance: 9m^2 generates 1,790 kWh 21m^2 generates 3,878 kWh 35m^2 generates 6,563 kWh
Economic Performance:	Installed cost is of the order of $7,000-$25,000 depending upon size and technology selected. Prices have been falling at an astounding rate. According to My Solar Quotes, current prices provide NZ users with a return on investment of 10%. ***Solarzone*** quoted similar returns.
Relevance to Ōtaki:	Ōtaki has a similar climate to the sunny Nelson-Marlborough-Wairarapa axis, so is a favoured NZ site for solar energy systems. Solar PV installations are modular and fully scalable from individual household scale to large community facilities. A complementary energy storage technology/ capacity is required. Access to the grid through the local lines network is critical for the current business case for solar PV. If local storage is developed, transfer across the local Electra network would need to be agreed.

LOCAL TECHNICAL CAPACITY

A number of members of **the Ōtaki Clean Technology Centre** have experience in the Solar PV value chain. ***Astara Technologies*** provides consultancy, design and project management services.

Energy Saving Specialists undertakes energy audits for small & medium sized firms to identify energy use savings & self-generation solutions, including solar PV.

Solarzone designs, sells, installs & commissions solar PV & thermal systems.

In 2012, SAFE Engineering in Drury, Auckland installed a 68kW solar array, with 360 PV panels & 6 inverters. It supplies electrical energy for SAFE's heat furnaces, forges and machine shop, generating more than 70% of SAFE's annual electric power, with a return on investment of 9%.

SHORT TERM PV OUTLOOK IN AN OTAKI CONTEXT

Based on the commercialised technology currently available, and the regional circumstances described in this report, the most suitable PV technology currently available at a scale appropriate to the Otaki area is the silicon-based flat-panel[2]. Insofar as large, utility-scale PV farms are less suitable for the region – relative to current technology and the substitutability of other renewable energy sources – PV installations will range from 2-3kWh supplemental household systems to facility- or neighbourhood-dedicated arrays with output as high as 100kWh.

The primary variables in determining price and conversion efficiency of the flat panels are the type of silicon material and the manufacturing methods.

9.3.3 Wind Turbines

New Zealand is considered to be an optimal location for energy farming from the wind. The country lies across the prevailing westerly winds of the Southern ocean, giving it many viable land-based, though turbulent wind sites. In other countries, ocean sites have an increasing accent, as wind over the ocean is generally stronger and less turbulent than wind over land.

New Zealand farmers have long used small windmills for pumping water. The use of windmills for the milling of grain and in salt farms had a long tradition in Europe which and later in NZ, but was soon overtaken by steam and then electric power.

Wind energy for electric power is captured through wind turbines. However, wind is both intermittent and variable, so users require complementary power generating technologies and energy storage. The International Electrotechnical Commission has graded wind sites into 3 categories:

1. I, High Wind, with an annual average wind speed of 36km/hour and extreme gusts of up to 252 km/hour
2. II, Medium Wind, average wind speed of 31km/hour, extreme gusts of 214 km/hour
3. III, Low Wind, average wind speed of 27 km/hour, extreme gusts of 190km/hour.

Again, with its mountain terrain and high proportion of hydro storage energy, NZ has a ready-made partner for wind turbine electric power generation. Details on the industry are available from the NZ Wind Energy Association: http://www.windenergy.org.nz

[2] CIGS thin-film technology deserves attention due to indications that it may outperform silicon cells in areas with a greater degree of cloud cover. Although CIGS panels reached a point of near price parity with silicon panels, the collapse in prices has favoured the silicon technologies due to their lower cost basis. Companies using CIGS-based technologies have not tended to be commercially successful.

Wind turbine power emerged in the late 1970s. It is a very important part of the generating capacity of countries such as Denmark & Germany. Global capacity increased by 40 GW, or 20%, in 2011, the largest capacity increase of any renewable energy. Offshore capacity grew by 28%.

The international trend is generally to larger scale turbines and larger wind farms for cost efficiency reasons. There is also a growing movement for community owned wind farms, for reasons of energy security and ecological concerns (to displace nuclear and fossil-fuelled generation). REN21 reported that in 2010, small scale independent installations grew by 26% globally, driven by the high cost of renewing grid reticulation for remote locations. There are some 300 manufacturers of small turbine systems in 40 countries. In Germany, community and individually owned wind now represents more than 50% of the nation's wind generation capacity.

These trends can be seen in the turbine range offered by Danish manufacturer Vestas, one of the longest established suppliers in the world. Their current turbines range from 2 to 3 MW, typically rated at wind speed of around 43km/ hour. An 8 MW offshore model has just been added.

REN21 reports that the wind turbine construction industry is in a state of serious overcapacity. Combined with the retreat in key materials prices since 2008, the overcapacity has lead to a marked fall in turbine prices. Preferred turbine sizes in the OECD countries were in the 2.0-2.3 MW range, and 1.1-1.5 MW in India & China. Offshore sizes increased significantly to greater than 4 MW. Offshore wind turbine farms are increasingly using HVDC connections to deliver power to shore.

Wind currently generates about 5% of NZ's electricity. The NZ Wind Energy Association projects that wind power can increase 6-fold to 3,500 MW by 2030, on current demand forecasts.

New Zealand has its own developers of wind turbines, including *Windflow*, a Christchurch manufacturer of 500 kW systems with special capabilities for strong & turbulent wind conditions. Special aspects of the system are a torque-limiting gear box and teeter-control systems. With 2 blades rather than the more common 3, the system has a very high power to weight ratio relative to other systems. The company has recently achieved significant contracts for its turbines in Scotland.

Powerhouse Wind has developed a domestic-scale turbine, the Thinair 102. The firm's principals are from the NZ domestic appliance industry, & have applied mass production designs to their turbine. The system has a teetering hub to cope with strong, variable winds, a downwind single blade with 2 counterbalances and a cut off system to swing the blade into a horizontal park position in extreme winds. As with the UK's *Kingspan Wind,* another down-wind turbine, it has no gear box. A demonstration unit of Thinair now operates at Waitati, north of Dunedin.

US firm *Sheerwind* has developed a venturi effect design with a stationary tower, a funnel and a horizontal, permanently fixed turbine at ground level. The system is 50% shorter than standard turbine towers, has a smaller footprint, and claims a 3-fold increase in power generated as it operates at speeds as low as 3 km/hour. NZ agent, *Pacific Wind* is building a demonstration site in near Whangarei this year.

Ōtaki lies in a semi wind shadow from the prevailing north westerly wind created by Kapiti Island. The economics of a community or large scale wind farm are unlikely to be strong. However, the 3 technologies noted above, or others, may be viable for community, neighbourhood or individuals.

Table 9.3 Wind Turbines – Windflow, community scale turbines

Proprietor:	Windflow – NZ public company. http://www.windflow.co.nz
Value Chain:	Electric power
Application:	Community scale wind turbine
Status of Technology:	Fully commercial now. Client-based operating data available. 97 turbines installed in NZ. Exports have commenced to the UK. Licensee appointed in US market.
Technical Performance Characteristics:	Single size. Twin blade, upwind teetering hub 500kW generator with a torque limiting gear box. Hydraulic system and controller. Low weight. Cut in speed 20 km/hour, cut out 110 km/hour. Tower height, 30m. Rotor diameter 33.2m.
Economic Performance:	This wind turbine technology has a distinct market niche.
Relevance to Ōtaki:	Potential candidate for community scale generation. The INVELOX system below may be more appropriate given the Ōtaki area's wind rating. A complementary energy storage technology/ capacity is required. Access to the grid through the local lines network is critical for the current business case for community wind energy. If local storage is developed, transfer across the local Electra network would need to be agreed.

Table 9.4 Powerhouse Wind, small scale turbines

Proprietor:	Private NZ company. http://www.powerhousewind.co.nz
Value Chain:	Electric power
Application:	Small scale household/ farm site wind turbine. Larger scale versions to be produced.
Status of Technology:	Second version in demonstration in Waitati, Dunedin. Commercial operations scheduled for mid-2013.
Technical Performance Characteristics:	Downwind single blade turbine, direct drive & no gearbox. Current version - 2kW, permanent magnet, 3-phase. Cut in wind speed 12.5 km/hour, cut out 72 km/hour. Suitable for sites with an annual average wind speed of 16 km/hour or higher. Scalable from 1.5kW to 15.0 kW Minimum tower height, 8m. Rotor diameter, 3.6m.
Economic Performance:	Calibration of manufacturing demonstration unit is not yet complete. Projected annual energy output at average speed and incidence approx 3,250 kWh
Relevance to Ōtaki:	Relatively high cut in speed for Ōtaki's wind profile. Potential application for rural properties. A complementary energy storage technology/ capacity is required if energy surplus to the owner's use is generated. Access to the grid through the local lines network would then be critical for the investment case. If local storage is developed, transfer across the local Electra network would need to be agreed.

Table 9.5 Sheerwind, INVELOX Venturi Fixed Tower, scalable wind turbines

Proprietor:	Sheerwind, Minnesota, USA. NZ agent, Pacific Wind. http://sheerwind.com
Value Chain:	Electric power
Application:	Scalable, micro to utility, small footprint, low profile turbine with no external blades.
Status of Technology:	Manufacturing demonstration unit in test in US. Initial results below. Commercial availability, 2013/14. Not yet tested for NZ conditions (wind & climate).
Technical Performance Characteristics:	Fixed, hollow, & tapered funnel tower with venturi effect for air turbine. Wind's velocity is increased by 4-fold. Cut in speed 3km/hour, cut out 96 km/hour. Energy production is 3-fold standard large turbines. Current scale, 50-250kW. Ground level access to turbine & generator.
Economic Performance:	Capital costs in US are quoted at around 45% of standard 3-blade turbines, operating costs around 42%. When combined with higher productivity these elements give a claimed estimated cost of energy of US$0.035/kWh, nearly 1 cent lower than the average natural gas fired generation.
Relevance to Ōtaki:	Very low cut in speed, low capital & operating costs combined with low footprint & profile signal INVELOX as potentially a very suitable technology for Ōtaki. A complementary energy storage technology/ capacity is required. Access to the grid through the local lines network would then be critical for the investment case. If local storage is developed, transfer across the local Electra network would also need to be agreed.

9.3.3 Biogas Engines

Biogas engines employ the technology of the reciprocating internal combustion engine. In a petrol engine, the fuel is ignited, and in a diesel engine it is compressed, creating hot gases which deliver pressure to push a piston. The mechanical energy is either used directly for motive power, or connected to a generator for conversion to electricity. As discussed earlier, the internal combustion engine has low energy use efficiency, but this is lifted significantly if the thermal energy in the exhaust gases is captured and deployed in heating air or water, or for chilling.

9.3.4 Micro Combustion Turbines

Microturbines are small combustion (gas) turbines around the size of a domestic refrigerator generating from 35 to 500kW at temperatures of around 1,000^{o}C, much higher than internal combustion engines. Turbines have a very high power to weight ratio, and the advantage of fewer moving parts. The system uses foil or carbon-air bearings, which can withstand over 100,000 start/ stop cycles. Microturbines can be fuelled by natural gas, biomethane, hydrogen, propane, kerosene or diesel. They have a very high temperature exhaust, from which the heat can be readily captured.

Recent success of micro turbine technology is attributed to two developments. The first was reliable high speed generators which could spin at the same rpm as the turbine. This eliminated the need for reduction gear boxes. The second was advances in electronic control systems permitting "lights out" operation.

Gas turbines work by:

- compressing air (to 3-5 bar) in a single stage centrifugal compressor
- passing the compressed air through a "recuperator" to recover some of the energy from the turbine's own exhaust gases
- the (now heated) air and fuel are mixed in the combustor, causing combustion at around 900-1,000^{0}C
- the combustion gases are directed over the blades of single stage radial turbine, causing them to spin on the turbine shaft, and exiting at around 650^{0}C
- the shaft powering the compressor and a high speed alternator to generate high frequency electric power to be converted to the desired voltage and frequency via a power conditioning system
- exhaust gases pass through the recuperator and their temperature drops to 250-350^{0}C
- passing the exhaust gases pass through a second heat exchanger (in a combined heat & power configuration) to produce steam, hot water, hot air or chilling with an (absorption chiller).

Microturbines typically have an electrical efficiency of between 25 & 35%. If applied in a co-generation situation, the combined thermal efficiency is at least 60%, and can often be lifted to around 80%+. The market was largely created in North America, & the leading US manufacturers are Capstone, Elliott, and Flex Energy.

The European Biomass Industry Association quotes the capital costs for small scale and micro turbines deployed in a combined heat and power configuration at around €1,500/ kWe. Electrical conversion efficiency is estimated at 30-40%, and total energy efficiency 70-80%. Application for the heat and power outputs are important determinants of these efficiencies, as is the nature of the load factor.

Dutch firm Micro Turbine Technology has developed a nano scale turbine of 3kW electric power system with space heating. Demonstration tests commenced in mid-2010, and field & certification tests commenced in March 2013. Certification is scheduled for completion in September 2015. The system achieves a 16% electrical efficiency, which is high at this small scale. The system is targeted at home heating and extending the range of electric motor vehicles. MTT CHP system reduces a home's energy bill by 20-25%.

Bladon Jets is a UK-based micro turbine producer with outputs from 5-100kW. It has developed a single piece compressor blade disk, and has enabled the production of miniaturised axial flow gas turbines. Its markets are in power generation and electric vehicle range extension. Tata is its largest shareholder. They have an interest in Brayton Energy Canada, specialists in heat exchanger & co-gen systems.

Biofuel & biogas powered micro turbines are a strong candidate for deployment in Ōtaki's proposed renewable energy complex. However, as the systems have to be customised for the energy off take of their specific location, no technical details are set out here. The nearest relevant current day commercial applications are the landfill biogas installations in some NZ centres, including Wellington. Installations in Ōtaki are anticipated to be somewhat smaller than these.

9.3.5 Stirling Engines for Co-Generation

Where natural gas is used for home space and water heating a form of co-generation can be used. WhisperGen, originally a NZ company, developed such a system using the Stirling cycle engine. Under normal operations, a domestic system will generate about 1kW of electric power. The system is marketed in Europe, and the units manufactured in Spain. Several other manufacturers now offer this technology.

The Stirling engine improves the efficiency of current fossil fuel usage, but can also be used with biomethane. Use of the technology is expanding to use other biofuels such as wood chips to generate the thermal energy for the Stirling engine.

9.3.6 Fuel Cells

Fuel cells combine hydrogen with oxygen (usually from the air) to produce electrical energy, with heat and water vapour as by-products. The chemical energy of hydrogen is captured in a chemical reaction by which oxygen rich ions leave the cathode, pass through an electrolyte to the hydrogen ions in the anode, where they chemically combine, forming water vapour and thermal and electric energy. As the circuit that is created is usually less than a single volt, fuel cells are arranged in stacks. Some manufacturers, including Ceramic Fuel cells of Australia, supply versions which do not require biofuels to pass through a reformer to convert them into hydrogen.

There are several types of fuel cell:

- Molten carbonate
- Solid oxide
- Polymer electrolyte, or proton exchange membrane
- Phosphoric acid
- Alkaline.

NZ firm ESG Energy employs alkaline fuel cells in its technology, as it is designed for stationary applications. The automotive industry has put a large amount of research effort into developing lighter weight polymer/ proton exchange fuel cells for use in light vehicles.

Typical electrical efficiency of fuel cells is 30-60%, which can be lifted to an overall energy efficiency of 70-90% if the heat can be used. Fuel cells have a relatively high capital cost, and need regular replacement of some components.

9.4 BIOMASS

Biomass in the form of wood has been the traditional source of energy for cooking and heating for humankind. With the development of the metal trades, charcoal was produced under anaerobic conditions to provide higher temperatures, at the cost of serious depletion of the earth's forest cover.

Wood was superseded by fossil fuels, initially coal, and more recently natural gas. Wood remains an important source of energy for homes in many countries, and more widely for industrial & agricultural processes in other economies.

Today, there is a renewed interest in the use of biomass for generating energy. The major forms are:

- Agricultural residues such as corn storks & leaves and sugar & sorghum bagasse (residues)
- Dedicated energy crops such as *miscanthis* & other high yield grasses
- Wood residues, including timber & paper mill off-cuts
- Municipal paper waste
- Algae
- Food & food processing waste
- effluent.

9.4.1 Biofuel for Industrial Heat and Space & Water Heating

Wood and pellets (often from waste) are typically used to heat a boiler to provide heat & steam for industrial processes. Recently there has been a move to combined heat & power plant (or co-gen) systems to lift the recovery of energy generated.

Biomass has the advantage of having a diversity of feedstocks and a wide array of conversion technologies. The biomass fuels typically are transformed into:

1. Solid, eg wood pellets, wood chips & agricultural pellets (hay & straw)
2. Bio gases including biomethane & syngas
3. Liquid fuels such as ethanol & biodiesel (cellulosic ethanol). We do not explore cellulosic ethanol further in this report. However several groups have been exploring it in NZ, including Solray & Genesis. Large commercial plants are being built and commissioned this year in the US by firms such as ZeaChem (combined bio & thermal chemistry), Ineos, KiOR (biomass fluidic catalytic cracking), POET (reactor plus steam explosion), and Abengoa (enzymatic hydrolysis). Large scale is required for competitiveness, beyond Ōtaki's scope.

Efficient technology for burning wood and derivatives is available on two scales, industrial/ large community facilities and household scale (ie wood burners). For Ōtaki, the most appropriate technology is the modern wood burner for homes. The NZ Energy Efficiency & Conservation Agency estimates that the running cost of home space heating with a modern wood burner is 10-12 cents per kWh of useful heat. Wood pellet burners are 13-16 cents/ kWh.

These costs are higher than energy star qualified heat pumps (4-7 cents/ kWh), but significantly lower than electric heating of 25 cents/ kWh of effective heat.

Some models of wood burner include a wetback unit for hot water heating. If the wood can be collected for free, the wood burner running costs would be very low. As heating accounts for about 29% of all the energy consumed in a NZ home, there are significant advantages in the use of heat pumps or modern wood burners.

Table 9.6 Solid Biomass – Wood Burners & Wood Pellet Burners

Proprietor:	Several commercial suppliers available to Ōtaki.
Value Chain:	Biomass
Application:	Home space heating, water heating
Status of Technology:	Mature, commercially available. Comparative performance data for competing brands readily available. Value chain for supply of consumables well established.
Technical Performance Characteristics:	Comparative data and energy star rating available from EECA.
Economic Performance:	EECA estimates the running cost of modern wood burner home space heating is 10-12 cents per kWh of useful heat. Wood pellet burners are 13-16 cents/ kWh. These costs are higher than energy star qualified heart pumps (4-7 cents/ kWh), but significantly lower than electric heating of 25 cents/ kWh of effective heat. Costs can be reduced by the use of free wood.
Relevance to Ōtaki:	Open fires in Ōtaki took 2,750 MWh equivalents of energy in 2007. Migration to heat pumps &/or wood burners would secure major energy savings for the Ōtaki area. Resistance electric heaters consumed 3,980 MWh in Ōtaki. This is another opportunity for replacement with highly more efficient heat pumps and/or wood burners.

9.4.2 Green Waste Biochemical Conversion – Ethanol

This is predominantly the use of green bio mass for fermentation to ethanol. The primary use of ethanol is for transport fuels, usually as an additive to gasoline. Because of its large scale, competition with food producers for horticultural land, and the requirements for blending & distributing into gasoline, ethanol is not considered to be a technology of relevance for the Ōtaki area.

9.4.3 Biomethane

Methane

Methane (molecular formula CH_4) has a very wide distribution in nature. It is the principal component of natural gas (about 99%) and of firedamp in coal mines. In ambient conditions, methane is a lighter-than air gas, and is odourless. It can be compressed or liquefied by refrigeration for transport. It is a significant element in the atmosphere, and is a very powerful greenhouse gas.

There are large methane hydrate deposits on ocean floors especially around India, Japan & NZ. Japanese technologists announced in March 2013 that they had developed a technology to extract methane from the ocean floor.

Methane is flammable in air over a narrow range of concentration (5-15%). Globally, methane (natural gas) is important in the generation of electric power through gas turbines, gas engines and steam boilers. It is reticulated into homes for cooking and water heating (this is available to most north Island communities in NZ). In compressed form, natural gas is used as a transport fuel, and this use has been available in NZ for several decades. In liquid form (LNG) the methane is cleaned and condensed at low temperature, and has an energy density around 2.4 times that of CNG.

Methane can be used as a chemical feedstock, and NZ has seen 2 versions of this use. One is its conversion into a liquid petrochemical, methanol. In NZ, the feedstock was drawn from natural gas fields in Taranaki. Methanol is a widely traded chemical used in the manufacture of formaldehyde for construction materials, paints, nylon, and acetic acid for recyclable plastic bottle manufacture and for additives for the fuels industry, including methyl esters for bio-diesel. Methanol was the basis for the second process in NZ – the Motonui synthetic fuels plant which opened in Taranaki in 1986 & closed in 1997.

Bio Digesters of Livestock & Plant Material – Biomethane

Biomethane production technologies range from simple effluent ponds to bioreactors of various degrees of scale and complexity (plug flow, covered anaerobic ponds, anaerobic digesters and high rate bio reactors). A key factor is the time taken for the bacterial digestion process (retention time) as this determines the scale of the reaction chambers and thereby capital & operating costs.

Biodigesters are a carbon neutral renewable energy technology. Originally developed largely for the treatment of effluent streams and avoidance of offensive odours, the energy and plant nutrients were considered by-products. Biodigesters are a widely used technology for green waste and farming effluent in Europe, Asia & North America. In Europe, digestion of sewage treatment bio solid waste is industry standard. In NZ, only a few cities, such as Christchurch, Hamilton & Manukau have such systems, primarily for reduction of solid waste disposal volumes and to aid in sludge de-watering.

The energy generated is biomethane, which is used directly for heating & cooling, or for the generation of electric power by means of a gas engine or a gas turbine. The US EPA estimated that in 2010 there were 162 anaerobic biodigesters operating in US agriculture generating 45.3 GWh of energy. The International Energy Agency identified that Germany had 6,800 large scale anaerobic biodigesters, processing agricultural, industrial & municipal waste. Other European countries with large numbers of biodigesters were Austria, 551; France, 468; Switzerland, 459; the Netherlands, 237 and Sweden, 230. In Asia, small scale biodigesters have been widely adopted in rural districts – China is estimated to have 8 million, Nepal 50,000.

Biodigesters operate at two distinct temperature bands - 35^{0}C (mesophilic) and 55^{0}C (thermophilic). Different colonies populate the bioreactors depending upon the temperature, which must be controlled. Mesophilic digesters sustain a wider population of bacteria than higher temperature bioreactors, and a slightly higher rate of biomethane production.

To date, biodigesters have not provided biomethane at a cost that is competitive with other energy sources. There has been ongoing research into a design that will transform bio digestion from a cost to a profit centre.

Biodigesters have typically taken 3 forms in the western world:

1. Covered lagoon or up-flow anaerobic sludge blanket, including fixed film
2. Complete mix/ continuously stirred enclosed digesters
3. Plug flow digesters for solid manure (solids above 11%) deposited in long, heated tanks

MIT D-Lab Waste students Hojnacki et al undertook a study of global biodigester technologies for Waste Ventures of India. They identified several additional forms of biodigesters at different scales in a number of countries. These included:

1. China

   Rubber membrane biodigester

   Rubber membranes are a widespread technology in China, typically used with systems such as CSTRs.

   Turbulent laminar pulsation (TLP) modification of upflow Anaerobic Sludge Blanket (UASB)

   This technology is ideally suited to waste streams from starch type processes (eg noodle manufacturing).

2. Central America

   There is wide use of *partially buried polyethylene tube biodigesters.* The region also makes extensive use of *effluent lagoons (ponds).*

3. India

   Floating drum biodigesters

   An underground well-type structure is deployed to hold digestion material, and a floating drum sits on top of it, floating up and down as the volume of gas and digestate rises and falls. The floating drum regulates the pressure inside the biodigester and also pressurizes the methane gas. The technology has been modified into a small HDPE moving drum for urban installations (such as apartment roofs).

   Fixed dome biodigesters

   This model has begun to displace floating drum biodigesters in rural India, as it has a smaller footprint. There are 2 forms, both using a well with a dome of permanent materials.

Over the last decade, an Australian company, Active Research (AR), has developed a new configuration of biodigester technology aimed at maximising the production of biomethane and clean water, and avoiding the production of hydrogen sulphide gases. The AR biodigester has been designed to be both modular and scalable.

The first small scale demonstration plants are in operation in Melbourne (December 2012) and rural Victoria (2013) but performance data is not yet available. If production trials validate the claims of high biomethane production (<70%), then this technology offers a potentially significant source of energy generation that could contribute to the goals of Energise Ōtaki. The high methane content would make it an ideal partner for gas engines or micro turbines.

Table 9.7 Anaerobic Biodigester: Enclosed, Constantly Stirred, Fixed Film Membrane

Proprietor:	Active Research Pty Ltd, Melbourne http://www.activeresearch.com.au
Value Chain:	Biomethane for heating and transport biofuels.
Application:	Bio energy production, neutral carbon cycle, waste treatment of effluent and green materials.
Status of Technology:	System includes a short pre-treatment phase for the biomass. Field tests in train. Potential to be available in commercial scale in 2014/15. Potential to be suitable for Ōtaki dairy & poultry farms. Possibly other biomass.
Technical Performance Characteristics:	Validated data not yet available. Prototype performance gave high biomethane yields and clean water.
Economic Performance:	High production rate/ short retention time/ fast re-generation/ low capital costs. Has the potential to be a viable process in its own right, rather than relying upon waste treatment benefits.
Relevance to Ōtaki:	Technology appropriate for Ōtaki-scale farms and within the project timeframe. Offers potential to treat green waste and effluent streams of Ōtaki community after appropriate trials and product evaluation (public health etc). Biomethane stream could be used as a transport fuel, heating fuel or for micro turbine feedstock. Note, some of these applications have heavy compliance and monitoring requirements. Upgrading the biomethane & certifying it for reticulation in the natural gas pipelines is not viable on cost grounds, so use within Ōtaki is important. The alternative is compression/ liquefying and container distribution to sites not requiring biomethane to be finished to pipeline standards.

The production of clean water from biodigesters also offers important waste treatment benefits to the farming community and the environment. The solid materials from the digester have nutrients able to be formulated into fertilisers.

9.4.4 Liquid Bio Fuels

Algae Biomass

Several NZ companies have been involved in the development of algae as a feedstock for biofuel production. Building on the work of the Aquatic Species Program at the US Renewable Energy Laboratory formed under President Carter in the late 1970s, the rationale was that algae would produce more liquid fuel per area of land than any existing regular crop, and could utilise liquid effluent streams as part of the energy production system. Algae were therefore seen to greatly reduce the competition between human nutrition and energy for productive land ~ the now infamous food-vs-fuel dilemma that is presently a heated debate in many countries.

Bio scientists located 3,000 strains of algae, and found that, under certain constricting conditions, algae would sharply lift their production of oil-forming lipids, but they also stopped multiplying. In 1996, the US DOE closed the algae program to focus upon ethanol. The algae collection was broken up, with much of it going to Hawaii and to NZ, with the appointment of one of the directors to a senior position at the University of Otago. Today, the Cawthron Institute in Nelson houses a national algae collection for NZ.

The DOE has re-started the algae project at a re-constituted national Renewable Energy Laboratory in Golden, Boulder, CO. Private sector investors in algae biofuels projects include Exxon Mobil & Chevron.

Several NZ companies became engaged in extending the algae biofuel development programme. The organisations include NIWA, who worked with Solray Energy. Solray developed a reactor specifically for the processing of the algae into liquid biofuels. Aquaflow, also worked with algae-based bio oils, and developed a value added process in petrochemicals from this feedstock. Cawthron has used its knowledge for the production of shellfish nutrition and nutriceutical extracts. While successful, the algae bio energy projects have not yet demonstrated their economic viability as an integrated production chain, although Aquaflow has demonstration projects now underway in the US.

http://www.nrel.gov/biomass/proj_microalgal_biofuels.html

http://www.niwa.co.nz/our-science/freshwater/research-projects/biofuel-from-wastewater-algae

http://www.aquaflowgroup.com

http://www.cawthron.org.nz/aquatic-biotechnologies/micro-algae-culture-collection.html

9.4.5 SolarConverter of Sunlight, CO_2 & Water to Ethanol & Biodiesel

New US firm Joule Unlimited has developed a new SolarConverter plastic tube system laid directly on the ground. This makes the system fully modular. Photons are directly transformed into fuels without having to transit through an intermediary stage such as lipids or sugars. The system uses a patented 'helioculture' platform with modified microorganisms, which are structured to directly synthesise and secrete ethanol and diesel, rather than keeping themselves alive.

The Joule Sunflow microorganisms use sunlight, waste CO_2 and non-potable water to produce the fuels. Its tests have generated 15,000 gallons of ethanol/acre/year in the lab, and 8,000 in the field.

A demonstration plant, SunSprings, was opened in New Mexico in September 2012. It is targeting a production rate of 10,000 gallons of ethanol/acre/year. It can be expanded to a full 1,200 acre production site. The long term aim is to achieve production rates of 25,000 gallons/acre/year, at which rate the delivered price of the ethanol would be US$1.28/ gallon, excluding subsidies, or 0.34/litre (NZ$0.40/litre @ US$: NZ$ of 1.18). Construction of commercial scale plants is projected to commence in 2014 in several countries. The plants are scheduled for commissioning in 2015.

Trials for the diesel equivalent, a long chain hydrocarbon, are to follow. The Sunflow product is comprised of diesel-range paraffinic alkanes, and can be blended with conventional diesel in concentrations above 50%. It is sulphur- free with a high cetane value. The target production rate is 15,000 gallons/acre/year at a cost of US$50/ barrel without subsidies, or NZ$0.37/ litre.

On 15 April, Joule announced that it had extended the range of its fuels to the essential components of gasoline and jet fuel, medium chain hydrocarbons. Again, the fuels are inherently sulphur-free.

In the SunConverter process, CO_2 is pumped into the tubes, keeping the microorganisms in motion, & maintaining their exposure to the sunlight. The microorganisms consume the CO_2 and continuously secrete the fuel into the (water) medium. The medium is continuously circulating through a separator that extracts the fuel, & sends it to a central unit for final separation. The life cycle of the medium is 8 weeks before cleaning & re-inoculation is needed.
http://www.jouleunlimited.com

9.4.6 Super Critical Water Reactors - Biodiesel

Supercritical water reactors (SCWR) have been an accepted technology for the extraction of liquid and solid bio materials for many decades. The process separates a component from biomaterial by diffusion using fluids in a supercritical state as extraction solvents. Common uses are for decaffeination of coffee and the extraction of bio oils. Carbon dioxide is the most common fluid, but ethanol and water are also used, sometimes with catalysts.

The supercritical state of the solvent is created through the application of heat and pressure which can be modified by altering the temperature-compression configuration and the flow rate. Continuous process versions of the processes have been developed in recent years.

In NZ, this technology has been applied to biofuels extraction from algae and solid biomass by Solray. The demonstration plant was located at the Bromley sewage treatment site in Christchurch, but this site was badly affected by the city's earthquakes.

Table 9.8 Supercritical Water Extraction of Biodiesel

Proprietor:	Solray Energy, Invercargill http://www.niwa.co.nz/sites/default/files/algaeoilproduction_-_solray.pdf http://www.bioenergy.org.nz/documents/publications/Liquid%20Biofuels/KeyPlayers%20in%20NZ%20LiqBio/Solray%20Energy.pdf
Value Chain:	Liquid biofuels
Application:	Drop in replacement of diesel and aviation fuels
Status of Technology:	Version 1 in operation in Christchurch. Commercial scale demonstration plant of version 2 commissioned. Performance trials interrupted by the Canterbury earthquakes, and not completed. Liquid fuels component confirmed. Gas elements not calibrated.
Technical Performance Characteristics:	Modular & scalable, continuous feed system with "lights out" process control & monitoring.
Economic Performance:	Performance trials for version 2 to be restarted. System can be available within 12 months.
Relevance to Ōtaki:	Community-scale technology, able to process biomaterials directly to liquid fuels. Can handle solid & toxic materials. Preparation sequence determines economic viability. Economics of this system need to be demonstrated. Potential interface with other technologies & activities of the **Ōtaki Clean Technology Centre** is possible.

9.4.7 Pyrolysis

Pyrolysis is the thermo chemical deconstruction of organic material at high temperatures in the absence of oxygen. Typically, a bio-oil is produced form condensed biomass vapour. Its original application was in the production of charcoal. Today, it is a commonly used chemical process, generating syngas, bio char, and for petro chemical cracking. The process requires heat inputs, but some-all can be drawn from the syngas that it produces. A vacuum may be created to lower the boiling point of the materials

Ōtaki Clean Tech centre tenant, Spectionz (now Waste Transformation) has developed a small scale version of the system using a microwave to induce the pyrolytic state. It has been used for the processing of sewage waste solids, plastic and rubber tyres. Originally aimed at waste reduction, the process generates a bio diesel fuel. The scale is applicable to the needs of communities the size of the Ōtaki area, and the Kapiti Coast district. The smaller scale markedly reduces collection costs of the waste materials.

Rayners, an Invercargill engineering firm have a similar pyrolysis technology prototype, also processing car tyres. Operating details are not known.

Table 9.9 Small Scale, Slow Pyrolysis for Rubber, Plastics & General Organic Waste

Proprietor:	Waste Transformation Ltd (NZ), previously Spectionz http://www.digitaltree.co.nz/Demo/Spectionz
Value Chain:	Waste reduction with biodiesel and bio syngas as by-products
Application:	Plant has optimal configuration for the treatment of and recovery of fuel from tyres & plastics. System is both modular & scalable.
Status of Technology:	Large scale plants are an established international technology. Demonstration phase of NZ small scale design with micro wave initiation in progress, including at Ōtaki.
Technical Performance Characteristics:	Conversion factor 5:1, waste: product. Simple blending operation. Feed-in can be automated for standardised feedstocks.
Economic Performance:	Final data from demonstration sites not available. Modest capital costs ($80,000)
Relevance to Ōtaki:	An important technology to eliminate solid waste with modest net energy production.

9.4.8 Gasification

Gasification is a process whereby biomass is burnt with a restricted supply of air, oxygen or other oxidising source. The process involves devolatisation, combustion & reduction. Gasification is an effective way to convert biomass into a gas stream able to be deployed in a range of applications.

Various products are generated in the 3 different phases of gasification:

1. devolatisation, where heat creates:
   - an active char
   - methane gas
   - other hydrocarbons
2. combustion partially burns the above products generating;
   - heat
   - CO_2
3. Reduction, where the CO_2 reacts remaining bio char and produces Producer gas (CO)
4. Water from the biomass vaporises and forms hydrogen, another fuel component.

The gas products from gasification can be used directly in gas turbines, boilers or as a feedstock for other chemicals. The quality of the gas can be managed through utilisation of a number of ancillary technologies such as indirect heating, pressurisation and oxygen injection.

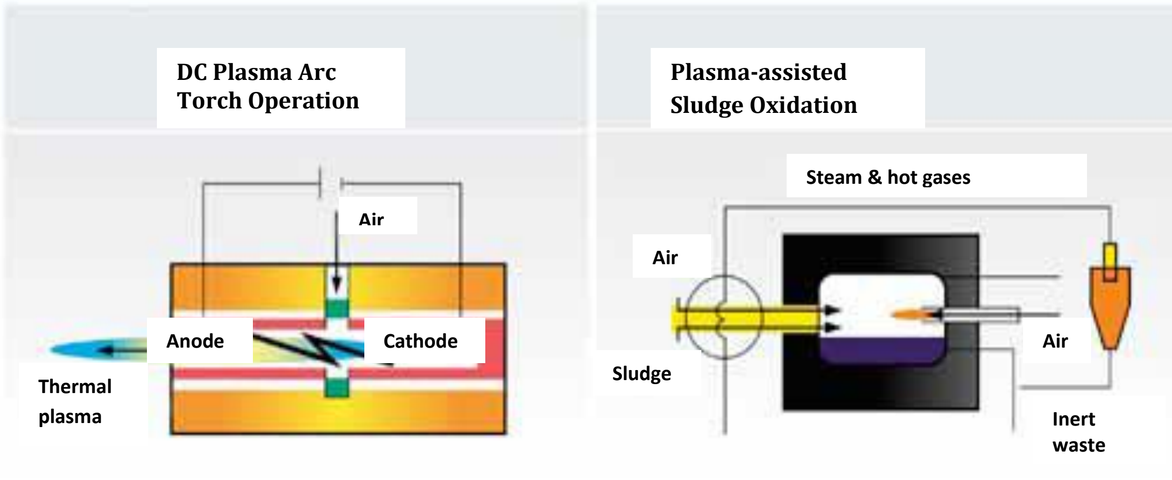
Gasifiers come in various designs, including up & down draft, fluid beds and entrained flow. Each has distinct performance characteristics, different feedstock synergies, and produce different qualities of gas. In general, gasifiers require technical operator skills. Many are a part of co-gen systems. There are a number of pilot plants that are taking the biogas through to liquid fuels - biodiesel in Germany and bioethanol in the US.

Plasma-Assisted Sludge Oxidation & Heat Generation (PASO)

Canadian firm Fabgroups Technologies has developed a system for the treatment of sludge from industrial processes such as paper making, food processing waste treatment plants. Developed in collaboration with Hydro Quebec, the PASO process is an incineration technique that deploys an atmospheric-pressure rotary kiln operating at 600ºC. It is fitted out with a low-power plasma arc torch, which supports oxidation by catalysing the destruction of organic matter in biomass sludge.

The design permits continuous operation, and does not melt or sinter inert waste. Fuel consumption is 125 kWh per wet tonne of sludge (> 20% organic content). The ash that accumulates in the kiln acts as a heat transfer medium between the kiln walls and newly loaded sludge. Some of the air used to oxidise the organic material is used directly as a plasma-forming gas. Diagram 9.2 provides a schematic outline of the PASO process.

Diagram 9.2 Process Outline of the PASO Incinerator



Source: Hydro Quebec
http://www.hydroquebec.com/innovation/en/pdf/2010G080-32A_OHAP_(PASO).pdf

The use of thermal plasma produces a much reduced demand for energy, and reduces the sludge to 5% of its original mass. Heat from the process can be recovered for hot air, hot water or power co-gen applications. The PASO process can handle biomass heavy with fats and contaminants.

9.5 SOLAR THERMAL ENERGY SYSTEMS

Solar thermal energy systems harness solar energy for heating of building space, water and drying. They may heat either air or liquids. Building design can also utilise thermal mass to capture solar energy during the day and release it for space heating in the evening.

The US recognises 3 categories of heat collectors for solar hot water:

1. Low temperature, typically flat plates for the heating of swimming pools
2. Medium temperature for domestic and industrial space and water heating
3. High temperature collectors that concentrate sunlight for electricity generation, a fast growing application, but not explored further in this study. Their main advantage is that they can store energy as heat before its conversion to electricity. Storing heat is presently much cheaper than storing electricity.

Solar hot water systems (SWH) have become a feature of the NZ market place, and are typically roof mounted. However, the systems have a significant up front capital cost. Experience is that, as cost effective measuring & display of SWH performance have not been available, household members tend to regard their hot water as "free" and sharply lift & miss-time their use it. New, simpler, more accurate and more reliable units – which include a dashboard for the users - are currently being released by Sunnovations & competitors in the US.

http://www.youtube.com/watch?feature=player_embedded&v=qJIHF8KUng

Two types of system are available in NZ:

1. Flat plate collectors which have copper pipes within a glass covered collector, connected to a water storage tank, usually located on the roof. The water thermosyphons through the tank to heat the home's water.
2. Evacuated tube solar collectors which use a glass tube inside a vacuum with copper tubes running through the centre. These pipes are connected to circulation pump that pumps water storage tank in the house.

NZ firm, Thermocell has developed a patented evacuated plate collector, combining features of both flat plate evacuated tube collectors. It is a pumped system with protection to eliminate boiling and to provide frost protection. Thermocell has been supplying these systems for 30 years. http://www.solarcity.co.nz/thermal

NZ's solar "endowment" is around 2,000 hours of sunshine pa, similar to that of Melbourne and greater than that for much of northern Europe. The average NZ house rooftop collects 50 times more energy than is required for its water heating. Allowing for variability, a well designed & installed solar hot water system should supply 50-75% of a home's annual hot water requirement.

Ōtaki Clean Technology Centre member ***Solarzone*** distributes solar hot water systems in the Wellington Region. Energy is stored in an (insulated) hot water cylinder.

http://www.solarzone.co.nz/solar_hot_water.html

Table 9.10 Solar Thermal Energy – Hot Water

Proprietor:	Several imported and domestic systems commercially available in NZ
Value Chain:	Energy for heat
Application:	Hot water generation for home to commercial buildings
Status of Technology:	Fully commercial. A market quotation service for accredited suppliers and installers is available at http://www.mysolarquotes.co.nz
Technical Performance Characteristics:	*Solarzone* specs provide an example: 3m^2 collector, 200 litre water tank, supplies around 120 litres/ day of hot water 5m^2 collector, 300 litre tank, 150 litres/ day (equivalent of 1,858 kWh)
Economic Performance:	Initial investment \$3,500-\$10,000 depending upon size of household and technology choice. Energy savings in NZ are typically of the order of 50-75% of hot water energy (equivalent to a reduction in total power costs of 20%). The return on investment is similar to that of solar PV in NZ – around 8-10%.
Relevance to Ōtaki:	Ōtaki has a similar climate to the Nelson-Marlborough-Wairarapa axis, so is a favoured NZ site for solar energy systems.

Solar Steam

In late 2012, Rice University in the US announced the success of a new version of solar energy - *Solar Steam.* Solar steam utilises light capture by nanoparticles to generate heat. Rice claims an overall efficiency of 24% for the technology they have called photo thermal conversion. The technology has applications in medicine and biotechnology. In biotech manufacturing, it offers major savings in heating and the use of solvents.

9.6 ENERGY AVAILABILITY

The following 2 chapters explore the options available Ōtaki for the storage of renewable energy so that the demand profile of the area's energy users can be met. Chapter 12 then considers some options for community scale energy facilities, and the role of Electra's lines network within Ōtaki as a "smart mini grid".

10 OFFGRID ELECTRIC POWER STORAGE

10.1 OVERVIEW

Implicitly, renewable energy technologies that Energise Ōtaki wishes to exploit commit the area to distributed generation. This is in direct contrast to the legacy lines network in the area, which was designed to distribute power from the national grid to Ōtaki's customers. A new collaboration with Ōtaki's lines company, Electra, will need to be explicitly negotiated so that the network can be transformed into an "intelligent" grid able to handle energy generated within the area, and distribute it to local and external customers.

Local lines company, Electra, already has in place protocols for local generation of different size and types. An application process is required – see the Distributed Generation section of this web site: http://www.electra.co.nz/services

For larger than residential installations, Electra would welcome direct discussions, as these projects might require changes to the Ōtaki network. These projects will need to be handled on a case-by-case basis.

Distributed energy systems also need to be designed to be flexible and efficient. Individual customers, generators and those with their own micro & mini networks need to design systems that can interface effectively with the lines network. An important aspect of this is intelligent demand management, and load management to assist in managing short peaks that require large, but briefly used capacity. There are several ways to do this, including "smart metering" and smart home energy management. In November 2012, a Japanese task force set a goal of ensuring that each of Japan's 53.4million homes will be equipped with a home energy management system by 2030 as a foundation for a totally smart grid. Japan is also to promote the installation of cogeneration fuel cells (these can run on natural gas or biomethane) and solar thermal power.

As Ōtaki moves to self-generation by means of renewable energy, it will need to install some storage capacity. This can take several forms, but if it is to be an effective partner with the Electra lines network, it needs to have the necessary response times and management systems that enables safe & sound management of the local lines network. Energy storage candidates are:

1. Electric power:
   i. Hydro pumped storage
   ii. Battery systems
   iii. Hydrogen with fuel cells
   iv. Supercapacitors
   v. Superconducting magnetic energy storage
2. Direct heating & cooking:
   i. Wood biomass
   ii. Hydrogen
   iii. Biomethane
   iv. Hot water storage

3. Compressed gas storage
4. Liquid fuels:
    i. Biodiesel
    ii. Ethanol

10.2 ELECTRIC ENERGY STORAGE

10.2.1 Pumped Hydro Storage (PHS)

Pumped hydro storage is the dominant form of bulk storage of renewable energy worldwide. It is used to collect excess or energy generated in low demand periods to shift energy to be available for peak demand. Energy efficiency is typically of the order of 75-80%.

The PHS system uses 2 interconnected storage lakes at different heights with off-peak electricity used to pump water from the lower lake to the higher, and when needed, the water is released to the lower reservoir, generating hydro-electricity. The Fraunhofer Institute and US Electric Power Research Institute (EPRI) estimate that there is around 127,000MW of pumped hydro storage globally.

10.2.2 Other Gravity Systems

A new California company, *Gravity Power*, has a 2-shaft, underground system, 1 shaft with a much larger diameter than the other. The 2 shafts are connected top and bottom, with a pump-turbine/motor-generator configuration. A large piston is located in the larger shaft, and is lifted when power is being stored, and falls as energy is drawn off through the generator. Designed for grid-scale deployment, the system has energy efficiency above 80%. This may have the potential to serve as an area scale energy storage technology for Ōtaki?

http://www.gravitypower.net

Another California company exploiting the power of gravity for energy storage/ load shifting is *Advanced Rail Energy Storage*. It uses modified railway cars and a specially built low friction rail track to pull shuttle trains with axle drive motors uphill to an upper storage yard. When energy is required, the process is reversed. The system exploits new breakthroughs in motor/ generator traction drive and power control technologies, and combines them with established railway technologies. The charge/ discharge efficiency is 78% and is constant over the full range of discharge - power output. Storage capacity is in the range of 200MWh and 100MW withdrawal capacity up to 24GWh of energy storage with3GW withdrawal capacity. The capital cost is approximately 60% of pumped hydro storage. We consider this technology to be too large (in terms of footprint) for Ōtaki.

http://www.aresnorthamerica.com/ares-performance
http://www.nwcouncil.org/media/4440767/ares.pdf

Energy Cache is another company developing a novel form of gravity – aerial ropeway with gravel buckets - as an energy storage system. Their demonstration system is a 50kW installation. http://www.energycache.com

10.2.3 Inertia Systems – Flywheels

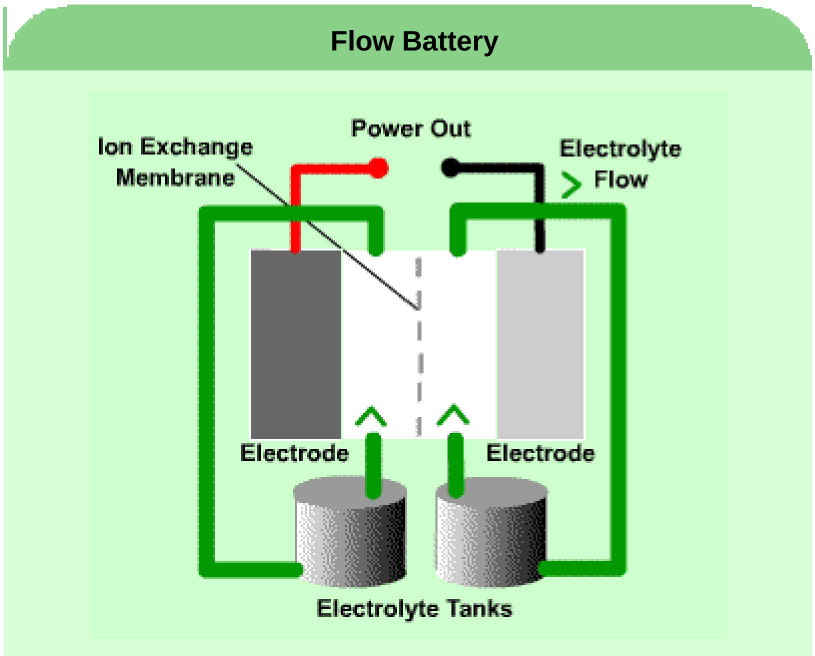
A flywheel is accelerated to very high speeds and maintains that mechanical energy in rotational form. This energy is drawn off as electricity and the flywheel slows down. Modern flywheels are manufactured from advanced materials, operate in a vacuum with magnetic bearings, and rotate at very high speeds <50,000 rpm. The engineering is very advanced and capital costs high.

Leading producer Beacon Power went through financial restructuring in 2012, but still trades as a private company. The 4th generation of its technology is being introduced to the market now. Recently formed Velkess claims to have developed a self-stabilising rotor system which greatly reduces costs. http://www.beaconpower.com http://velkess.com/about.php

10.2.4 Flow Batteries

Flow batteries (redox) are built around 2 aqueous electrolytes which are held in separate tanks. When the electrolytes are pumped into a chamber separated by a membrane, an electron-producing chemical reaction occurs. To store energy, external electric current is applied across the membrane and the system works in reverse. The system has pumps & tubes, which require a maintenance cycle. Flow batteries have high energy density, can back up neighbourhood power supplies, and smooth power from renewable energy generators.

Diagram 10.1 Flow Battery Schematic



Source, Electropaedia

Flow Batteries have relatively high energy density; can be expanded by increasing the size of the electrolyte reservoirs, and have a long cycle life. They are generally applied to relatively large stationary applications (100kWh – 10 MWh range). They are not prone to thermal runaway as systems like Li-ion are. The efficiency is around 60-75%.

The technology remains expensive, but new versions have brought cost to US$500/ kWh, or around ⅓ the cost of Li-ion and ¾ of the sodium sulphur battery. There have been several problems scaling up, which has seen some of the development companies fold. Attractive For Ōtaki, because of the scalability, but the capital costs are quite high and the electrolytes have to be renewed and recycled. New designs are being offered which overcome these issues.

Austrian-German venture Gildemeister Energy Solutions has announced the release of an integrated system of a vanadium redox flow battery & recharging system optimised for integration with solar PV and wind turbine generating technologies. Known as the CellCube, the battery is supplied by Cellstrom and is modular and scalable.

http://www.primuspower.com http://enervault.com http://en.cellcube.com/en/index.htm

10.2.5 Sodium-Sulphur Battery

The sodium-sulphur battery is one form of a molten salt battery. It is constructed from inexpensive materials, and uses liquid sodium and sulphur. It has the advantages of high energy density, a high efficiency cycle of charge/ discharge of 82-92%, and a long cycle life. However, it runs hot at temperatures around 300-350^{0}C, and sodium polysulphides are highly corrosive. The technology is therefore restricted to stationary applications. Sumitomo has developed a version that can operate at temperatures under 100^{0}C which it plans to have in commercial production in 2015.

The cell is usually a tall cylinder, enclosed by a steel casing whose inner surfaces are protected from corrosion. The molten sulphur performs as the positive electrode, and the molten sodium as the negative electrode. The electrodes are separated by a solid sodium-alumina ceramic. During discharge, polysulphides are formed.

The economics of the battery are enhanced with increased size. The technology is used as a major grid storage technology in Japan, championed by Tokyo Electric Power Co. The batteries have been in production since 2000, with an efficiency of 87% and a life time of 2,500-4,500 cycles, depending upon the depth of discharge (DOD).

The large scale required for an economic storage solution places this technology outside the scope on Energise Ōtaki's needs.

10.2.6 Ceramic Tube Batteries

A new ceramic tube solid electrolyte battery was released by *GE* in 2010. It is based upon South African molten salt technology, acquired in 2007. In mid-2011 GE opened a $100m manufacturing facility in Schenectady, NY, for its new Energy Storage Technologies unit. It offers a fast charging cycle, (20% of lead batteries) and does not require air conditioning.

Their first markets are remote cell-phone towers in Africa and US wind farms & grids. This technology is scalable, and would be one candidate for Ōtaki's energy storage needs.

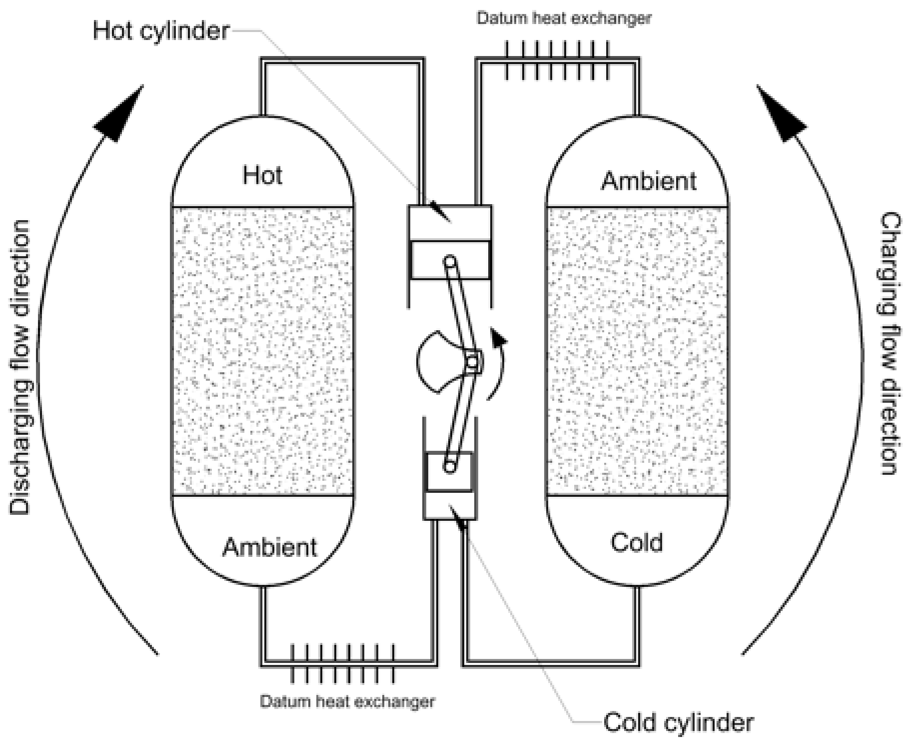
http://www.timesunion.com/business/article/GE-plant-to-double-down-3697727.php

10.2.7 Pure Heat Storage

A Cambridge UK firm, *Isentropic* has developed a pumped heat electricity storage system which pumps argon gas to transfer heat between 2 large tanks filled with mineral particles. Incoming energy drives a heat pump which pumps heat from one container to the other, dropping the temperature in one to -160^{0}C, and lifting it in the other to 500^{0}C. The heat pump can be thermodynamically reversed to operate as an engine and power a generator. The heat is transferred from the hot to the cold container. The system is modular and scalable. It has an efficiency of 72-80%, depending upon size. Isentropic claims to have the lowest cost of any electricity storage device (a storage cost of US$35/MWh stored). Unit size is 2MW.

The company has just attracted significant scale up investment capital & project funding from the Energy Technologies Institute, to be deployed on a 1.5MW/6 MWh electricity storage unit for a UK primary substation in the Midlands.

Diagram 10.2 Pumped Heat Energy Storage



Source: Isentropic

From an Ōtaki perspective, the unit capital cost is extremely attractive, but the minimum scale is high. It seems that the minimum scale is falling fast from the specifications of the latest project. This technology should be incorporated as a potential candidate, but might fall outside the time envelope for initial installations. http://www.isentropic.co.uk

10.2.9 Aqueous Hybrid Ion Battery

US firm *Aquion Energy* produces storage batteries utilising salt water based electrolyte with an activated carbon anode and a manganese oxide cathode. These are fault tolerant, nontoxic, non-corrosive materials, and Aquion reports low fade after 5,000 – 15,000 cycles. The batteries are made in stacks of modular cells, and are suitable for deep cycle, long duration applications. The batteries will enter commercial production in 2013.

http://www.aquionenergy.com/technology

Oakland, California based *BrightSource Energy* has also developed a heat battery system to complement concentrated solar power. The storage system, SolarPlus uses a heat exchanger to transfer heat captured from the heliostat and feed it into steam turbine. The system is being deployed for power utility, Southern California Edison. CSP is a technology well beyond Ōtaki's size.

http://www.brightsourceenergy.com

10.2.8 Liquid Metal Batteries

MIT spin-out company *Ambri*, is pioneering a liquid metal battery. Typical units are refrigerator sized and greater. It consists of two common low cost metals and a salt that float on top of each other. The system operates at temperatures up to 500ºC. It is able to store <12 hours of energy and release it slowly over time. It is able to respond to regulation signals in milliseconds. It has a very low maintenance requirement.

. http://www.ambri.com/storage/documents/ambri-brochure-web5.pdf

Table 10.1 Liquid Metals Battery

Proprietor:	Ambri Inc. Bill Gates, Khosla Ventures & French oil company Total are cornerstone investors
Value Chain:	Electric power
Application:	Storage of renewable energy and peak power shifting (load levelling) on networks and grids. Emergency power supply.
Status of Technology:	Commercial prototypes to be delivered in 2014. Scale: small neighbourhood to community.
Technical Performance Characteristics:	Demonstration unit results; o 7 months continuous operation, 75-80% efficiency o <10 minutes assembly o 4" square cell is building block for a modular system o Cells operated in series & parallel strings o Cells are sealed in circular steel containers similar in size to an ice hockey puck o the intense flow of current creates the heat to keep the metals in a molten state. Full scale prototypes in 2014 <500kW + 2MWh storage (equivalent of daily electricity demand of 70 US homes). Long lifespan, no cycle-to-cycle capacity fade.
Economic Performance:	2014 full scale prototype costs well below US$500/kWh
Relevance to Ōtaki:	Can be scaled to user requirements. The small cell size enables a battery to be customised to the scale and needs of the network/ power user. This battery has all the inherent response and storage needs of a community network. Available for non-grid deployment from 2015. Major issue is to what extent the capital cost will fall as production is stepped up. A technology to monitor.

10.2.10 Supercapacitors

Superconductors have been characterised by high initial cost offset by a very long service life. They can capture and facilitate the reuse of kinetic energy whether from braking, or forklift dropping and shortly from elevators. Many of these situations require rapid charge & discharge, ideally suited to the performance profile of superconductors. Long used in trains and trams, supercapacitors have begun to be deployed in modern aircraft such as the Airbus 380.

Recently, and led by the motor industry, supercapacitors have been used across a Li-ion battery to both improve the battery's performance, and to extend its life. The high up-front cost of a supercapacitor is no longer the block it once was. An important reason for this is that the supercapacitor will last for the life of the vehicle, avoiding mid-life replacement costs. The supercapacitor is beginning to eat into the market of the Li-ion battery.

One reason for the increase in credibility of the supercapacitor is the recognition that it is a much safer technology. As non-flammable aqueous electrolytes are deployed, supercapacitors are less and less subject to fires and toxic accidents as is the Li-ion technology (witness the Boeing 787 Dreamliner troubles).

10.2.11 Superconducting Magnetic Energy Storage (SMES)

SMES store energy in a magnetic field which is created by the flow of DC electricity in a superconducting coil, cooled to very low temperatures where the super conducting state of the coil is achieved. The superconductor does not lose energy at these temperatures.

The advantage of SMES is their almost instantaneous response time for charge & discharge. Combined with its high costs, the rapid response time of SMES technology means that it is largely applied to power quality control situations such as grid stability, and to sites requiring ultra-clean power such as microchip fabrication plants. NZ firm *HTS 110* is an important company within the high temperature superconducting industry.
http://www.hts110.co.nz

10.3 BIOHYDROGEN

Hydrogen, as atomic H, is most abundant, lightest element in the universe. In ambient conditions, it is a highly combustible non-metallic gas in the form of H_2. It is present in water. It has the highest thermo conductivity of any gas and thus is used as a coolant in a number of applications including power stations. It readily forms covalent compounds with most non-metallic elements. Hydrogen is typically produced industrially from steam reforming of natural gas (as in the production of methanol) but can also be produced by the electrolysis of water with electricity generated with renewable sources.

Hydrogen can be either extracted from methane (natural gas, a fossil fuel) oil or by electrolysis of water (around 5% of global production). Electrolysis processes have energy efficiency of 50-80%. In the fuel cell, the hydrogen reacts with oxygen to produce electric power and water.

In late March 2013, researchers Curtis Berlinguette and Simon Trudel of the University of Calgary published a paper in *Science* demonstrating the manufacture of much cheaper catalysts for electrolysis of hydrogen. They also announced the formation of FireWater Fuel, a company to produce the catalysts by 2014. The key invention is the making of catalyst films from any metal using light decomposition. The aim is to service wind farms, and then by 2015 to have freezer sized electrolysers that could convert litres of water a day into electricity for consumers.

Hydrogen is most commonly used for processing petrochemicals and the manufacture of fertilisers via ammonia. It can also be used for cooking and heating. The automotive industry has been developing its use for transport through hydrogen fuel cells, as they are 2-3 times more efficient than the internal combustion engine (refer to Section 9.3.6 above).

Hydrogen has been promoted as a clean energy alternative to the present day hydrocarbon economy for motive power, heating and cooking.

Hydrogen can be used to store renewable energy from intermittent sources. It can then be re-used as needed either in heating/ cooking or in generating electric power. In this peak load role, hydrogen may be applicable to the situation in Ōtaki.

Hydrogen storage is an issue. It can be stored underground for grid energy storage for intermittent renewable energy sources. It may be liquefied by cryogenic cooling, but as its boiling point is around 20⁰K, a significant energy loss is involved in this cooling.

Liquid hydrogen energy has less energy density by volume than hydrocarbon fuels (around 25%). By comparison, compressed hydrogen gas has a good energy density by weight, but less by volume than hydrocarbons. Approximately 2.1% of the energy will be lost to powering the compressor. Hydrogen may also be stored with metal hydrides.

NZ firm ***ESG Energy*** is currently commercialising a new low cost system for the storage of hydrogen – low pressure "earth batteries" which are based upon common plastic pipes laid underground. The system was developed by Industrial Research, and details are given below. This is not unlike the use of large natural underground caverns utilised by ICI for many years.

Table 10.2 Stationary (Underground) Hydrogen Storage

Proprietor:	***ESG Energy***, Lower Hutt, NZ. http://www.esgenergy.co.nz
Value Chain:	Hydrogen gas for motive power, heating and chemical industries.
Application:	Low pressure, low cost, safe storage of hydrogen gas in underground storage tubes. Scale: small neighbourhood to community.
Status of Technology:	Small scale prototypes completed for stationary and mobile applications. Stationary unit is in test within a hydrogen energy value chain for remote locations in Wellington. Multi-user delivery & metering systems in development. Volume manufacture prototype in development. Projected supply is 2015. Technology is scalable and modular. Effective operational scale is projected to be from neighbourhood to district.
Technical Performance Characteristics:	Storage in underground plastic pipes at 2-4 bar. Slow leakage rate. Fully scalable and modular.
Economic Performance:	The HyLink storage system is low capital and operating cost, providing a cost-efficient storage system for renewably produced hydrogen. If used for cooking & heating, useful energy performance is good. Second transformation into electric power substantially lowers overall energy use efficiency unless heat from fuel cell can be captured and utilised. Initially, there is a very strong business case for energy storage in remote locations, including remote farming communities and South Pacific island nations. The distribution pipeline can be used for storage capacity as well.
Relevance to Ōtaki:	The earth battery has potential as a storage medium for renewable energy (electricity) generation (solar PV or wind turbines). The hydrogen may be transformed back to electricity via a hydrogen fuel cell, or deliver the hydrogen for heating & cooking. Prospective scale of hydrogen production in Ōtaki is unlikely to be sufficient for supplying to industrial chemical/ fertiliser industries outside the area.

10.4 COMPRESSED AIR STORAGE

Compressed Air Energy Storage systems are the second largest renewable energy storage systems globally, albeit at 440MW, only a shadow of the capacity of pumped storage hydro.

Another 500MW has since been commissioned in Texas. The established plants were built to manage peak loads, but the growth of intermittent, variable renewable energy generation has created a new demand for energy storage.

The compression of air generates heat, and its expansion absorbs heat. Storing and re-using the heat in the compression/ expansion cycle greatly improves the efficiency of compressed air energy storage. The heat management systems are known as isothermal or isentropic. With isothermal, the air is kept at a constant temperature, and the heat removed through heat exchangers (intercoolers). Carbon fibre or Kevlar storage vessels weigh around 25% of steel gas bottles.

Today there are 4 CAES facilities in operation:

1. RWE's 320MW Huntdorf hybrid facility in Germany, built in 1978, which uses a salt dome & operates at 42 % efficiency
2. Southern Energy's McIntosh, Alabama, US hybrid 110MW facility built in 1991 with a 26 hour capacity, utilising a salt mine cavern & operating at 54% efficiency
3. General Compression's Watertown Massachusetts 100kW multi-stage demo facility built in 2011. Performance details are not known for this proprietary system.
4. General Compression's Gaines, Texas 500MW storage 2MW near isothermal facility commissioned in late 2012.

RWE, Zublin, DLR & GE are cooperating in the construction of ADELE, a €12m, 360 MWh demonstration storage facility in Stassfurt, with 90MW electric output. The facility provides substitute capacity at very short notice equivalent to the output of 50 local wind turbines for 4 hours. The technology is an adiabatic process, where the heat from compression is captured in ceramic moulded bricks in 40m high pressure vessels, stored and released during expansion. Operating conditions include heating compressed air to over 600^{0}C and 100bar. The efficiency is estimated to be 70%, approaching that of pumped storage hydro.

French/ Luxemburg firm Motor Development International is developing a set of standby and production generators that can be used for renewable energy storage. Their technology is discussed in Section 10.6 and Table 10.5 below.

US firm *SustainX* is also active in compressed air energy storage, with an isothermal design/ crankshaft engine design which captures the heat energy of compression. It uses an MAN turbo-diesel crankshaft. SustainX has a grant from the US DOE to build a multi-megawatt grid-connected energy storage system in Seabrook, NH. Effective life time is estimated to exceed 20 years. http://www.sustainx.com

LightSail Energy is another US company rapidly developing compressed air energy storage. It uses a fine water spray to capture the heat energy of compression, separates it from the compressed air. The water is stored in a tank and releases it in the expansion phase. The company claims a thermal energy efficiency of 90% per full cycle. Commercial production has not commenced yet, although the company has just received substantial investment funds for scale up.http://lightsailenergy.com

Table 10.3 Compressed Air Energy Storage

Proprietor:	RWE European consortium & General Compression, USA.
Value Chain:	Electric power
Application:	Compressed air storage for renewable energy
Status of Technology:	Commercial plants in operation. The technology of General Compression is modular & scalable from community energy to utility scale installations. RWE's is large utility scale. Reviewing projects under construction and in planning approval processes, this technology will see a significant increase in the number of suppliers and sites from 2016.
Technical Performance Characteristics:	Both systems are forms of adiabatic (isentropic). RWE reports 70% energy efficiency through use of the compression heat. If electricity is renewable, no greenhouse emissions are made. RWE Strassfurt plant is teamed with a wind turbine farm. Energy storage gives greater flexibility for the operator.
Economic Performance:	Data for General Compression is not available, but the Texas plant is also located in a wind farm. Energy efficiency of 70-75% is claimed. The stored energy in the installations can also be used for load shifting.
Relevance to Ōtaki:	Smaller scale units may provide an energy storage facility for renewable power generation which can take advantage of load shifting. The business case would need investigation. This technology is now sufficiently advanced in market to be on the list of alternatives for Energise Ōtaki.

http://www.rwe.com/web/cms/en/365478/rwe/innovation/projects-technologies/energy-storage/project-adele-adele-ing

http://www.generalcompression.com

10.5 LIQUID AIR STORAGE

UK firm Highview Power Storage is developing utility scale energy storage systems using cryogenic (super cold) technologies to liquefy and store air or nitrogen. Highfield has deployed an industry demonstration system hosted by Scottish & Southern Energy. The system enables large volumes of air to be stored at atmospheric pressure for use either on site or transported to other customers. The expansion factor of the air between -196^{0}C and ambient temperature is 700 times. A cryogenic engine captures this energy from phase-change within a confined space.

The essentials of the system are that electric power is used to drive a cryogenic air liquefier, and the liquid air is stored in an insulated tank at atmospheric pressure. To generate power, the liquid air is released from storage, pumped to high pressure and vapourised & heated to ambient temperature. A high pressure gaseous air stream is created, and is used in an expansion turbine/ generator. The 'cold' exergy is captured and used again in the liquefaction process. The recovery halves the cost of liquefaction, and gives a full cycle efficiency of around 50%. The system can utilise waste heat to power the recovery process, even low grade heat.

10.6 LIQUID BIOFUELS

Liquid biofuels are a form of energy where the carbon fixation has been created biologically. They offer a drop-in replacement or substitute for the fossil fuels widely used today in the transport sector. With their high energy density, liquid fuels are a good medium for energy storage, but do require dedicated infrastructure for storage tanks and distribution.

10.6.1 Bioethanol

Bioethanol is a bioalcohol typically fermented from crop sugars or starches. Recent growth in production has been criticised for the competition it creates for land which could otherwise be used for food production. Bioethanol can also be generated from cellulosic sources such as tree foliage and grasses. While able to be used as a fuel in its own right, bioethanol is typically used as a gasoline additive. It has significant market penetration in Brazil & the USA, and is the world's largest biofuel by far. Other 'first generation' biofuels include propanol and butanol. Butanol is widely considered to have high potential, but in a time horizon beyond that used for this study.

10.6.2 Biodiesel

Biodiesel is made from vegetable oils such as soya, rapeseed, mustard, flax & sunflower, and from animal fats. A process known as transesterification is used. As it has a reduced amount of carbon and higher amounts of hydrogen & oxygen, it is a low emission fuel. Biodiesel can be used alone (B100) but diesel engines need to be designed for this. Biodiesel is usually blended with fossil-derived diesel. Recently, new technologies for the production of biodiesel have been demonstrated. Biodiesel is Europe's most common biofuel.

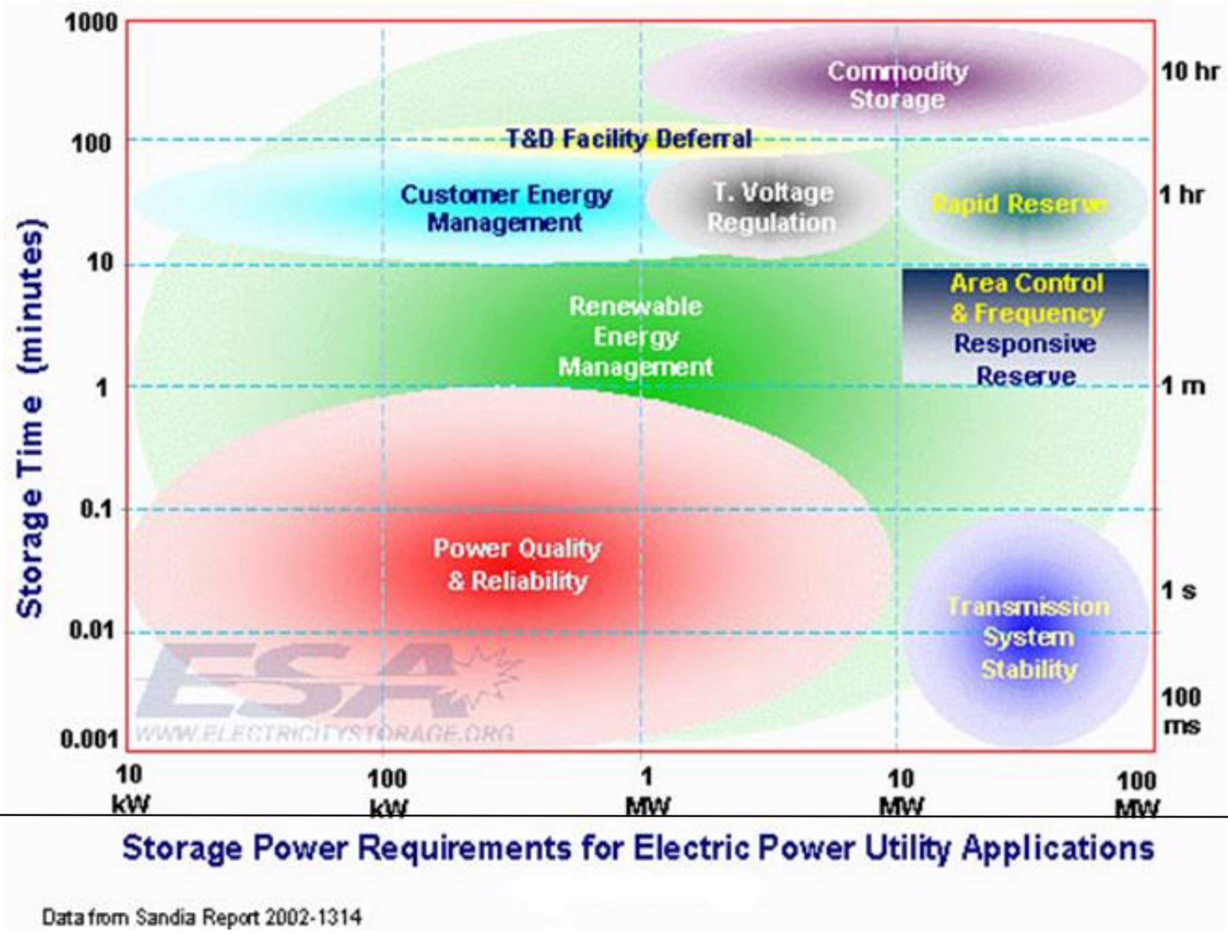
Two of the **Ōtaki Clean Technology Centre** members have expertise and capacity relevant to these fuels. ***Blended Fuel Solutions*** is the NZ agent for an emulsified & fuel blending system licensed from US firm Alternative Petroleum Technologies. Water is suspended in the fuel as a fine droplet with an emulsifying agent, generating a 3% improvement in fuel efficiency by promoting complete combustion & providing a sharp drop in CO_2 & N_2O emissions. The system can also be used with biodiesel. The system requires no modification of the engines, & delivers complementary benefits in terms of cleaner engines, cleaner lube oils (less frequent oil changes) and longer engine life.

The Solray SCWR and the ***Waste Transformations/ Spectionz*** pyrolysis process both produce liquid bio oil, and are profiled above in Section 9.4.4/ Tables 9.8 & 9.9.

10.7 ASSESSMENT OF ENERGY & STORAGE TECHNOLOGIES

Diagram 10.3 sets out the array of applications for energy storage from a study undertaken for the Washington DC-based international Electricity Storage Association. The large role energy storage management plays for renewable energy generation can be seen by the scale of the green oval.

Diagram 10.3 Energy Storage Applications

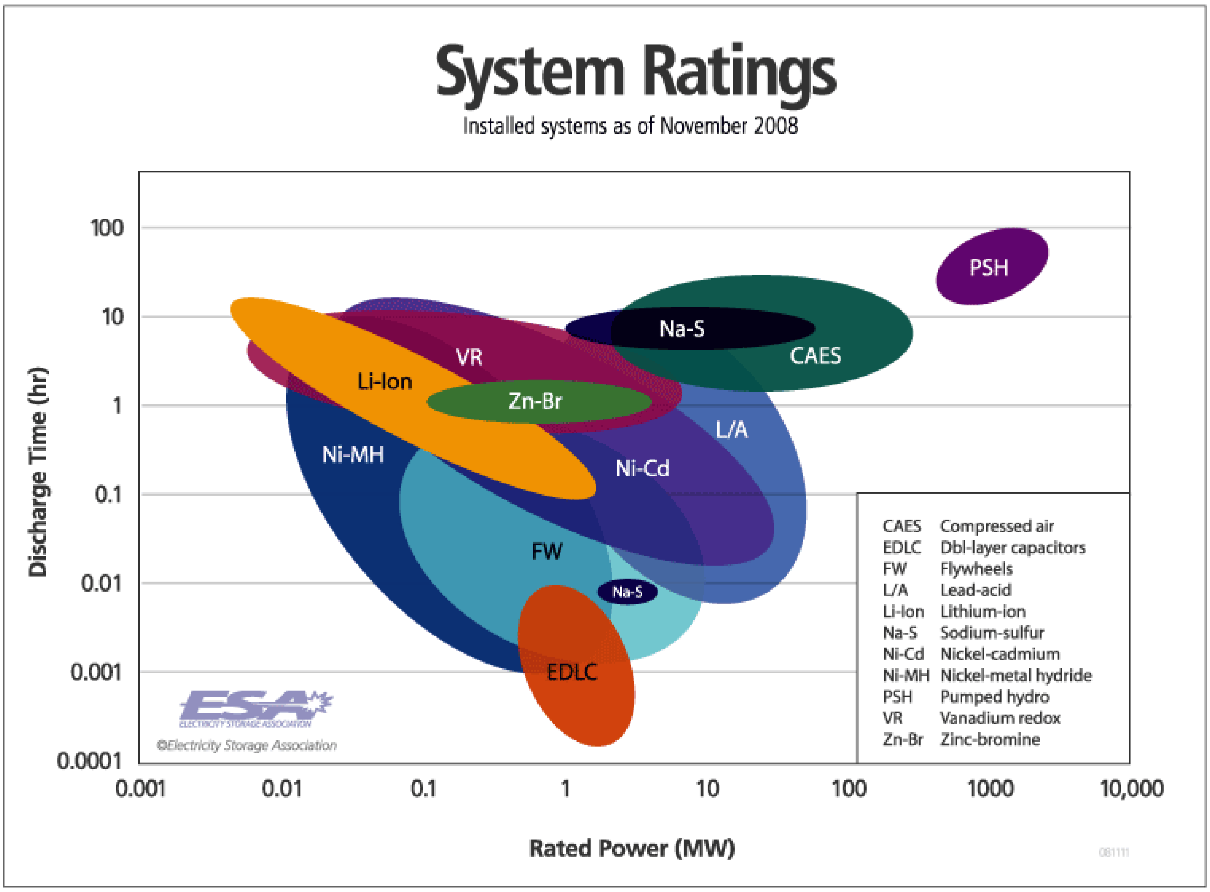


The review of the technologies above has also identified that many of the storage technologies have a mix of characteristics that can be utilised to secure several of the roles identified for energy storage within a grid or network. In the case of renewable generation, this tends to be related to power quality & reliability and stability.

Diagram 10.4 (below), sets out a rating of the performance of energy storage systems from installations as at 2008. The leading performance of pumped hydro storage is clear, as is that of the next 2 challengers, compressed air storage and sodium sulphur batteries.

Traditional lead acid batteries still demonstrate a strong performance, but issues regarding their weight, cycle life and disposal are increasingly important issues with their deployment. It should be noted that strong innovation continues in most of these storage technologies.

Diagram 10.4 Rating of Energy Storage Systems



Source: Electricity Storage Association

10.7 GRID ECONOMICS & INDEPENDENT STORAGE

A feature of most energy grids is the variability in demand patterns across any 24-hour period. This is influenced by daily living patterns within the communities served including residential (morning breakfast, evening meals & entertainment and air conditioning and heating) and commercial (operating times) and mass transport (electric power for commuter rail & tram services etc). For suppliers & distributors of electricity & gas, this profile means that there are periods of significant load redundancy that they must have in their grid if they are to meet peak demand. This creates additional capital costs. Some markets, including NZ's electricity market, are structured so that these peaks offer the generators/ suppliers an opportunity for peak prices and high margins.

Energy storage systems enable distributed generators (including renewable energy) to shift or shave their peaks and troughs. Indeed, with certified energy storage, a customer is able to purchase energy cheaply and sell at the peak, benefitting from the price differentials.

Load shifting has become an area of intense debate in some countries such as the US. How the NZ market regulations and generators will handle distributed energy storage in the national grid is unclear. Significant distributed storage will change the economics of the NZ energy market.

11 RENEWABLE ENERGY FOR MOTIVE POWER

11.1 STATUS OF RENEWABLE TRANSPORT TECHNOLOGIES

Motor transport has been identified as a major energy use in Ōtaki. It is also dominated by private vehicle use, reflecting the area's location and small population. It is an area in which significant change and efficiencies will be needed to in order to secure Energise Ōtaki's vision.

Internal combustion engines (ICE) have become the dominant fuel for private motor transport. This reflects the very high energy density of liquid hydro carbon fuels, which enable long range driving (< 1,000 km/ full tank), and therefore individual independence. It also brings the disadvantage of net major emissions of CO_2 to the atmosphere. The 20April 2013 edition of The Economist has a special report on the car industry, but does not address some technology developments such as supercapacitors, compressed air and drop-in replacement biofuels. It does cover the rise of the electronics, GPS, sensors and the self-driving car, although this is somewhat beyond our time horizon.

In energy efficiency terms, internal combustion engines suffer a major disadvantage – very low fuel efficiency. The poor fuel efficiency reflects 4 dimensions of motoring:

1. losses of energy to engine operating requirements
2. losses of energy to drive train inefficiencies
3. kinetic energy lost during braking
4. Engine idling while vehicle is stationary.

ICE technologies for motor vehicles and other motorised transport has seen an acceleration in the number of innovations, including drop-in bio fuel replacements, direct fuel injection, turbo chargers & variable valve timing. Competing/ complementary technologies such as batteries, biomethane & super capacitors have also advanced quickly. The issue then is, what to invest in and when? Will today's investment decision become an orphan or a lemon as other innovations arrive & displace it?

Facing this dilemma, we have adopted the approach of using the commercial status of renewable energy applications in the global automotive industry as a key indicator of the international market status. As renewable energy systems for transport typically face energy storage demands, we treat the two in a combined analysis. The key is, where is the renewable energy and the associated storage technology placed within the global market, and what developments will enter the market as a mainstream within the next 2 years?

11.2 REGENERATIVE BRAKING AND HYBRID PROPULSION

Regenerative braking transforms kinetic energy into another form for either immediate use or for storage. Conventional (dynamic) braking systems convert the kinetic energy into heat by friction. The most common form of regenerative braking is where electric motors are used as electric generators. In the braking/ generator mode, the electric output is applied to an electric load, and that transfer provides the braking effect.

The largest application of the technology has been in electric trams and railways, where it has been used since the early 1900s. Modern electronic control systems have greatly improved the utility of regenerative braking systems relative to the alternative of dynamic, where the energy is dissipated as heat. The braking trains & trams generate electricity which is fed back into their traction supply system. Demands for improvement in the fuel efficiency of road vehicles saw the concept adopted by the car industry using batteries.

11.2.1 Batteries

Batteries are an important feature of the electricity world. Invented by Alessandro Volta in Italy in 1800, they consist of one or more electromechanical cells that can convert (stored) chemical energy into electrical energy. Batteries come in 2 main types:

1. Dry cell, non-rechargeable (and therefore disposable) with applicability to low power & infrequent use situations
2. Rechargeable batteries, with high discharge rates and suitable for frequent use.

Battery selection depends upon a number of parameters, including weight, compactness, voltage & discharge profile, load current, charging efficiency, service life, safety and (initial & life cycle) cost. A very common form of battery, especially in the motor industry in 6 cell form, is the lead acid (rechargeable) battery, invented in France in 1859. The high surge current capability makes the technology particularly effective for automotive starter motors. Today, although heavy, it has a relatively high power to weight ratio, and a low cost. In addition to motor starting, lead acid batteries are also used for lighting, power back systems and off grid energy storage, and for battery electric vehicles.

Alkaline batteries, developed in 1899, are the most common form of battery. With a few exceptions, alkaline batteries are disposable. They have a high energy density and long shelf life. The dry form of the battery was invented in the 1950s, and commercialised by the Union Carbide company.

The lithium ion (Li-ion) battery is the rechargeable battery which most nearly replicates the performance of the alkaline battery in terms of energy density, and with the advantage of a longer cycle life (it is rechargeable)the next lowest self-discharge rate, and high cell voltage. The Li-ion battery has the disadvantage of high relative cost.

11.2.2 Hybrid Vehicles

American Motors produced a compelling version of the technology in its 1967 concept car – the Amitron, a fully electric small urban car. The car was very advanced in its use of technologies to enhance the performance and range of an electric vehicle. However, the high cost of the batteries prevented commercialisation. http://www.retrothing.com/2008/09/1968-amcs-amazi.html

Toyota developed the technology with the launch of the Prius hybrid car in 1997 in Japan and worldwide in 2001. This has become a volume selling car. The technology has been extended to other Toyota vehicles. By April 2013, Toyota had sold 5m hybrid cars, 1m in the last 11 months.

The Toyota hybrid system enables the car to run on the electric motor only. It has a special electromechanical transmission providing a performance similar to a continuously variable transmission. A high voltage battery is used to slowly capture, store and deliver the kinetic energy. The 2013 model has a solar sunroof which powers a fan to circulate air in the vehicle. The original nickel metal hydride battery storage technology is still being used (albeit in upgraded form. http://www.toyota.com/priusv/#!/Welcome

Variations on the hybrid system are now in production by many large automotive manufacturers. Over the last year, high performance hybrid supercars have been introduced by McLaren, Porsche & Ferrari. The control systems introduced with these models are informing the improvements in the performance of all electric vehicle hybrids – see below.

Rechargeable lithium-ion (Li-ion) batteries are the most common form of electricity storage for automobiles. Li-ion batteries are common in consumer electronics as a rechargeable battery, because of their high energy density, nil memory effect and a slow rate of discharge when not in use. They have quickly moved into other applications such as power tools and aircraft.

Research has been yielding a constant stream of improvements to the technology. Solid state designs are delivering up to 3 times the energy density of previous versions. Washington State University has announced that it will bring to market in mid-2013 a new anode with tin nano needles which will again triple the capacity of Li-ion batteries.

Hybrid cars such as the Prius, the Honda Insight and other makes and models are now an accepted part of motoring. With higher sales volumes, the relative cost of the vehicles has fallen.

Table 11.1 Lithium-Ion Storage Batteries

Proprietor:	Widely available & mature technology. There are major & successful efforts to improve their performance to cost ratio and total charge (especially to extend the range of all electric motor vehicles).
Value Chain:	Electric power
Application:	Widely used for consumer electronic products and for transport energy storage. Could soon be capable of supporting micro grids.
Status of Technology:	Mature and well established in market. Nano technology and new battery architecture are creating a continual improvement in performance.
Technical Performance Characteristics:	Larger units, such as for vehicles or a micro grid back up, require multi cell architectures. This imposes the need for a management system for the battery to prevent any single cell operating beyond its safe operating area (eg, to prevent over-charging or over-heating) and to keep the state of charge common across the cells. Li-ion batteries have a prescribed life before recharging capacity fades. This renews the cost if this is less than the service life of other parts of the vehicle.
Economic Performance:	Li-ion batteries remain more expensive than competing technologies, but the high energy density has generated distinctive market segments.
Relevance to Ōtaki:	Li-ion batteries are available in local hybrid and electric vehicles, & their market share will increase. The rate of innovation indicates that these batteries will be a candidate for micro grid energy storage within 2-3 years. Replacement costs will be an issue.

There are a number of chemistries that can be deployed in the manufacture of Li-ion batteries. All have lithium metal or compounds of lithium as the anode. There is a wide choice of chemistry for the cathodes and electrolytes. The choice of chemistries determines a trade-off between performance in various dimensions, such as life span, specific energy & specific power. These elements have to be traded off against safety and cost, plus the requirements of the intended application.

Lithium iron phosphate is claimed to be the safest[3], and is the chemistry used in the Kapiti Coast District Council's new all-electric waste truck. Li-cobalt has a particularly high specific energy profile (energy/ kg), moderate cost & performance, but low ratings on safety & specific power. It is understood that Boeing used a Li-cobalt oxide battery in its 787 Dreamliner aircraft.

11.2.3 Capacitors

Capacitors (condensers) are an electrical component that stores energy in an electric field as an electric charge. Their storage potential is measured in *microfarads.* High voltage is used to increase the energy density. There is a wide diversity of forms of the technology, but all have at least two electrical conductors separated by an insulator (dielectric). A potential difference between the conductors creates a static electric field across the insulator, and a positive charge develops on one conductor, and a negative on the other. Energy is stored in this electrostatic field.

Capacitors can be used as temporary batteries and for power conditioning. They can be assembled in banks as reservoirs. They are used for either starting motors, because of their very high torque or as running motors. They are used in a wide array of applications, including wind turbine blade control, emergency power for bus door opening and fall-back for when regenerative braking fails. The size of capacitors is increasing, as they enable the reuse of dropping and turning energy of forklifts & cranes and soon elevators. Capacitors are now the preferred option for capturing the kinetic energy from trains & trams.

Capacitor technology in has been improving rapidly, and at a rate faster than that for Li-ion batteries in recent years. Supercapacitors now have a much longer life (10-20 years) than Li-ion batteries (<8 years), have a faster re-charge cycle, are more reliable, and are safer (fewer fire & toxicity failures). While total life cycle cost of supercapacitors is lower than Li-ion batteries, supercapacitors do have a higher initial cost.

[3] BCG Research

Table 11.2 Capacitors

Proprietor:	Long established technology with many applications & suppliers. Present in most electronic & electric systems.
Value Chain:	Electric power
Application:	In vehicles, a battery system to store kinetic energy in electric power form. Indicated scale in the Mazda 6 is small, and larger units would be required for a local network.
Status of Technology:	Mature in many segments. In development for power storage for motor transport & renewable energy storage.
Technical Performance Characteristics:	The UK Rail Safety & Standards Board 2009 study into energy storage systems concluded that super capacitors have the same life time as other traction equipment, can store braking energy, but have a limited distance for solely powering the engine (< 500m). IDTechEx analysts consider supercapacitors to be a burgeoning disruptive technology, threatening the role of rechargeable batteries. In the successful new MAN electric bus, a supercapacitor has completely replaced a Li-ion battery. Capacitors increasingly use non flammable electrolyte.
Economic Performance:	Useful life of 20 years+. High initial cost has undermined the economics of the technology, but this has fallen significantly in recent years.
Relevance to Ōtaki:	Technology is now entering global market in volume. Capacitors have the potential to be a viable storage medium for renewable energy in Ōtaki.

Italian rail & tram equipment builder, AnsaldoBreda, has commenced a demonstration project with the city of Bergamo, users of its SIRIO trams, to undertake trials to establish the advantage of super capacitors as an energy recovery system. The claim is that the super capacitors can reduce energy use by 20-25%. Bergamo city runs 25 of its fleet of 192 buses on methane, and has 2 dedicated quick delivery filling stations.

http://www.atb.bergamo.it/ENG/Default.aspx?SEZ=2&PAG=22&NOT=95

The automotive industry has undertaken a lot of research into applications of the technology to reduce the electricity demand of accessories upon the motor. Mazda has just announced an integration of capacitor technology for its new mid-sized car, the Mazda 6. This car incorporates a stop start system to eliminate the motor running when the car is idling. i-ELOOP, a capacitor system, instantly captures the kinetic energy from deceleration/ braking and makes it available for electric accessories such as air conditioning and for re-starting the car. This system provides a step change in energy efficiency, and opens the gate to a new deployment of capacitor technology. http://blog.caranddriver.com/mazda-introduces-i-eloop-capacitor-based-regenerative-braking-system

11.3 BIOMETHANE & HYBRID MOTOR CARS

Biomethane production is growing rapidly & displacing fossil natural gas in motor vehicles, especially heavy vehicles such as buses. Italy is a leader in the deployment of CNG vehicles. In 2012 Fiat launched a new methane-petrol hybrid version of its Panda city car/ small SUV. This subsequently won the 2013 Swiss award for the most eco-friendly car in Switzerland, beating 9 other contenders. The power plant is a 2-cylinder turbocharged engine which is able to use either methane or petrol. It has very low levels of CO_2 emission, and achieves 3.1 kg/100km consumption in methane mode. http://www.ngvaeurope.eu/fiat-presents-2012-panda-natural-power-in-paris

In November 2012, Sweden opened a liquefied biogas plant in Lidköping. This offers a way to replace diesel in heavy duty vehicles. Volvo Trucks released a methane-diesel engine which can replace 75% of the diesel with biomethane. DHL freight is one company trialling the new engine.

11.4 ALL ELECTRIC VEHICLES

Electric vehicles (EVs) were a part of the early history of road and rail transport. However, the internal combustion engine displaced most road EVs leaving them serving specialist uses such as forklifts and in activities where there are many stops, such as milk floats. Now, in the pursuit of better energy efficiency and reduced pollution, automobile manufacturers are producing all electric general purpose vehicles using rechargeable batteries. These vehicles are solely electric, and have no fuel cell, internal combustion engine or fuel tank. They are externally charged. Some also use regenerative braking systems, and are known as plug-in hybrid electric vehicles (PHEVs).

The critical issue for EVs is the speed and range of the vehicle on a full charge, determined by the battery performance and numbers incorporated. The size, weight, recharge time and lifetime of the batteries also determine the EVs' performance. Battery costs have remained an issue, causing many of the cars to be priced well above their internal combustion engine siblings.

The development of the rechargeable Lithium Ion battery technology, with higher power and energy density, has greatly improved the performance of all electric vehicles. The batteries are also light & have a slow self-discharge rate relative to other batteries. With more improvements and increasing production, the cost of the batteries has fallen. However, the batteries are subject to thermal "runaway" and cell rupture if they are over-charged or overheated. There are also issues regarding the life of the Li-ion battery of 4-8 years. These cause PHEVs to have a low re-sale value.

Prior to Easter 2013,EnerG2, a Seattle start-up company spun out from the University of Washington, announced that it had successfully developed a new carbon anode made of amorphous carbon, rather than graphite. The new anode improves the storage capacity of Li-ion batteries by up to 30% without requiring a new battery design or a new manufacturing method, but at a cost premium of 20%. The technology is scalable. Commentators consider the technology unlikely to be used in EVs (Tesla might be an exception). The new anodes would enable lighter & thinner electronic gadgets. http://www.energ2.com

Most manufacturers now produce a wide range of EVs, including cars, heavy motor vehicles, forklifts & cranes, mobility vehicles, military & marine vehicles and electric aircraft. China now manufactures 90% of EVs worldwide, mainly for its domestic market.

In 2013, electric vehicles can be considered to be part of the mainstream automobile market. Many models are now available, including "World Car of the Year 2011", the Nissan Leaf (PHEV), the Mitsubishi i-MiEV, Bollore BO, Renault Be BOP & Fluence ZE, Mini E, Smart Car EV, GM's HPEV Cruze-based Volt & Venturi of Monaco. GM plans to manufacture 36,000 of the Volts in 2013, an increase of 20% on the previous year. GM has also released an all EV version of its Spark at the 2013

Seoul Motor Show on 28 March. In mid-March, VW released the details for its upcoming electric vehicle, the e-UP.

http://www.nissanusa.com/electric-cars/leaf

http://gm-volt.com/about
http://www.mitsubishicars.com/MMNA/jsp/imiev/12/showroom/overview.do

At the April New York Motor Show, Nissan's luxury brand Infiniti introduced its new electric sedan, the LE Concept. To be in production within 2 years, it uses an induction charging system, a technology pioneered at the University of Auckland. The target price for the sedan is US$36,000.

On 11 March, Formula E, sister company to Formula 1, announced an 8-race series for electric vehicles in leading cities in Europe, Asia and the Americas. The cities included are London, Rome, Los Angeles, Miami, Buenos Aires, Rio de Janeiro, Beijing and Putrajaya.

According to industry analyst IDTechEx, cars represented around 41% of the global EV market. In the US, all electric car maker Tesla Motors announced its first profit in MarQ13. It is now able to pay off its Government energy development loan twice as fast as contracted. US luxury HPEV manufacturer, Fisker, has struck problems following the late 2012 bankruptcy of its battery supplier, A123 systems. Chinese group Wanxiang has purchased A123's assets and plans to recommence production. An old US marque, Detroit Electric has just announced its revival after 74 years with a direct competitor to the Tesla Roadster.
http://www.detroit-electric.com

http://www.teslamotors.com

http://www.a123systems.com

The Volt has just been released in NZ. Like the Nissan Leaf ($69,600) and the Mitsubishi i-MiEV ($59,900) it is priced as a premium car at $86,000. Compared with similar conventional engined cars in the GM Holden's NZ range, the price premium is around 160%, compared with previous premia for the Nissan & Mitsubishi PHEVs of around 200%. The Volt's configuration gives it a range typical of other cars, bringing performance levels to those familiar to NZ motorists. The difference is that it only drives off the electric motor – the internal combustion engine recharges the batteries.

In December 2012, Mitsubishi announced that it plans to release a PHEV version of its NZ market leading Outlander SUV in mid 2013 priced at $60,000, which is a premium of only 40 - 50% on its conventional fossil fuel siblings. If realised, this pricing would be a market breakthrough for PHEVs in NZ, certainly signalling the beginning of the availability of this technology for everyday motoring.
http://www.roadandtrack.com/car-shows/paris-auto-show/first-look-2013-mitsubishi-outlander-phev

Table 11.3 Electric Road Vehicles

Proprietor:	Automotive companies internationally
Value Chain:	Electrically propelled public and private transport
Application:	Transport of people and goods
Status of Technology:	Fully commercial, but has a large price premium over petrol & diesel siblings in NZ. Indicative Mitsubishi pricing for new Outlander model in mid-2013 signals a major reduction in this premium.
Technical Performance Characteristics:	Typically delivered with regenerative braking. Sometimes with a petrol engine "booster" to gain extra distance. No idling energy penalty when vehicle is stopped in traffic. AA Directions magazine April '13 test results showed the Nissan Leaf, with a 192-cell Li-ion battery an 80kW of power & 280Nm of torque electric motor performance had a range of 120-170km. The smaller iMiEV has 88 Li-ion batteries, 49kW/ 180Nm electric motor & a range of 100-160km. The Volt has 288 Li-ion batteries, 111kW/ 370Nm motor plus a petrol powered 1.4 litre motor to charge the battery & extend its range. Pure electric mode range is 64-87km. This gives the Volt a range similar to petrol-fuelled cars.
Economic Performance:	An electric vehicle requires 150-200Wh/ km. At a domestic electricity price of 25 cents per kWh, this is equivalent to an average energy cost per km of around $0.044. Charging on off-peak tariffs would cut this cost significantly. An equivalent sized petrol car averaging 6l/100km would have a fuel cost of $0.132 per km at February 2013 retail prices. In a user test in Dunedin in March 2013, David Thomson of Drive South (ODT) reported an electric energy cost in the Volt of $10 for a typical week of city driving, compared with $90 for his normal petrol vehicle. The Volt brings EVs into the motoring mainstream. Mitsubishi's indicated reduction in the price premium to ≈50%for PHEVs in NZ heralds a new competitiveness for EVs.
Relevance to Ōtaki:	Adoption of electric vehicles would be a major contributor to the Ōtaki area's energy efficiency, given its heavy reliance upon private transport. The renewables resource endowment in Ōtaki seems better suited to the generation of electric power than the production of large volumes of liquid fuels.

In March, financial markets agency Bloomberg reported that PHEVs were having market difficulties in China. Market penetration has not been as strong as expected. The reason is that, in prolonged traffic jams, the demand for energy from ancillary units (eg, heating, air conditioning, lights) in the EV was eating into the energy available for traction, cutting their range on the charge that the driver had available. The Volt's configuration of technologies would not be susceptible to this problem.

Ōtaki Clean Technology Centre member company ***Zero Emission Vehicles (ZEV)*** designs energy solutions at organisation & community scale. It builds battery systems and electric power solutions especially for heavy commercial vehicles in the 6.5 – 18 tonnes range. **ZEV** has devised a system to manage Li-ion batteries that doubles the battery life, a major breakthrough in whole of life cost.

KCDC has purchased a fully electric rubbish collection truck from ZEV, which will enter service in early 2013. It is based upon ZEV's Enviro 9000 battery electric truck, & is believed to be a world first. This vehicle has a lower total life cycle cost than a diesel equivalent, but also has zero greenhouse gas emissions when charged with renewable electric power. http://www.zevnz.com

During April 2013, announcements with regard to EVs included:

- the start of EV trials for the New York taxi fleet with 6 Nissan Leaf vehicles
- GM's report that 80% of Volt mileage is around town on electric power only (<87km), with overnight recharging, exploding the argument that range is a fatal problem for EVs
- Ford (& other competitors) developing air heating & cooling systems that use coolant as the energy battery, leaving the Li-ion battery free for traction
- Protean Electric's announcement that its electric hub motors (in-wheel with integrated inverter, eliminating the need for external gears, transmissions, drive shafts axles & differentials), are to go into production in 2014.

In brief, the rate of innovation in EVs continues apace. The above developments signal further reductions in the cost of EVs, and a definite market advantage in central city areas.

11.5 HYDROGEN FUEL CELLS

The automotive market has been exploring the use of hydrogen as a motor fuel for many years. The market penetration to date is very limited, but fuel cell costs have fallen by 80% over the last decade according to the US Department of Energy. Honda, Mercedes Benz, BMW, Toyota & Opel all have commercialisation plans in train, with demonstration and test vehicles in place already. Most of these models are scheduled to enter into volume production in 2016. Indicated pricing of around €100,000 also limits the hydrogen vehicle's potential customer base.

Major Korean motor vehicle manufacturer, Hyundai, showed its hydro fuel-cell Tucson 4WD SUV at the Seoul Motor Show – a world first. It has been in production since February. It has the major advantage of being able to travel much longer distances than all EV vehicles. The production scale is limited, with output rising to 1,000 units by 2015, for lease to fleet customers.

http://www.bloomberg.com/news/2013-02-14/hyundai-s-fuel-cell-car-drives-more-smoothly-than-popular-hybrids.html

For the hydrogen motor vehicle to be a viable technology for NZ, a full infrastructure of storage and filling facilities would be required. This would be an expense beyond the capacity of the Ōtaki community alone, and there is no fleet hubbed there that would warrant it. No work has been done on designing a national infrastructure as yet in NZ. The lead time on this places the motive power application of the hydrogen technology well outside the time frame of the Energise Ōtaki project.

11.6 PNEUMATIC ENGINES

Pneumatic motors use the expansion of compressed air to deliver mechanical energy. They have a long history and are widely used in hand held tools on construction sites. Their use in the transport sector has been promoted as a cost effective means to reduce greenhouse gas emissions from fossil fuels. Pneumatic engines range in size from hand held turbines to several hundred horse power. Many lift their performance by heating the incoming air (or the engine itself).

Pneumatic motors come in two main types, linear or rotary motion. The energy is commonly captured by a piston although a vane can also be used in rotary type motors. Typically, piston motors are used in series so that the motors are in sync at certain times of the cycle. Rotary engines use a slotted rotor mounted on a drive shaft. Each slot of the rotor has a sliding vane which extends to the housing walls. Air pumped through the motor inlet pushes the vanes creating rotational motion of the central shaft. Rotary pneumatic motors can reach very high speeds of up to 25,000 rpm. Rotary motors are used to spin flywheels to start large industrial diesel or natural gas engines.

The concept of a "green" pneumatic vehicle has certain advantages:

1. compression of the gas is fuelled by electricity off the national grid, eliminating the need to transport liquid fuels. Refilling could be done at home. Regenerative braking can be accommodated as in a hybrid vehicle.
2. The rate of self-discharge is very low (cf batteries for EVs)
3. a compressed air motor eliminates the need for the vehicle to have;
    - a cooling system
    - an ignition system
    - a fuel tank (replaced with a cylinder)
    - silencers
4. the engine is several factors smaller in size than other engines, and therefore lighter
5. the engine does not generate high temperatures, reducing the specifications for materials in terms of weight and cost
6. the engines are simpler, and therefore cheaper, to manufacture and maintain
7. the air tanks can be recycled with less pollution
8. refilling rates are similar to current day liquid fuels (cf battery re-charging)
9. the cost of the air refill is set by electricity (for compression), and is therefore usually very cheap.

Pneumatic engines do however involve a conversion in the form of energy, which always results in efficiency loss. The underpinning relationship between volume and temperature of all gases (Charles' law) states that the volume of a given mass of gas increases or decreases as its temperature increases or decreases. Thus, as the gas in the engine expands, it cools sharply. It therefore needs to be heated to ambient temperature by a heat exchanger, and the air needs to be de-hydrated. Low end compressors that are likely to be used by households may take up to 4 hours to refill the tank. Specialised equipment would only require around 3 minutes. However, rapid refilling generates a lot of heat, and the air needs to be cooled if a pressure decrease after filling is to be avoided. This may be overcome with a spring system to maintain a low pressure difference between the tank and the compressor. At present there are some speed limitations in some vehicle applications.

In automotive applications, the typical configuration is for compressed air to be stored at high pressure (<30MPa or 300 bar) in carbon-fibre tanks which do not shatter when place under excess stress. Compressed air has a relatively low energy density, but this can be more than doubled by pre-heating the air. The low energy density places a premium on light-weighting the vehicle.

Two pneumatic motor transport initiatives are underway – an all-compressed air vehicle (CAV) and a hybrid. The current status of developments is:

1. Motor Development International (MDI)

   A French/ Luxemburg company, MDI won the financial support of Tata Motors in 2007. It has a business in the design & manufacture of compressed air engines for backup generators or industrial tractors. MDI also has hybrid "dual energy engines". A range of 5 vehicles has been designed. A NZ firm, *Indranet*, holds the license for Oceania and plans to offer vehicles in the market in the coming year.
   http://www.mdi.lu/english/entreprises.php

2. Air Car Factories

   Air Car Factories is a Spanish firm which is in the process of releasing a compressed air hybrid electric vehicle, with the ultimate aim of producing a CAV. http://www.aircarfactories.com

3. Engine Air

   Engine Air is an Australian firm which uses the rotary engine design invented by Angelo de Pietro. It deploys a 6-vane expansion motor and a cylindrical shaft driver. The motor is claimed to be virtually frictionless and weighs just 15% of an internal combustion engine. The compression system uses an isothermal process to remove heat from the air. http://www.engineair.com.au

4. Peugeot Citroen

   Europe's second largest automobile manufacturer, PSA Group announced in January the completion of a project with the French Government to develop a compressed air engine power train that it calls "Hybrid Air".

   It combines a petrol engine, a compressed air storage unit, a hydraulic motor-pump assembly and an automatic transmission working with an epicyclic gear train. It is designed to also capture the kinetic energy from braking.

   The key innovation was the design of a new gear box. The system deploys air compression components from Bosch.
   http://www.psa-peugeot-citroen.com/en/inside-our-industrial-environment/innovation-and-rd/hybrid-air-an-innovative-full-hybrid-gasoline-system-article

Table 11.4 Peugeot Citroen "Hybrid Air" Compressed Nitrogen Gas Motor Cars

Proprietor:	PSA Group
Value Chain:	Motor transport for passengers and goods
Application:	Compressed nitrogen/ hydraulic system used for capturing, storing & re-using kinetic energy from braking & deceleration.
Status of Technology:	PSA states that the vehicle will be available on its bestselling models in 2016, and will extend to its B & C class cars and light commercial vehicles. The technology is viable in all global markets.
Technical Performance Characteristics:	Low carbon technology, recyclable materials, low fuel consumption (45% savings in city driving). Vehicles able to operate on compressed nitrogen only for 60-80% of time in city driving. Nitrogen is stored in 2x20 litre under floor pressurised steel tanks. The nitrogen is compressed when the car is braking, and released upon re-starting. System uses a continuous transmission that optimises energy use from 3 modes: • Gasoline power for cruising • Compressed nitrogen via hydraulic power system transmitted to wheels via accumulators • Combined power Fuel consumption certified at 2.9l/100 km for small (B segment) cars. CO_2 emissions 69g/km (cf 104g/km from current 3-cylinder engines).
Economic Performance:	There is no Li-ion battery or electric motor, so no extraordinary expenses. Indicative UK price around £17,000. The Hybrid Air system is particularly suited to vehicles making frequent stops such as buses, street cleaning vehicles etc.
Relevance to Ōtaki:	This technology's roll-out marks the entry of compressed air-powered type vehicles into mainstream motoring. Elimination of the need for batteries & a second motor suggests that this technology might have a cost advantage in volume manufacture. The trajectory of this technology is behind that of electric vehicles, but the proposed scale of production planned by PSA Group will bring the CAV technology into market contention from 2016. It is understood that PSA is in talks with other vehicle manufacturers to adopt this technology, including GM and Chinese partners. In Ōtaki, this will be an individual motorist's choice, as no special infrastructure is needed.

Table 11.5 MDI - FlowAir Compressed Air Vehicles

Proprietor:	Motor Developments International. NZ Partner, Indranet Technologies Ltd http://www.mdi.lu/english http://www.indranet.co.nz
Value Chain:	Motor transport for passengers and goods
Application:	Currently used in back-up generators and for starting large industrial diesel engines. In market with small inner-urban AirPod. Tata has completed tests on larger motor vehicle prototypes. Currently being introduced to the market, incl NZ (certification & safety registration). The MDI motor will also be used as an emergency generator, or as a production generator with an air heating system (dual) that can include solar thermal. The production generators can be networked at neighbourhood level. Scale: Cars, micro to full-sized sedans. Tata developing heavy vehicle version for buses & trucks. Energy storage: household to neighbourhood, with the potential for further increases.
Status of Technology:	Emergency generators in production. European motor vehicle production scheduled for late 2012.
Technical Performance Characteristics:	City AirFlow for 3-6 people: • Weight 850kg • Mono or dual system (in-line heating <600^{0}C • Max speed, mono, 110km/h, hybrid, 130km/h • Urban range 50-180km, open road 1,500km (hybrid only) • Fuel consumption (hybrid) 2l/100km, CO_2 40g/km • Time to recharge, 3-4 hours @ domestic oven equivalent; 2-3 minutes @ an air station.
Economic Performance:	Average price €13,000 (mini car).
Relevance to Ōtaki:	Mono powered version for cars is a new application of the technology, and offers a use for electricity generated from renewables, including sale to visitors & travellers. Compressed air energy storage scale is falling rapidly towards district & area scale, and may therefore be a potential network technology for Ōtaki.

For Energise Ōtaki, the innovation in motor transport, and the rise of regenerative hybrid systems offers two main areas of action. One is the selection of vehicles by individual and fleet owners, which will be based upon their assessment of the tradeoffs between energy savings and capital cost. The price wedge in this regard appears to be closing quite quickly, and promises to continue to do so through to 2016 at least.

The second aspect is ensuring that essential infrastructure for new motor transport forms is available in a timely manner in Ōtaki. This could be achieved by collaboration between fleet operators such as Electra and KCDC, or an energy cooperative associated with Energise Ōtaki and/ or the Ōtaki Community Board.

12 INTEGRATION OF RENEWABLE ENERGY TECHNOLOGIES

12.1 OVERVIEW

This chapter investigates potential ways in which the renewable energy technologies might be integrated for the lifestyles of different groups within the Ōtaki community. This is done on a preliminary basis, as detailed assessments will be required of energy needs and options both individual and community. In Chapter 14, this is taken further into a possible technology road map for exploration by the Ōtaki community.

12.2 BUILDINGS FOR RESIDENCES & SMALL BUSINESSES

12.2.1 Zero Net Energy Buildings

Zero net energy (ZNE) buildings have zero net energy consumption and zero carbon emissions annually. This design concept is gaining support globally as the costs of renewable energy technologies and special building materials and systems fall. Goals for ZNE are most easily secured during the design and construction phase of any building.

A typical ZNE building will generate its own energy from its own site, usually solar thermal & PV, wood, and wind turbines. At the same time, their use of energy is reduced through efficiency measures such as ventilation and air conditioning and LED lighting technologies. To balance generation and demand, the power grid is usually used for energy storage capacity. While micro generating technologies can be used on individual sites, it is often better economics to use neighbourhood and community scale installations, and share the resources via the local lines network. This arrangement has the added advantage of reducing transmission losses.

The International Energy Agency is hosting a multi nation research programme "Towards Net Zero Energy Solar Buildings". The project includes a number of demonstration activities and performance data collection. http://www.iea.org/topics/sustainablebuildings

The International Living Future Institute (ILFI) sponsors the Living Building Challenge, a 7-factor (petal) influence on building design:

1. Site
2. Water
3. Energy
4. Health
5. Materials
6. Equity
7. Beauty

ILFI developed the Net Zero Building Certification system, called Petal Recognition, in late 2011.

http://living-future.org

12.2.2 Green Buildings

Green Buildings have the goal of sustainable built environment for all within the next generation. It relies upon informing design and architecture for the more efficient use of resources and reduction of the environmental footprint of a building. The green building concept therefore has a greater emphasis upon elimination of waste and upon recycling.

Certification of green buildings is done to the standard of Leadership in Energy & Environmental Design (LEED) developed by the US Green Building Council (USGBC). Founded in 1993, the USGBC is a membership organisation of builders, architects environmentalists and other concerned citizens, companies, organizations and professionals. The Green Building Council has become an international movement.

http://www.usgbc.org/about

http://www.nzgbc.org.nz

12.2.3 Passive House Movement (*Passivhaus*)

Originating in Hessen, Germany in 1988, from German & Swedish researchers, Passive House is a rigorous, voluntary standard (the Passivhaus) for energy efficiency in a building. It is a design process whose aim is to maintain comfort at a high level while minimising a building's environmental footprint. This is achieved through ultra-low energy buildings – houses, offices, schools & supermarkets. Typically used for new structures, the system has also been applied to building refurbishments.

The first homes built to the standard were completed in 1990. They recorded a space heating demand only 10% of that needed for equivalent new buildings of then standard design. This was achieved through applying the principle of radically reducing heat leakage, thereby limiting peak loading to the point where the ventilation system can be used for heating. The same principal applies for cooling. Minimum use is made of auxiliary energy.

A special set of products were developed to achieve the standard, especially windows and ventilation systems, allied with energy-efficient landscaping. Passivhaus buildings are very airtight, which minimizes the amount of new air, cold or hot, that can pass through the building, thereby enabling the ventilation technology to recover the heat energy prior to external discharge. Even in mid-winter, heat gains from the sun exceed heat losses. The performance of the buildings enabled conventional heating systems to be avoided. A supplementary system such as thermo siphons is used in their place.

The Passivhaus Institut (PHI) was formed in Darmstadt in 1996 to promote and control the design standards. The system has been strongest in Austria & Germany. The essence of the design process is the control of ventilation and temperature without using any products or systems that consume energy or other resources. The system is customised for different climate zones and building traditions. Limits are set upon a maximum heating demand.

For example, the central European standard is that the building must have:

1. an energy demand of not more than 15kWh/m^2 pa in heating, and 15kWh/m^2 pa in cooling. Alternatively, the building is to have a maximum peak heat load of 10W/m^2.
2. a demand for total primary energy less than 120kWh/m^2 pa
3. an hourly air leakage less than 0.6 times the volume of the house.

The International Passive House Association (iPHA) is a network membership organisation for architects, planners, scientists, suppliers, manufacturers, contractors & property developers. It acts as a critical hub for the exchange of Passive House information and the promotion of events such as design competitions. Australasia's first certified passive house was built for a North American family in Glendowie, Auckland in 2012. A NZ institute was founded in August that year. The NZ house incorporated the following features:

1. split level design
2. timber & masonry construction
3. pink batts insulation with air tightness membrane
4. concrete floor
5. double glazed windows
6. ventilation system with heat recovery from air being extracted
7. solar thermal space heating
8. solar PV electricity generation
9. rainwater harvesting.

http://passiv.de/en/01_passivehouseinstitute/01_passivehouseinstitute.htm

http://passivehouse1nz.blogspot.co.nz/p/publication.html

http://www.phinz.org.nz

12.2.4 First Light House

A team of Victoria University of Wellington architectural students was selected for the US DOE biannual Solar Decathlon 2011, held on the National Mall in Washington DC. This was the first entry from the southern hemisphere since the contest started in 2002.

Twenty university teams compete against each other to demonstrate clean-energy solutions using solar powered houses deploying energy efficient construction & energy saving appliances. There are 10 contests, and the Wellington team designed a Kiwi batch and came 3rd overall in the decathlon, winning the engineering contest, and coming 1st = in the energy balance contest (scoring a net energy zero rating) 2nd in architecture & 3rd in market appeal.

The design incorporated a number of technologies and features, including:

1. 28 polycrystalline solar PV panels which formed a 6.3 kW array
2. 40 evacuated tube solar collectors to provide the house's hot water needs & drying cupboard from LEAP Australasia, Wellington
3. an energy efficient heat pump
4. fully opening windows plus an energy recovery ventilation system
5. an interactive energy monitoring system with simple display and controls.

Diagram 12.1 First Light, NZ entry in the DOE 2011 Solar Decathlon

Source: Victoria University of Wellington School of Architecture & Design

http://firstlighthouse.ac.nz/home

12.2.5 Little Greenie

Little Greenie is a Golden Bay design and build enterprise building of energy efficient homes for NZ conditions. It is a tenant in the *Ōtaki Clean Technology Centre*. A demonstration home scored a 90% rating for energy efficiency on the NZ Home Energy Rating Scheme. The house maintains a year-round ambient temperature and is a low maintenance structure. The annual bill for external heating energy is $50. The structure deploys some simple design and construction techniques which could have a major impact upon NZ building practice.

Key features of the design are:

1. optimal orientation on site for passive solar design
2. high levels of insulation throughout
3. simple design with durable materials
4. high levels of thermal mass
5. good levels of ventilation and humidity control
6. air tight construction with high performance glazing.

The project has received support from the Hikurangi Foundation, and the concept has developed into a role of providing exemplar demonstration units (3 bedroom homes) around NZ combined with trades training for designers & builders. Negotiations for support of this model from KCDC, including an exemplar structure in Ōtaki, are in train.

http://goldenbayhideaway.co.nz/design_build

12.2.6 An Italian Alpine Example

Italian mountain villages are facing problems similar to many isolated NZ farms and holiday locations – small electricity demand at the end of a long power line. Today, the power lines require renewal, but doing so is not economic.

In Italy, the mountain villages are no longer occupied during the winter to the extent that they once were, partly reflecting a migration of younger people to urban centres, and partly the challenges of living in permanent winter snow conditions. As a result, village populations have declined, and energy services are not being renewed because of the lack of sufficient demand. This creates challenges for the residents who do want to remain in these locations following long standing tradition. These concerns led to the formation of the Green Mountain Village movement in Italy.

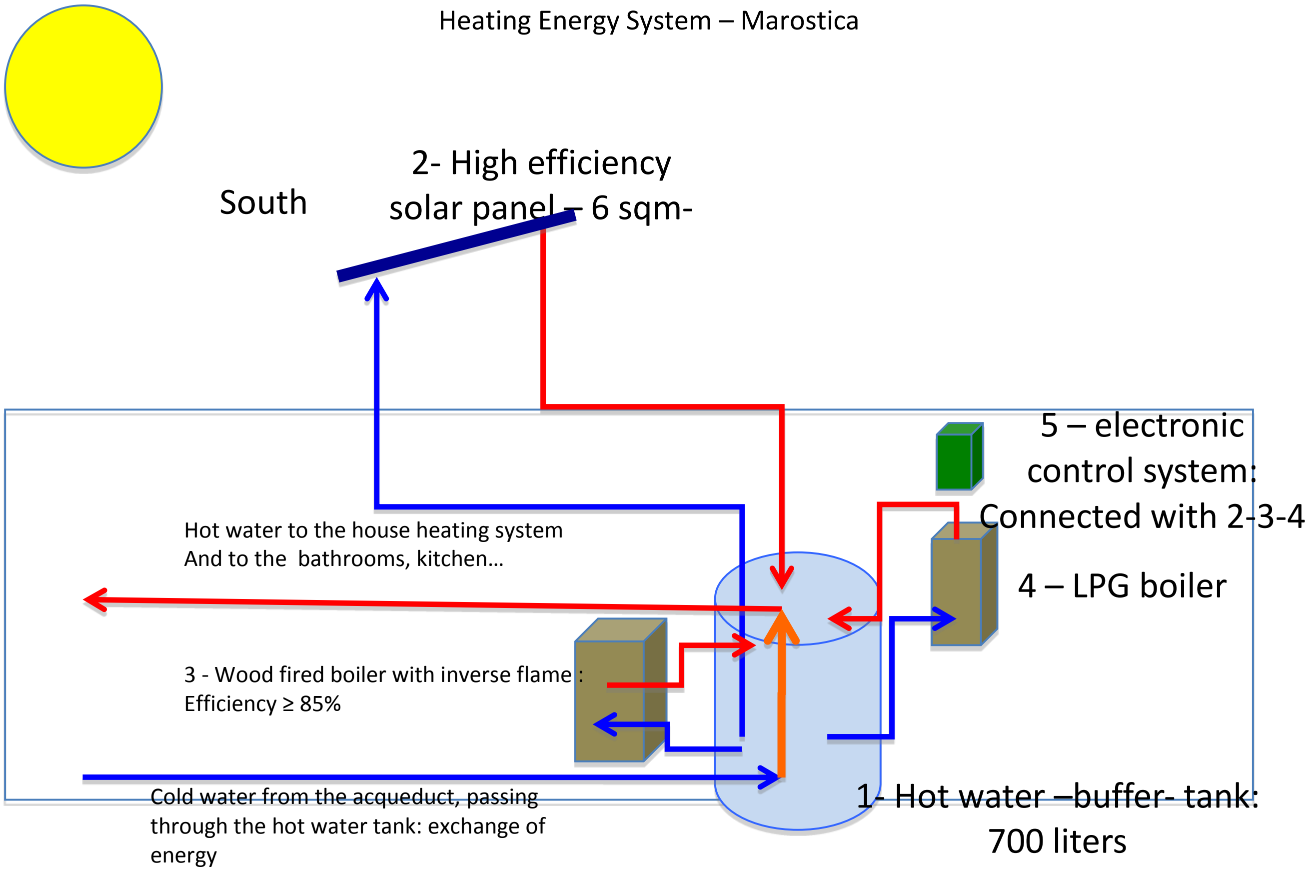
An example of a residential solution is provided by the isolated 170 m^2, 4-6 person home of the Altissimo family in Marostica, in the foothills of the Dolomites. As with the technology integrations above, the primary energy source is solar thermal. The house has been carefully sited for the sun (south) uses specially glazed windows and has 2 solar panels of 6 m^2 providing 100% of heating needs from April to October each year. A 700 litre highly insulated hot water storage tank is used.

Marostica residence, Adriano Altissimo, Land Lab.

A secondary energy source is wood cut from trees in the property's woodlands. A substantial amount of wood is required for the winter period, as temperatures can drop below -7^{0}C for at least 90 nights, and stay below zero in the daytime. A wood burner with inverted flame (efficiency >85%) is used for water & space heating. The wood burner needs stoking at 4-8 hour intervals. A small LPG boiler provides back-up energy for prolonged nil sun periods or for total absences from the house in excess of 1 day.

An electronic controller manages the balance of the whole system – solar panels, wood fired burner and LPG boiler. With solar and wood biomass, the site is fully self-sufficient, apart from extended nil sun periods.

Diagram 12.2 Energy Integration for an Isolated Italian Alpine Residence



Source: Land Lab, Quinto Vicentino (VI) Italy

Farms & Orchards

Modern farms are a centre of a complex of automated production systems, including farm vehicles, farm buildings and farm equipment. For example, a NZ dairy farm uses electric milking machinery, chillers to quickly cool & store the milk, power for pumping of effluent and for irrigation, DC power to run computers and process control systems, fuel for farm vehicles, and electric power for sheds and houses on the property. Today, farms are able to tap into economically viable self-generation technologies such as biomethane from biomass digestion, solar PV electricity and solar thermal power. Some may also be able to successfully utilise small wind turbines. Hill farms are also able to use micro hydro generation.

Orchards and market gardens are in a similar situation, with fuel for orchard/ field equipment, power for produce grading & storage, irrigation pumps and energy for sheds and houses. Again, renewable energy technologies now offer them the opportunity to meet some of their energy demand from self-generation.

12.3 LARGER SCALE BUILDINGS

Larger scale industrial and commercial buildings are also able to incorporate the design principles, materials and components of ZNE, ZEB, Green Buildings and Passive Houses. A lot of this comes available through the work of architectural schools, professional bodies and the associations such as those noted above.

12.3.1 Cogeneration of Heat & Power

Gas & Liquid Fuels

Cogeneration (or combined heat & power) is where the process of electricity generation and the production of heat occur in a single process or power plant. Many power generating technologies have a significant amount of 'waste' heat, as with micro gas turbines for example. Cogeneration captures this exhaust heat to apply it to other heat demand at the location, thereby lifting the overall efficiency of fuel utilisation.

The heat may be in the form of exhaust gases, steam or hot water, and at different temperatures. These systems use a variety of technologies to effectively capture and redeploy the heat, including boilers, Stirling engines and heat exchangers. In the EU, SETIS estimates that co-gen systems are now delivering around 16% of European industry's final heat demand, plus a significant share of district heating & cooling systems. The EU aims to have 67% of bio mass energy systems operating in co-gen mode by 2030. Recent moves by the EC to mandate for co-gen with bio digesters has caused the roll-out of this technology to slow recently.

In NZ, Meridian Energy has been an important promoter of co-gen installations through its subsidiary, Energy for Industry. The company was sold to Pioneer Energy in December 2012.

http://www.cogeneurope.eu

http://energyforindustry.co.nz

http://www.pioneergen.co.nz

Combined Solar Technologies

A number of start-ups and development teams have been engaged upon a single solar collector capable of capturing both PV and heat in the same installation. HERA in NZ is developing one such system. Technique Solar in Australia has been trialling its module system and seeking scale up finance. Its units generate 70% thermal energy, and 30% electric power. A special lens is used to concentrate the sun's rays onto the walls of a trough system, which then reflect the sunlight onto strategically placed heat exchangers and PV cells at the bottom of the trough. A sun tracking mechanism is used. Energy storage is hot water.

The system design is highly space efficient with a footprint a factor of 7 smaller than traditional solar PV systems. An electric power generation 40% greater than standard PV systems is claimed. The co-solar generation maintains a steady temperature in the trough, keeping the solar cells at optimum performance temperature.

Technique Solar worked with RMIT in development of its system. A demonstration site has been operating since late 2011, and the system is well advanced in certification & accreditation trials.

Production is scheduled for Australian deliveries in mid-2013. Composite Materials Engineering has been appointed the composites and systems manufacturer. Licensees have been appointed in China and India, and demonstration units are in place in those countries.
http://www.techniquesolar.com.au/technology

12.3.2 Green Energy Pod

Lower Hutt firm & Ōtaki Clean Tech Centre member ***ESG Energy*** has developed an integrated energy pod to demonstrate the integration of several generation and energy storage. The pod has been successfully demonstrated at the Pacific Leadership Forum in the Cook islands in August 2012. The pod includes:

1. small wind turbine
2. solar PV panels
3. micro hydro
4. hylink electrolyser
5. hydrogen earth storage battery
6. remote monitoring & control.

Energy off-take can be made in several forms:

1. hydrogen gas for direct heating & cooking
2. hydrogen to electricity via a fuel cell
3. electric charging units for cell phones, EVs, etc.

The energy pod is one demonstration of a possible integration of several energy technologies on a scale relevant to individual homes, farms and small buildings. The Hylink component of the pod is currently in scale up for volume manufacturing.

http://www.esgenergy.co.nz/energy-pod

12.3.3 Integrated Green Energy Complexes

In recent years, a number of large campuses and office complexes have moved decisively to utilise green energy supplies. One of the highest profile companies to do so is Apple Computer. All of Apple's data centres are powered 100% by renewable energy sources – solar, wind, hydro & geothermal. This is being carried over to its corporate offices, giving the company a 70% renewable energy supply in 2012. The company aims to be a 100% renewable energy company. Design elements that the company has deployed at various sites include:

- chilled water storage to improve chiller efficiency
- use of outside air cooling to minimise the use of chillers - to 25% of operating time
- careful control by cold air pods & variable-speed fans to match airflow to server cooling requirements in real-time
- distributing power at higher voltages to reduce distribution losses
- reflective (white) roof design to maximise solar reflectivity
- LED lighting combined with movement sensors
- real-time power monitoring & analytics

- use of recycled local construction materials
- contracts for energy supply from off-site made with renewable energy generators
- on-site use of solar PV, solar thermal and geothermal generation
- biogas fuel cells

Many other leading companies are pursuing similar goals and strategies. Importantly, these companies are all publicly reporting on their performance on their journey to becoming fully green technology, zero carbon emission sites.

http://www.apple.com/environment/renewable-energy

12.4 COMMUNITY FACILITIES

Some energy technologies incorporate significant economies of scale. Other technologies are modular and scalable. Some have a minimum size for viability. Some sites do not have the conditions for installation of some renewable energy technologies, but would like to have an ownership interest in such technologies in order to meet their demand energy profile (eg their site is shaded, preventing use of solar energy).

One solution to these challenges is to participate in the establishment and operation of a community facility, and to draw the users' energy needs from the community site. This requires some reticulation and metering arrangements, plus a management body for operating the system. Three aspects of such arrangements are discussed below.

12.4.1 Community Wind Farms

A common form of community endeavour in the renewable energy field is the construction of community wind farms. This has enabled the communities to acquire larger scale turbines than would otherwise be possible for any individual user. The earlier discussion of the Schonaü community in the Black Forest, Germany, is an example of this type of initiative. In considering such schemes, it should be remembered that wind turbine technology continues to advance at a rapid pace, especially in the small scale segment.

In NZ, Blue Skin Bay residents have formed a Resilient Communities Trust to promote, among other things, energy independence. A rural part of Dunedin City, the community, like Ōtaki, has a sole sub-station servicing it. Working with Trustpower, Pioneer Generation & Energy3, the trust has raised funds and in February 2013 installed a 30m wind testing tower in their locality. The aim is to provide data for the building of a 4-turbine wind cluster. The Trust is also exploring the establishment of a syndicate for purchasing solar PV panels for community members.

It is possible that some suitable sites for wind energy generation are available within the Ōtaki area, especially if the NZ demonstration trials for the venturi wind turbine are successful. These are unlikely to be in the townships, and therefore a community facility may be appropriate.

12.4.2 Community Solar PV

Most solar PV installations are for on-site power use. However, some of these can be quite large, as demonstrated by SAFE Engineering's 68 kW installation in Drury. Not all sites in any community are oriented to facilitate the economic operation of solar PV power.

However, this does not prevent those owners, or other consumers who don't a property, from pooling their finances and establishing a larger scale solar PV installation. They draw their energy from the installation over the local lines network. Such an arrangement has been implemented in an increasing number of communities in the US.

12.4.3 Community Energy Storage

Energy storage technologies were profiled in Chapter 9 above. While a few of these technologies are suitable for larger energy generation/ demand sites, many would involve excessive redundant storage capacity for most, including households. Such costs could then imperil the economics of the renewable energy generation installation.

One way of overcoming the storage issue for many sites with small scale renewable energy generation has been to enter into an agreement to buy and sell their shortfall/ excess power from a major energy generator using the national grid. This is particularly beneficial when the energy generated on site does not match the demand profile for its use.

Until recently, Meridian Energy has had a very attractive arrangement which allowed for the purchase and sale of energy at any customer site to be at the same price. This has just been changed so that, after the purchase of 5 kWh/ day of power, Meridian's purchase price will be 50% of their selling price to the customer. This new pricing formula will greatly affect the economics of any new renewable energy installations which need to rely upon such buy-sell agreements.
http://www.meridianenergy.co.nz/for-home/products/generate-your-own-renewable-energy

If the site is too small to host its own power storage facility and the pricing contracts with major generators/ retailers such as Meridian impair the generating economics, it is possible for the community to explore the establishment of its own power storage. The community facility would require appropriate use management and charging systems, and again, would need to utilise the area's electric lines network.

12.4.4 Community Heat Energy Systems

Internationally, the provision of heating energy is often undertaken on a community basis, and distributed to residences and businesses. This enables larger, more efficient plants to be built. A NZ example of this type of energy generation is the Dunedin Energy Centre, which was established by the Otago District Health Board.

The CBD-located Energy Centre has steam & hot water supply contracts with Cadbury Confectionary, steam laundry company ALSCO, the University of Otago and with some other small customers.

The centre has recently been upgraded under a Build, Own, Operate, Transfer contract with Energy for Industry (EFI). EFI has upgraded the pipelines and boiler house systems, enabling the Centre to reduce heat generation costs from those incurred under the previous coal blend options. Particulate & dust control systems have cut emissions into the CBD air to 7% of previous levels. The Centre can now co-fire with wood pellets.

The management agreement with EFI enabled the upgrades to take place without the health authorities having to fund the investment from their own capital budget. The funding came from the energy cost savings that EFI was able to provide. Thus, Otago health's capital budget was reserved for expenditure upon medical facilities & equipment.
http://energyforindustry.co.nz/experience/dunedin-energy-centre

12.5 ENERGY INFRASTRUCTURE FOR ROAD VEHICLES

It is clear from the review of technologies in Chapter 10 above that there is a new paradigm of energy for vehicle transport underway around the world, and that NZ is fully participating in it. At its heart, the technology trajectories are moving, in sequence, from fossil to renewable fuels, and from internal combustion engines to PHEVs, and from there to fuel cell driven vehicles, and compressed air vehicles. Liquid fuel-powered vehicles are beginning to be replaced by those using alternative forms of energy, all of which have electric power as their driver, either directly or indirectly.

Road users with renewable energy vehicles have 2 alternatives in this emerging new era. They can either re-charge their vehicle at home when not in use, utilising a slow but low capital cost delivery system. Alternatively, they can use a fast re-charge system at a commercial installation. With the limited range of present versions of PHEVs, there is also a demand for recharging stations for travellers on journeys longer than the range of their vehicle's power storage system.

Ōtaki's location on state highway 1 has always provided an advantage in the provision of re-fuelling services. This could be replicated with the new renewable energy vehicles now entering the market. This would provide an outlet for any excess power that the Ōtaki community might generate. But sale of that energy, whether in electrical or gas form would demand a commercial service outlet, and therefore supply from across the Ōtaki line network.

Care must be taken with respect to the establishment of these facilities. Energise Ōtaki will need to form alliances with external parties to ensure that any investment made is done so with minimum possible risk. This is therefore likely to involve collaboration with parties such as KCDC, Electra, road vehicle services companies and any fleet operator or grouping within the area.

One reason for caution is that the market penetration of PHEVs has been much slower than had been widely forecast. Once penetration accelerates, the opportunities for Energise Ōtaki increase markedly.

The capital cost comparisons canvassed in Ch. 11 above suggest that sales should grow much more quickly from 2014. The fuel cells (especially hydrogen) and the compressed air technologies are some way behind that of EVs, but the rate of adoption of compressed air technology has the hallmarks of a faster rate of uptake.

In total, the changes in road transport energy forms point to a major shift towards the use of electric power. In Ōtaki, this interfaces well with the expected configuration of renewable energy generation, which is likely to have a strong orientation towards electric power.

12.6 SMART AREA NETWORK FOR ŌTAKI

12.6.1 Overview of Smart Grids

Electricity must be consumed the moment that it is generated. Thus the over-riding imperative for any electricity system is its capacity and capability to deliver electricity sufficient for the demand of the users at all times, and of a quality consistent with their use of it. The challenge is that customers' expectations are very high – when they switch on, they expect energy to flow instantaneously. But there is often no signal from them as to when nor how much energy they will demand from the electric supply system. Further, most consumers do not have a steady profile of demand – at some times during the day their demand can be high, at other times it can be near to zero. Thus the system has to be able to meet their combined peak demand, even though that may be far above their average demand. Delivering that level of service requires the network to install levels of capacity that have short periods of use.

The "Smart Grid" is widely seen as the task of upgrading the electric power infrastructure (transmission & distribution) of the 20th Century with modern communication technologies and enables it to better meet the demand patterns of modern day users. It involves modern, high performance communications and the enabling of 2-way energy flow between producers/ managers and users of electric power. Intrinsically, it is a more consumer-interactive design. It incorporates decentralisation of energy supply, thereby enabling an improvement of overall system reliability.

The NZ national grid, and likewise the Electra lines network, including Ōtaki, was designed on a 'central generation –push to end consumer' model, using large hydro electric stations as the generating source. Energise Ōtaki's goals of being a net generator of energy, require modification of these systems in order to support distributed generation from several sites within the area, and the transmission of power across the local network. If electricity is to be sent from the Ōtaki network to users in other areas, then another level of 2-way energy distribution will be involved.

A Smart Grid or Network embodies 2 critical concepts:

1. the ability to handle electricity from generation & storage at many sites and to distribute this effectively to consumers, including to consumers in other lines networks (2-way flow). This capability offers the opportunity for generation to be sited near the demand location, thereby saving energy losses in transmission, plus operating & capital costs. In Ōtaki's case, this likely implies generation at both individual and community sites.
2. "intelligent" real time management to ensure that the correct supply of electricity is available at all times for consumers without excess stand by capacity being in operation. The aim is to secure a near instantaneous balance between supply and demand at the point of the customers' individual equipment or appliances.

   The intelligent communications also enable the network to self-diagnose its key performance parameters, quickly identify power outages & failures, and generate a speedy, optimised, automated response. Typically, these events are caused by trees falling on the lines, or similar events. The intelligent network can handle these events automatically & with minimum disruption to other customers.

An intelligent grid offers far greater opportunities for efficient handling of peak loads. This means that investment in transmission and distribution assets can be more productive, and operating costs can be reduced. The US Interstate Renewable Energy Council provides technical information on market, interconnection & technical design matters. One concept is that of aggregated net metering which allows a single participant/ meter to offset onsite electricity load from multiple meters through net energy metering credits. This has been extended to billing a single net-metered renewable energy facility allocated across the multiple participants' bills. Something adapted from this could be applicable to Ōtaki, or a sub-group of consumers in the area. http://www.irecusa.org

An intelligent grid offers customers real time information so that they can manage their power demand activities to avoid excessive peak demand. Combined, these smart grid elements create the opportunity for pricing tariffs to be established so as to ensure that there are incentives to minimise peak demand loads.

A smart grid relies heavily upon modern 2-way communications between all levels of the electricity system – markets, generation, transmission, substation, lines networks and users. It also enables the grid & networks to be far more resilient, as faults can be identified and responded to more quickly and with many more options to isolate them and sustain supply to the maximum number of users. The ideal smart grid and network can thus be summarised as performing such that it can:

- Enable effective participation by users
- Accommodate a full range of power generation and storage alternatives
- Enable the successful introduction of new products, services & markets
- Provide quality power for the digital economy (which is largely DC)
- Optimise asset utilisation and efficient operations (extending the old ripple control system for managing hot water heating to a wider suite of controls & enabling user response)
- Anticipate and respond to system disruption and disturbance (ability to self-heal)
- Be resilient in the face of natural disasters or sabotage.

Load management is at the heart of electricity network management. Traditionally done through control rooms, it selects what electricity will be generated where, and where it will be despatched to. As grids and networks become smarter and have a richer mix of generation sites & energy types, contractual arrangements become very important.

The interface of these arrangements, plus the amount of flexibility desired will determine the investment in key assets such as transformers. Prospective energy suppliers then need to assess their own basis for participation within the status of the network and the potential client base.

In NZ, The Lines Company, the lines network for the King Country has adopted a charging model that combines explicit charges for both capacity to the site plus the quantity of energy supplied. To achieve this, The Lines Company has assumed responsibility for lines charges, rather than billing the clients' energy provider with a fixed charge. The issues faced in the King Country are informative in suggesting some ways in which Energise Ōtaki may have to work with Electra.

Customers have had difficulty understanding the King country charging system. Its essence is that:

- meters are installed that warn users when they are at peak load levels
- client peak load is measured as the average of the highest six 2-hour loads placed on the network
- the charge is calculated as:
  - a network control fee (around $1.60/ month)
  - a meter fee (of the order of $5.00/ month) to fund the replacement of old kWh meters (which simply sum total energy supplied) with "demand" meters which measure both usage and time of day
  - a network capacity charge for the minimum capacity of the lines that would theoretically be needed to feed electricity to the client's site (actual capacity will typically be higher). In practice, this has become either:
    - twice the actual capacity demanded form the site, *or*
    - 5kW, *whichever is the greater (from around $3.60 to $6.95, depending upon location)*
  - a demand charge calculated from the site's actual energy usage at times of network peak load when ripple control is in use. The charge is calculated as the site's peak load in network peak load times, & is between $1.65 & $8.05/ kWh, again depending upon location.

The Lines Company charges full lines accounts even for properties which are disconnected from the electricity supply, but still have meters, relays & feeder cables in place. Customers who choose a full disconnection for their holiday home then have to reapply for a connection, and pay the fees that apply for that.

12.6.2 A Smart Power Network for Ōtaki

It is clear that the ability to transmit power across the Ōtaki network is likely to be crucial to achieving the goals of Energise Ōtaki. The ability to move and store power within the local area creates a greater opportunity to introduce renewable energy generation. It also provides Ōtaki power users independence from the pricing policies of the major NZ generators/ retailers.

With smart meters and similar advances for householders and SMEs comes the opportunity for power users to be proactive about the management of their own demand. US estimates put the potential energy saving in the order of 30-40% of previous use. But realising these savings is contingent upon the effective interface of power, sensors/ automation, hardware & communications.

The Ōtaki community itself could contribute to the matching of local generation with local demand through the transmission of power within the area, including to & from community energy storage. In so doing, efficiency gains and the displacement of fossil fuels with renewable energy will reduce Ōtaki's emission of greenhouse gases and global warming.

The Ōtaki area has the advantage of a single electric power sub-station servicing its community, both town & rural. This enables the area's network to be developed into a smart network to facilitate the distribution of energy between generation, storage, and user sites within the area. It is likely that such an arrangement would greatly improve the economics of renewable energy installations throughout the Ōtaki area.

Energise Ōtaki's desire to have its energy supplied from renewable technologies creates further challenges. Renewable energy other than hydro is both intermittent and variable, creating challenges for network management in ensuring continuous quality supply of power to all consumers at all times. The transition to a distributed network may create issues of fairness that will require new or modified charging structures.

Electra is the owner and operator of the Ōtaki lines network. However, Ōtaki is but one of its sub-stations. Thus, Electra has to act with equity in regard to all its customers including those serviced from other sub-stations/ lines. Energise Ōtaki will need to establish a positive working relationship with Electra, cognisant of Electra's need to act in good faith with respect to its other customers.

This study identifies solar PV as an early contender for investment by Ōtaki, if due diligence & risk profiling confirms the viability of the installations. In NZ, this implies a large number of installations/ lines network connections. The intermittent nature of solar PV generation and its uncontrolled distribution have the potential to de-stabilise network unless specific equipment is installed within the network. One place to do this is at the PV/ inverter module, and these can include system performance monitoring & optimisation, plus lines network controls, such as managing PV generation when there is a low voltage situation or a lines fault.

12.7 BATTERY SUPPLIED FREQUENCY REGULATION

Frequency regulation is an essential yet largely invisible service essential for the good performance of the national power grid. In the US, even expensive battery storage such as Li-ion batteries can be a viable technology in service niches.

US firm AES Energy Storage has developed 150 megawatts worth of energy storage projects in four locations using giant lithium-ion batteries. The trick to making them economic is using them for what they're good at and in this case, that's (response) speed. AES reported that it has provided 400,000 megawatt-hours-worth of frequency regulation services to the electricity grid in the mid-Atlantic US states, a portion run by grid operator PJM.

The Laurel Mountain system – 16 connected A123 Systems batteries packaged in shipping containers – draws energy from 61 mountaintop wind turbines in West Virginia with a capacity of 98 MW. That configuration has consistently outperformed competing natural gas and coal power plants in providing the service. AES President Chris Shelton stated that the battery storage "... is competing every day in getting selected and winning. It's a commercial, scalable proof point that storage is economic," he says.

A similar service has been provided in Texas by Duke Energy. Its 36 MW Nortress Battery Storage facility from Xtreme Power is coupled to a wind farm, and is used to smooth the flow of power into the grid, plus provide frequency regulation services.

The batteries absorb power from the wind turbines at different rates, which charge the batteries. On discharge the batteries then deliver a more stable power into the grid. In effect, the dry-cell batteries are being used as a “chemical” capacitor, providing the ability to rapidly store or release energy as needed to better interface with the grid.

12.8 DEMAND RESPONSE MANAGEMENT

The high cost of high-peak loads in a grid or network (in the form of largely redundant capacity to meet demand peaks) can be met by demand management – as simple as turning off some appliances or machinery at peak load times. NZ has had this type of system on its national grid for some time, with centrally managed “ripple control” of electric hot water heating. This has now moved into voluntary participation by consumers, especially large industrial users, who can turn off non-essential electrical equipment during extreme peaks, in return for payment. Known as demand response, the agreements enable the system to operate with much less peak generation capacity.

As intermittent and renewable energy generation become a more significant contributor to overall power supply, it is necessary to have a multi-component strategy to smooth out power fluctuations. Demand response management includes such strategies as dimming lights, controlling hot water heating, temporary re-setting of thermostats on air conditioning & heat pumps by a few degrees, and agreements with major users over progressive shut down of non-critical demand. In the US, grid operator PJM has been surprised at the level of participation in its power demand management scheme, largely led by commercial and industrial users. The big change is that these responses are no longer organised by phone calls, but by automated software & control hardware which automatically reduce the power drawn off at the site. The user receives a rebate for the reduction in the amount of power demanded.

Demand response agreements are increasingly seen as a cheaper solution than “peaker” generating plants. However, they also compete with the role, and thus the economics of power storage systems on grids & networks.

In Ōtaki, there are not the major consumers that feature in other systems, although there are some users which are much larger than others. At the moment, we see an important role for power storage in a ‘smart’ Ōtaki lines network, as much of the required demand shift will be residential driven to cover morning and early evening peak demand.

Even in residences, an informed consumer can react to demand and peak pricing signals. This can be done by wall displays, internet sites and other signals to the home. And modern metering and monitoring technology can anticipate household living patterns so as to prepare the residence’s air & water temperatures for the expected use, while avoiding the supply of power over the peak demand period. It can also run key services in a far more efficient manner than “full time running”, to provide consumers with significant cost savings.

13 ENERGY MARKETS AND INVESTOR RISK

13.1 SHALE GAS

In the last 5 years, development of shale (natural) gas fields in the US (Pennsylvania, Texas & other states) and Canada has moved ahead sharply. New drilling technologies, including horizontal drilling and hydraulic fracturing (fracking) releases the gas trapped in the shale fields. A light shale oil is also released by this process. Providing only 1% of US gas supplies in 2000, shale gas now supplies well over 20%, and it is projected by the DOE to provide 46% by 2035. Other nations, including China & the UK, also have large shale gas deposits.

This significant new source of energy has led to major change in global energy markets. In the last year, shale gas has dislodged coal as the major fuel for US thermal electricity power plants. That displaced coal has gone onto spot markets, causing a large fall in coal prices. This price pressure is unlikely to ease substantially, but further falls are also unlikely as demand for steel and other industrial raw materials continues to be strong in emerging middle class economies.

The result is that the locus of power in the hubs of the fossil fuel markets have tended to shift away from the Middle East and Russia towards a more energy self reliant North America. There will be flow-on effects into other fossil fuel markets, which places a ceiling on prices, and could hinder the pace of renewable energy market penetration.

13.2 NZ ELECTRICITY MARKET

13.2.1 Market Configuration

The NZ electricity market operates under a regime whereby all power producers receive the price for their supply priced at that charged by the last supplier to be sourced for meeting the demand of the charging period. For long established hydro generators, this offers a huge value wedge when peak demand has to be met from high marginal cost sources such as coal and gas fired thermal power stations.

As the cost of building new generating capacity increases, hydro generators are able to revalue their assets upwards with the increased earnings. This economic “rent” earned by the hydro electricity generators is seen by some as an unfair charge on electricity consumers.

Electricity prices for residential users have increased at a rate well ahead of that of consumer price inflation. In April 2013, the NZ parliamentary opposition parties announced that they would restructure the NZ electric power market to remove the rents from the electricity generators, which they hold acts against the interests of energy users.

From Energise Ōtaki’s perspective, the opposition’s policy would reduce residential electricity prices, at least in the short term. The lower prices would set a tougher threshold for new renewable energy technologies to become viable. While not the policy of the present government, this potential market restructuring needs to be borne in mind by any commercial activity created for the delivery of renewable energy solutions for the Ōtaki area.

13.2.2 Major Power

The NZ electricity market has 1 major power user, the aluminium smelter at Tiwai Point in Southland. Producing some of the world's purest aluminium, the smelter is operated by NZ Aluminium Smelters (NZAS) and consumes more than 12% of NZ's total electric power.

NZAS consumes about 600MW of electricity. The smelter is now some 32 years old, and technology has advanced since its design. It has 624 P69 technology cells in 3 pot lines, and 48 CD200 technology cells in 1 line. The plant makes aviation grade aluminium alloy, and has been viable until recent rapid expansion of capacity in China, reduced demand from the global recession and a high NZ$ exchange rate collectively reduced operations to below break-even trading levels.

Staff cuts were announced in September and a $70m capital expenditure programme was put on hold in October 2012. The smelter is managed by Rio Tinto Aluminium. NZAS was spun out of the main group into a new business unit of Rio Tinto, Pacific Aluminium, in 2011. This unit is understood to be on the market.

Pacific Aluminium has announced that NZAS is no longer a viable business unit, and faces scaling back or closure. However, there is a take or pay agreement in place for the power until the end of 2015, with ongoing commitments after that.

The issue for Ōtaki is that any closure or scaling back of smelting activity at Tiwai point will release electric power to the national grid, which is expected to lead to reduction in wholesale electricity prices. In so doing, the price per kWh available to renewable power generation will be lowered. Again, this movement will alter the economics of renewable energy generation.

Partner investment at Tiwai Point suggests that a closure is not immediate. The power purchase commitments under the current supply contract between NZAS and Meridian Energy suggest that major change on the part of the smelter is unlikely before 2016. Nevertheless, with their typical cost profile of heavy upfront capital cost and low operating costs, any investors in Ōtaki renewable energy should take into account that there is a risk that the value of energy generated might be lower than current prices indicate, possibly substantially lower.

13.3 TECHNOLOGICAL INNOVATION

A major feature of the scoping study has been the rapid rate of technical innovation in power generation, power storage, bio fuels, kinetic energy capture in motor vehicles, new power sources for vehicles and the deployment of information systems to enable real time management of energy demand by both suppliers and users. In part, these are a response to new environmental regulations and policies, and in part to a major increase in research & development into renewable energy production. Collectively, these changes are leading to more energy efficient economy, and reducing the output of green-house gases per unit of GDP. However, a number of countries with very large populations are experiencing strong economic growth, despite the economic troubles in Europe and the US, and their demand for energy and industrial materials is expanding the overall demand for fossil feedstocks.

From an Ōtaki perspective, the case for green technologies has not been reduced. However, the financial challenge is high during periods of such rapid market and technological change. It is possible that breakthrough technical advances in one area will have disruptive impacts across many energy market segments, in terms of both price and ease of use. The role of a technology road map, such as that set out in the next chapter, is to promote/ provoke interaction around the likely trajectories of a range of technologies, and to create a consensus around a preferred investment strategy for the area.

With many parties making co-dependent investments, a major investment risk can be reduced by an informed & coordinated approach.

The pace of renewable technology development should also inform the investment strategy of the community. Today's technologies carry a risk that they may become costly or obsolete in the near-term. Depending upon how high one rates that risk, the lifetime of the plant and the payback period for the investment should feature in the investment evaluation.

13.4 POWER STORAGE, SMART GRIDS & DEMAND MANAGEMENT

The financial case for power storage facilities is strengthened by the need for load shifting to lower peak demand on the generating capacity in Ōtaki. However, as lines networks become smarter and more automated with 2-way communications, the role of power storage is reduced. This results in a lower value on the storage of the power.

We consider that a smart lines network in Ōtaki is of paramount importance, as it can facilitate the generation and distribution of renewable energy within the area, with big savings in transmission costs and market price wedges. The degree of flexibility and power quality control necessary to make this a success will not benefit as much from peak power shifting as would previously been the case. This fact adds to the financial risk of the renewable generation strategy of Energise Ōtaki and should be borne in mind, as the capability of smart networks will increase significantly in coming years.

13.5 DUE DILIGENCE MUST BE UNDERTAKEN ON ALL ENERGY INVESTMENTS

This study is only a scoping study to identify the broad outline of technology options, and to begin the process of identifying which ones could best fit into the circumstances and goals of the Ōtaki community. Any technology must be thoroughly investigated both for technical performance and reliability, and also for investment returns and compatibility with the area's energy use profile and resource endowment. In part, these decisions will also be influenced by the response of the Ōtaki community to offers of access to renewable energy, and to investing in the technologies at individual and community scale.

14 TECHNOLOGY ROAD MAP

14.1 STRATEGY

14.1.1 Is a Clean Energy Community Scale a Possibility?

The first driver for this study was to assess whether or not Ōtaki could generate its own energy? The international evidence is that it is certainly possible, and some similar sized communities have already done so. But those communities have been able to access significant incentives, which are not available in NZ. So the question takes on a second dimension – can the goal be achieved with economically viable investments?

The answer to this second dimension is not clear. The cost: performance ratio of renewable energy technologies is improving quickly as innovation proceeds at a fast pace. The opportunities for energy users to manage their own demand in real time could deliver big savings in energy consumption. But a direct match of energy form in generation with energy demand is not likely, at least in the foreseeable future.

Offsetting these positives is the uncertain situation in the market for energy. Big savings of themselves reduce market demand, and will lower energy prices. The Opposition parties have announced that they see the need for a reform of the NZ energy market that is more orientated toward the interests of users, and are aiming to deliver significant power price reductions. And the major power user in NZ has given notice that it may close its operations, transferring 12% of the present electric power generation on to the open market, which will cause a fall in prices.

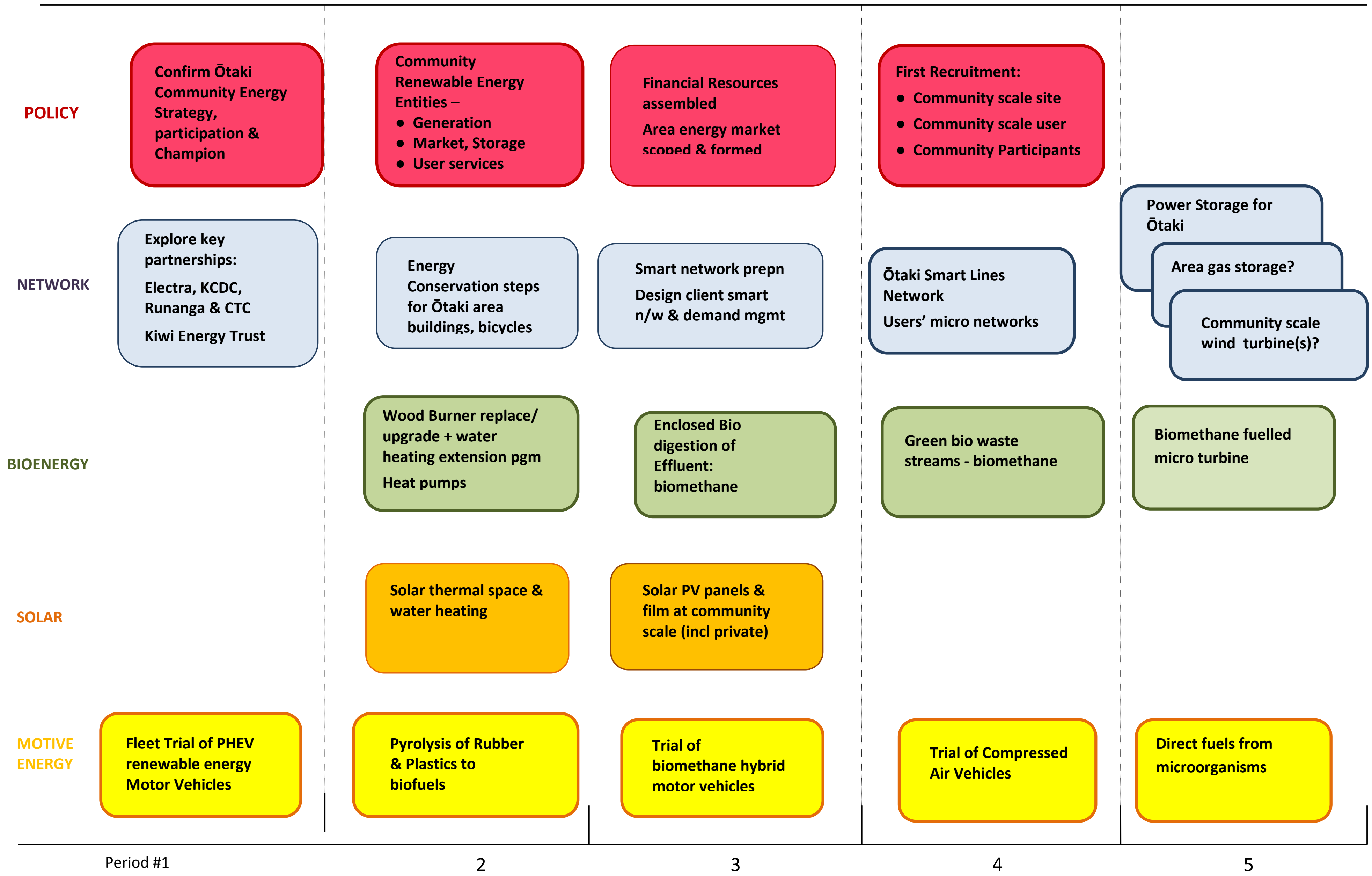
A number of technologies are now viable candidates for moving the area towards the "net energy exporter" vision of Energise Ōtaki. However, significant progress towards net exporter status demands more than individual action. Community facilities and coordinated action are required, to reduce risk, create market access and to provide scale. This implies that there are a number of investment decisions to be made by independent parties which are contingent upon the investment decisions of others. Securing complementary action is both challenging and crucially important.

One way of achieving the necessary communication and focus within Ōtaki is to develop a technology road map (TRM) which provides information on technology/ market development and timing. Combined with appropriate organisational structures, a TRM can provide a medium for testing alternatives, selecting technologies and market trajectories and for setting common understandings as to scale and other standards.

For the Energise Ōtaki project, the TRM needs to cover 5 dimensions as set out in Diagram 14.1:

1. The creation of an organisational scaffold and key network & market relationships
2. Energy conservation & demand management, including local power storage & a smart lines network
3. Generation of renewable electric power within the Ōtaki area
4. Bio energy
5. Motive energy

Diagram 14.1 Overview of Technology Road Map



14.1.2 Energy Generation

Solar

Ōtaki's relative strength in its resource endowments is solar energy. It is located in NZ's sunniest climatic band – Nelson/ Marlborough/ Kapiti/ Wairarapa. In comparison, it does not have the high wind energy classification of other parts of the Wellington region owing to its location in the wind shadow of Kapiti Island.

Solar energy can be exploited in 2 forms – photovoltaic and the heat of the sun. With present technologies & energy prices, solar thermal installations for buildings are viable. This technology can be utilised now. Solar PV is in the middle of a major technology & cost revolution. Life cycle electric energy costs are now below the power prices of the major NZ generators/ retailers and are now near to wholesale market prices.

Recent changes to energy purchasing terms limits the scale of solar PV (and other renewable energy technology) installations to individual building owner needs + a 5kW ceiling. This runs against the goals of Energise Ōtaki. It is therefore necessary to secure some independence from the major generator, possibly by energy storage plus power conditioning. The organisational scaffold should enable sale & purchase of power between parties within the Ōtaki area, using local energy storage.

Wind

New turbine technology may overcome Ōtaki's locational wind disadvantage. Commercial scale demonstration installations are being built now. In general, wind turbines have moved to 2 poles of scale: domestic and very large. The new venturi design, Invelox, offers a fully scalable turbine, but no demonstration site is available in NZ as yet. One is promised near Whangarei this year.

Power Storage

The importance of wind capacity in a renewable energy configuration is wind's complementary generation profile with that of solar. The Hylink solar PV/ wind turbine electrolyser and hydrogen storage tests on Soames Island in Wellington harbour confirm the complementary generation patterns of wind & solar in NZ. Daytime solar generation is matched with significant wind generation at night. While not in the same climate or geographic location zones as Ōtaki, these results are comparable with overseas results.

Subject to satisfactory trials and favourable economics, we recommend that investment in wind turbine technology be made in the context of power storage decisions. That will be after the community scale solar PV installations have progressed. An evaluation of available wind technologies of appropriate size can be made then.

Mini Hydro

Ōtaki's hydro power generation potential is not significant, and would likely compromise a major recreational area for the Wellington region.

Bioenergy

A second Ōtaki strength is biomass. Ōtaki is a market gardening area. It has dairy farms creating effluent. It has 3 townships which generate a significant volume of bio waste material, green and other. There are commercial forests and woodlots which offer biomass from logging slash. And there is driftwood available from the beachfront. This endowment offers 2 energy options for Ōtaki – anaerobic bio digestion to biomethane and heat from wood burning. There have been significant advances in both which Ōtaki could implement to advantage.

Transport

EVs have now achieved social acceptance. Technical advances are simplifying the application of electric power to transport and reducing the up-front capital cost at the same time. Similarly, compressed gas traction is simple and is scheduled to enter volume production in 2016.

Smart Lines Network & Micro Grids

The review of technologies that use energy identify a notable shift towards solar thermal & electric power, either directly for space & water heating, or indirectly for motive energy (eg compressed air). This trajectory points to a key role for the local area's power lines network, provided by Electra. The electric power component also points to the importance of systems to provide storage for power. Local storage in Ōtaki offers one avenue for storage, and independence from the major generators/ retailers who hold significant market power. Alternatively, the area could rely upon trading with the power majors, but current terms provide a large price wedge in favour of the major generators. See http://www.economist.com/blogs/babbage/2012/10/nitrogen-cycle

New ICT & sensor technologies now offer the potential for energy users to be proactive managers of their energy demand. Suppliers are able to charge for power on a time-supplied basis. New feedback displays for users make this sort of management available even to the smallest household. Major system-wide energy savings become available with these tools.

14.2 ORGANISATIONAL SCAFFOLD

Corporate or administrative vehicles are required to execute a number of roles in the Energise Ōtaki project implementation. Those roles include:

1. a community organisation to promote energy conservation, efficiency and wise demand management
2. a market organisation in Ōtaki to coordinate the sale & purchase of locally generated renewable energy within the area
3. a renewable energy generating group within Ōtaki who will invest to establish renewable energy installations within the area
4. a technical systems operation to work with the generating group and the infrastructure providers such as Electra and renewable fuel recharging centres.

The critical roles are to activate a vehicle for marketing renewable energy, and another to generate the energy. A core relationship then becomes the distribution of that energy across the Ōtaki area.

The structures of these organisations could be an area cooperative, or other community focused ownership model. Some could be strictly commercial, and some a mixture. Whatever form they take, all need to collaborate to deliver a common vision and intermediate goals. This will require a high degree of interaction and mutual trust & support.

14.3 ENERGY CONSERVATION & DEMAND MANAGEMENT

The aim in this area is to wisely minimise the Ōtaki community's use of energy, while sustaining a positive and enjoyable lifestyle. The less energy consumed, the less energy that Ōtaki needs to generate, and thereby, the less capital that has to be found for investment.

14.3.1 Space & Water Heating

The 2007 census results for Ōtaki showed that installed technology for water and space heating is traditional, and typically has low energy efficiency. There is a large amount of open fire space heating, which has very low energy efficiency. These fires could be readily converted to efficient wood burners with water heating, or to heat pumps. Hot water heat pumps are now available. The challenge is the up-front capital cost, which is a significant barrier for many home owners. Also, there is a need for trusted advisors and project organisers that can specify an optimal solution and organise the work. This role could be performed by one of the community organisations utilising services offered by members of the Ōtaki **Clean Tech Centre**.

14.3.2 Home insulation

Dry warm homes are critical for good health and comfort. Insulation is a must for all Ōtaki dwellings and buildings. The Passivhaus and similar systems have even tighter air conditioning standards and controls, and some retrofitting of existing structures is viable.

The Ōtaki housing stock is relatively old, and therefore the potential for structures not to be adequately insulated is quite high. This is an area where local knowledge & leadership has a significant role to play. The organisational scaffold should be capable of providing this leadership, including the provision of a thermal imaging service.

14.3.3 Efficient Appliances & Equipment

The performance and efficiency of appliances is continuously being upgraded. US appliance manufacturer Whirlpool has just released a "smart" refrigerator. Smart meters are now available which report energy use patterns & costs to users and enable them to make changes to their energy demand.

Similar trends are taking place with motor vehicles, but until recent times, these improvements were largely being applied to improved performance & larger vehicles, not energy conservation. Now, improvements in vehicle efficiency are being applied to energy savings.

Replacing an appliance or a motor vehicle is a large decision for most households. Up-front capital cost is a significant decision criterion, even if the total life cycle cost gives a different ranking. Further, there comes a point where poorly performing appliances and vehicles, although not worn out, have a heavy cost relative to new models, and should be replaced. Encouraging informed consideration of these issues is an important role for Energise Ōtaki.

14.3.4 Travel

Internal transport within the Ōtaki area can be enhanced to encourage walking and cycling. In this way, motorised transport can be reduced, and this minimises a very inefficient use of energy. Public transport facilities, such as rail and bus, can offer similar minimisation contributions if timetables are suitable for the needs of the community.

Separate corridors for motorised vehicles, cyclists and pedestrians are the preferred infrastructure configuration. The current road layout within Ōtaki could readily be enhanced to lift the attractiveness and safety of cycling relative to motor cars. The major challenge is the safe crossing of the state highway, but the planned bypass will alter this.

14.3.5 Design of Buildings

New materials and new building designs are able to provide a much more energy efficient building than earlier designs. A number of design types were canvassed in the study, and there are many others in addition. However, not all homes are built by firms who have energy efficiency as their clear objective. Often, the additional up-front costs for high efficiency are a barrier, or the building owner wishes to maximise usable space or some other element, and energy efficiency is compromised. Changing attitudes to over-sized, over specified dwellings is not easy, but should be a part of the Energise Ōtaki action programme.

14.4 RENEWABLE ENERGY GENERATION, POWER

Technical innovation, both in energy generation and motor transport, will increase electric power's proportion of total energy consumption in the Ōtaki area. These changes are already underway, and will accelerate as the relative price competitiveness of the new technologies continues to improve.

A number of technologies were reviewed, with solar energies assessed to be the first that can make a significant contribution towards Ōtaki's goal of self generation. Solar thermal space and water heating technologies are viable now, but organising the funding and the work is a stressful exercise for many homeowners. If the organisational scaffold around Energise Ōtaki can win sufficient profile and credibility, it may secure a position where it can act as the trusted agent to facilitate these improvements.

The most common trigger for renewal is the failure of an existing system or appliance. Replacement is then done under an urgent time constraint, and often on the advice of the tradesman undertaking the repair. In Italy, the accreditation of a wide array of trades' people into an energy efficiency network was a key element in the green community movement. Action on this front in Ōtaki, and perhaps in the wider area from which such services are drawn, could be an important role for the Energise Ōtaki organisational scaffold.

Several international studies show that areas such as Ōtaki have the solar energy to transform their power supply footprint sharply towards renewables. Then the task is about smart lines networks, markets for the local sale & purchase of the area's energy, and cost effective energy storage.

Biomass offers a new opportunity for energy self sufficiency for Ōtaki. At present, most are not economic, but several changes are being applied that offer the possibility of an economic activity in the energy production context, especially generating biomethane. In Europe, the biodigesters are widely used to fuel micro turbines for power generation. In Sweden, biomethane is upgraded and fed into the natural gas grid, but this requires a large volume of methane to justify the capital expenditure and quality assurance.

Wood, burnt in open fires or in burners, sometimes as wood pellets for larger installations, is the only significant renewable energy source used in Ōtaki in 2007. However, it is often deployed in very low efficiency applications. This situation could offer the possibility of early gains for the energy generation & efficiency goals.

14.5 COMMUNITY SCALE ENERGY STORAGE & DISTRIBUTION

Energy storage in Ōtaki could be deployed to support community-scale generation and to lower the investment risk. The community is already utilising energy storage mediums in the form of hydro storage, accessed through the national grid, through liquid fuels, natural gas, and batteries.

New technologies currently entering commercial markets offer the prospect of community scale storage that would enable the Ōtaki area to create an internal market on more competitive terms & conditions than those now on offer. It will also be necessary for these facilities to provide power conditioning and rapid response if the local area lines network were to become dominated by variable renewable energy power supply.

There are a number of candidates that should be investigated further in the context of an overall energy plan. The new GE ceramic tube battery is one that has relevant scale and large volume manufacturing. Local firm ***ZEV*** has special expertise in systems for battery management, and therefore may be able to bring Li-ion storage into a viable proposition for Ōtaki.

Looking further ahead, the Earth Battery technology from ***ESG*** offers an inexpensive storage medium for biomethane, and through electrolysis of water into hydrogen, a base line comparison for the economics of other storage mediums.

It is too early to make selections from the new storage technologies now entering demonstration trials, but compressed or liquefied air or other gasses have a level of simplicity that suggests that they will become leading contenders. However, we do not expect them to be available within the 2-year lead time used for this study.

14.6 RENEWABLE ENERGY FOR MOTIVE POWER

Motive power is a major part of the Kiwi lifestyle, and particularly so in Ōtaki. Automobiles offer independence and mobility that are critical to everyday life, not only for recreation, but also for employment and servicing day-to-day needs. However, as set out in Chapter 1, this energy use is one of the least efficient in the array of energies used by Ōtaki area residents (as everywhere else).

Meeting the challenge of improving fuel efficiency relies on many actors. One group is the new economy and clean air demands of transport regulators in Europe & the US, and more recently China. Another has been the rising cost of fuels, and a third, increasing community concern regarding congestion, pollution & greenhouse gas emissions.

A major breakthrough has come with the introduction of regenerative braking and the redeployment of the kinetic energy into traction. This is vehicle-specific, so remains a decision of the individual motorist or fleet manager. Informed leadership by larger organisations in Ōtaki could spark the credibility for such purchases.

Chapter 11 explored a number of new traction initiatives coming to market. One is the improving performance of PHEVs in terms of price and distance. New systems are being introduced to ensure that internal services such as heating do not excessively impinge upon performance. KCDC has already moved to purchase an all-electric waste truck, and this remains the most accessible green fuel at present. Some biofuels are available in the form of bioethanol petrol blends and biodiesel, but these are not yet significant in Ōtaki.

Three major new technologies are coming to market:

1. Fuel cell powered vehicles: these have the advantage of a long range, but the cost of key components is high. In addition, a new distribution & storage infrastructure would need to be put in place, although local generation could eliminate the transport dimension of this cost. At present, fuel cells for motive power do not look to have strong economics in Ōtaki.
2. Compressed gas regenerative braking: utilising compressed nitrogen, this technology offers a much simpler form of capture & redeployment of the kinetic energy created in braking. PSA Group of France has already announced plans for volume production from 2016, just outside our timeline. The advantage here is the elimination of a second engine in the vehicle.
3. Pneumatic engines: These are likely to be based around nitrogen, which in liquid form has a very high energy density. Recent breakthroughs eliminate the need for a heat exchanger during the expansion phase. British industry is building a value chain around this technology.

It seems likely that innovations in both electric vehicles and in compressed air technology will advance quickly over the coming 5 years. Further, there is likely to be synergistic developments between the motive power applications and stationary energy storage. Compressed air (including nitrogen) has the hallmarks of being the breakthrough technology, but in the meantime, PHEVs seem to be on their way to being a competitor to fossil-fuelled automobiles in specific market sectors (central city area and regular stop-start applications with return to the same site, which enables recharging).

There is also a strong stream of innovation in the development of drop in replacement for fossil liquid fuels. The widely acknowledged technical breakthrough of Joule Unlimited has set a new cost performance record for both ethanol and biodiesel.

If the company makes only 80% of its target delivered cost for the fuels, it will have a set a price of US$62.50/ barrel - well below the $100+ threshold that most of its competitors had been planning on. The price of gasoline would be the equivalent of NZ$0.42/ litre before excise taxes and road user charges.

Joule's breakthrough uses specially modified microorganisms which directly excrete the biofuel, thereby eliminating the need for further transformation processing. While still being used in efficient internal combustion engines, the technology is almost CO_2 neutral in environmental terms. At the same time, it has set a cost ceiling that is quite low. Joule has likely eliminated algae based technologies from the renewable liquid fuels competition. Joule's ethanol culture is being rolled out at present, and biodiesel is to follow.

15 CONCLUSIONS

Can Ōtaki become self-sufficient in energy demand and use? The answer is no. Not in a direct energy form match. But it could become a net renewable energy producer, trading excess energy in one form to procure renewable energy in an alternate form which it cannot produce cost effectively.

In NZ however, there is another dimension to the proposition – could this also be achieved solely through investments which are commercially viable? Some investment in renewable energy capacity can be viable in present market conditions, notably solar PV & solar thermal. However, there are a number of market risks.

Energy conservation through things such as insulation and efficient appliances and equipment is always a key first step. Good maintenance of these items is also important. Feedback and automated systems for users enable them to manage both the scale and timing of their demand. Reported energy savings from the use of these devices is high.

Energy market conditions are undergoing change with the introduction of smart grids and even smarter appliances, motors & equipment. The major NZ generators & retailers are changing their sale and purchase terms. There is also the prospect of a sudden increase in power supply on the NZ market should NZAS scale back its smelting operations significantly. The value of revenue generating/ cost saving energy investments is uncertain, and made more so by the rapid pace of technology innovation taking place.

Some of the financial risk can be ameliorated through the creation of community scale energy capacity; especially for power storage and biomethane fired micro turbines. This could be extended to providing opportunities for community scale solar PV farms and market opportunities for those who invest to generate surplus energy from their properties. Collaboration with Electra to use the local lines network as a smart grid would be essential.

Recognising the market uncertainties and investment risks, should Energise Ōtaki or its members individually, decide to continue on their vision of becoming a net renewable energy exporter, then the focus should be on solar technologies. With solar PV, a counterpart wind turbine capacity may assist balance the generation profile and provide a more economic generation/ storage configuration.

Selection of the appropriate power storage medium will depend to some extent on the scale of the community's participation in the Energise Ōtaki enterprise. Hydro storage via the national grid is a standby that is available from day 1.

The second area to be explored is the use of biomass waste streams for the generation of biomethane. Methane has a number of value streams in which it can be deployed, but some of these require production volumes that won't be achieved in the early days of operations. The advantage of the more modern bioreactors is that they produce relatively clean water, which can be available for irrigation, and can readily be brought up to higher standards if required.

A third area for investment is the development of drop-in replacements for liquid transport fuels. The outstanding candidate here is Joule Unlimited's microorganism direct production of liquid fuels. Otaki has some low productivity land that could host such an installation. There are also fossil fuel efficiency technologies available within the Ōtaki **Clean Tech Centre.**

Investments in liquid fuel production don't aid the shift towards more efficient energy use. However, they do answer the environmental challenge of the use of the existing stock of internal combustion engined motor vehicles through their near neutral carbon footprint status.

Electric vehicles are emerging into the mainstream of motoring. They provide very high energy efficiency. Fleet operators in the Ōtaki area could provide an initial impetus for the introduction of EVs and the accompanying infrastructure. With its new all electric waste truck, KCDC has already made the first step in this direction.

Beyond the immediate horizon, compressed gas technologies are rising as a strong technology for both motive power and for energy storage. The emergence and progress of the compressed air & gas technologies should be actively monitored.

Greenchip Limited

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