TE140/2

Renewable energy opportunities in the New Zealand residential built environment

Final

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About This Report

Title

Renewable energy opportunities in the New Zealand residential built environment

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Abstract

This report provides a high-level view of low and renewable energy technologies in New Zealand, the level of uptake, who is involved in the market, and the potential changes which will bring Beacon closer to its goals. It considers two main types of energy, low grade and high grade.

Reference

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1 Executive Summary

The purpose of this report is to provide a high-level view of low and renewable energy technologies in New Zealand, the level of uptake, who is involved in the market, and the potential changes which will bring Beacon closer to its goals.

This report considers two main types of energy, low grade and high grade. Low grade energy can be used for space heating and water heating – it does not have to conform to any particular delivery specification. High Grade energy is the type which would run a computer, DVD player or microwave oven. It must meet strict standards when delivered.

Electricity is the most commonly used high grade energy source in New Zealand for a variety of uses including space and water heating. Given that the production of electricity is expensive, both from a generation and distribution perspective, it makes sense to reserve this type of energy for end uses specifically requiring it, and to look at low grade energy to satisfy space and water heating demand.

The BRANZ Household Energy End-use Project (HEEP) suggests that baseload and domestic hot water standing losses are virtually the same (annualised) as the electric space heating load. Baseload is composed of all of the appliances that run constantly, including standby load, and requires high grade energy. Given we are looking to maximise use of low-cost or free low grade energy, it is sensible to target hot water and electric space heating.

This report considers five sources of renewable energy for the home:

1) **Solid fuel burners** provide some of the warmest homes during winter, and use carbon neutral and free or low cost fuel. The problem of atmospheric (particulate) pollution is pushing the replacement of solid fuel burners with heat pumps, which deliver similar heating, but at a dramatically increased load on the grid. Atmospheric pollution however can be largely dealt with if the burners are designed to run hot and combust completely at a relatively low total output.
2) **Heat pumps**, both for heating water and the air, are increasingly popular and demand appears to exceed capacity. Compared with a solar water heating (SWH) unit, heat pump water heaters offer more security of supply for a very similar capital outlay but are more expensive to run. Owners are increasingly using heat pumps for summer cooling which may cause electrical demand peaks in summer. The national impact of a widespread change to heat pumps must be better understood in order to encourage or discourage use of these units.
3) **Solar Water Heaters** are a promising technology with the potential to save 150 GWh of high grade energy per annum based on EECA figures. Work is under way to establish the actual performance of solar water heaters, but high capital costs and expensive installation costs are limiting market growth.
4) **Photovoltaic (PV) arrays** are extremely reliable, long-lasting and clean to run. They are also expensive to buy and require additional equipment to run. This is unlikely to change

unless the constraint on supply of high-grade processed silicon in the world market is removed. Building-Integrated PVs combine energy supply with roofs and walls – but these typically use lower-efficiency cells, so the cost recovery is less than detached arrays. PV conversion efficiencies are increasing however as the technology progresses.

5) **Wind generation** also has a high financial cost and requires additional equipment beyond the generator itself. However, the biggest hurdle for domestic wind generation is the noise and visual aspects. This is a major problem in urban areas where planning laws and consent requirements have not made it a simple matter to install a turbine.

Conclusion

Fundamentally, Beacon is well-placed to effect change. The availability of credible demonstration facilities (NOW Homes) and the funds to explore a number of specific technology adoption scenarios means that Beacon has the ability to reach both the regulators and the consumers with compelling arguments for change.

Solid fuel burners, in 4-6kW size, appear to offer a sensible route to reducing overall electricity consumption, by substituting electricity with low-grade heat. Care will need to be exercised in piloting this perspective through the regulators, as many appear to favour heat pumps.

Heat pumps appear to offer the best simple opportunity to reduce energy usage across the board, but establishing the number of actual and potential sales, and relating this to the potential impacts on the grid, is necessary to demonstrate to the regulators how uptake of heat pumps will affect the country.

Solar Water Heater performance in the field is not well understood, and they are comparatively expensive.

Wind and PV technologies are currently sensible for off-grid residences, but until installation prices fall and low-intrusion wind technologies are acceptable in the neighbourhood, uptake will be slow. A watching brief over advances in these technologies is recommended.

2 Introduction

"The amount of solar energy that hits the surface of the Earth every minute is greater than the total amount of energy that the world's human population consumes in a year."

\- *US National Renewable Energy Laboratory*

The intent of this work is to explore the potential of current promising renewable energy technologies in the New Zealand perspective. Beacon needs to understand where to apply its resources to best effect national-scale changes in the use of sustainable energy, and thus is seeking to establish the development levels of the technologies themselves and their present capabilities to deliver energy or reduce reticulated energy consumption. The present level of regulatory influence is also of interest, as the uptake of the technologies examined is in many cases tied to the degree of regulatory control imposed, as well as incentives available.

This work is focused on the domestic installations of the relevant technologies, as this is Beacon's primary focus.

3 Solar Water heating

3.1 Introduction

The BRANZ HEEP study (Isaacs et. al. 2004) records that on average, NZ houses use approximately 10,620 kWh of energy per year. About 29% of this (3,080 kWh) is used to heat water, and keep it warm.

Stoecklein (2005) has calculated that a New Zealand house rooftop of 150 m² collects 220,000 kWh of solar radiation per year (an indicative figure, obviously dependent on the location of the house), more than 20 to 30 times the house's total energy requirements. The total household rooftop area in New Zealand is exposed to primary solar energy that is equivalent to about twice the total national energy consumed for all uses. This puts the potential of solar-derived residential energy into perspective.

The energy output of a domestic solar water system is generally measured in terms of the "solar fraction" - that is the fraction of the hot water demand which is replaced by solar energy. As a general design guide a value of 75% is generally seen by the industry as a cost-effective target, although for service hot water systems with storage, this value can range anywhere from 20% to 80%. SWH systems designed for year-long operation in temperate climates will have solar fractions typically between 40%-70%.

The solar water heater itself is only part of the resultant solar fraction seen in use – the hot water usage behaviour of the occupants of the house is also a large contributing factor. Reference again to the 2004 HEEP report indicates similar issues for conventional resistance and gas-heated water supplies, however given their "always available" nature the similarity with SWH ends there.

3.2 Potential Energy Savings (Best Case - National)

Currently, installations are around 2500 units per year, mostly in the residential sector. (SIA – Pers. Comm.) According to the South Australian government's Energy Advisory service, about 20,000 are installed in Australia – this market for solar water heaters is much more mature than in NZ. Beasley Water Systems in Australia have calculated the potential energy savings for their water heaters using the Australian Standard 4234 method, arriving at an average across all climate zones of 2900 kWh per year. With 20,000 units installed per year, this would mean that present national savings are of the order of 58 GWh per year.

Using bottom-up logic to construct a similar argument for NZ: from Stoecklein (2005), the number of hot water cylinder installations in New Zealand is approximately 80,000 units per year, including both new built and failed cylinder replacements. Assuming mandatory energy efficiency requirements on all new hot water systems including replacements and the introduction of financial and legislative incentives for solar water systems the solar installation rate may reach 50% of these. Corresponding energy savings from this would amount to approximately 80GWh of new capacity per year (40,000 x 2,000kWh/yr). This would require a significant investment by the government in terms of financial assistance as well as upskilling of the workforce.

The proportionately higher level of uptake in Australia indicates the greater maturity of that country’s manufacturing base, and also the higher level of incentives available from both state and central government. One of the ways that this has been accomplished is by the creation of Renewable Energy Certificates (RECs) each one of which represents 1 MWh of generation displaced from a power station – essentially these are user-tradeable emissions credits.

3.3 System Types

Three general system types are available in NZ: unglazed, flat plate, and evacuated tube. Each of these are explained below in further detail. Additionally, there are also different methods of moving the water through the collectors to the storage unit(s): pumped systems, thermosiphons, and heat exchanger systems. Again, these are explained in greater detail below.

3.3.1 Thermosiphons

These are simple and reliable system designs widely used for domestic hot water throughout the world and for seasonal use in cold climates. Thermosiphon systems are generally direct loop systems, without heat exchangers. No pump is required; the water circulates naturally in the solar loop under the action of heat generated in the solar collectors. Heated water becomes lighter than the cold water in the tank, and gravity then pulls heavier cold water down from the tank and into the collector inlet.

Because of this natural action, the storage tank needs to be placed above the collector array level (at the roof level). Hot water is accumulated with a natural stratification which means that hot water accumulates first at the top of the reservoir. Because the hot water cylinders are normally located on the roof the roof structure may need to be strengthened to accommodate it. The New Zealand Building Code (NZBC) requires a structural report when installing cylinders of 300 L or more. For best performance, the solar loop must be as short as possible and made of a larger pipe diameter than pumped systems.

Thermosiphon systems also have the advantage of also working during power cuts. This not only offers better reliability during natural disasters, but also protects the collector from overheating in the event of a pump failure, which could reduce the life expectancy of the system. Systems meeting the technical standard AS/NZS 2712 are designed to avoid destructive stagnation events when overheating could occur.

3.3.2 Pumped Systems

Pumped systems are slightly more efficient than a thermosiphon system for the same collector area. In New Zealand conditions, a pumped system allows for more flexibility in building layout – there are no structural restrictions on the solar panel and hot water cylinder configuration so that the hot water cylinder can be placed for optimum usage and the solar panels for best performance. However, the inclusion of a pump into the system means that energy is needed to run the system, compared with the simple thermo siphons.

3.3.3 Heat Exchanger (Indirect) systems

Some indirect looped systems use an anti-freeze mixture in the solar loop, and thus are less subject to potential limitations on their installation environments. One of the

These systems require a heat-exchanger. There are several options for these:

external:

1) external with natural circulation ('side-arm' type operating like a thermosiphon) – avoids the use of a secondary circulator in smaller systems; and
2) external with a secondary loop using a secondary circulator (the only configuration with two pumped circuits) – a common design for larger systems (15 m² and above). There are two common configurations:
    - coil-in-tank (also called internal coil); and
    - wrap around or tank-in-tank.

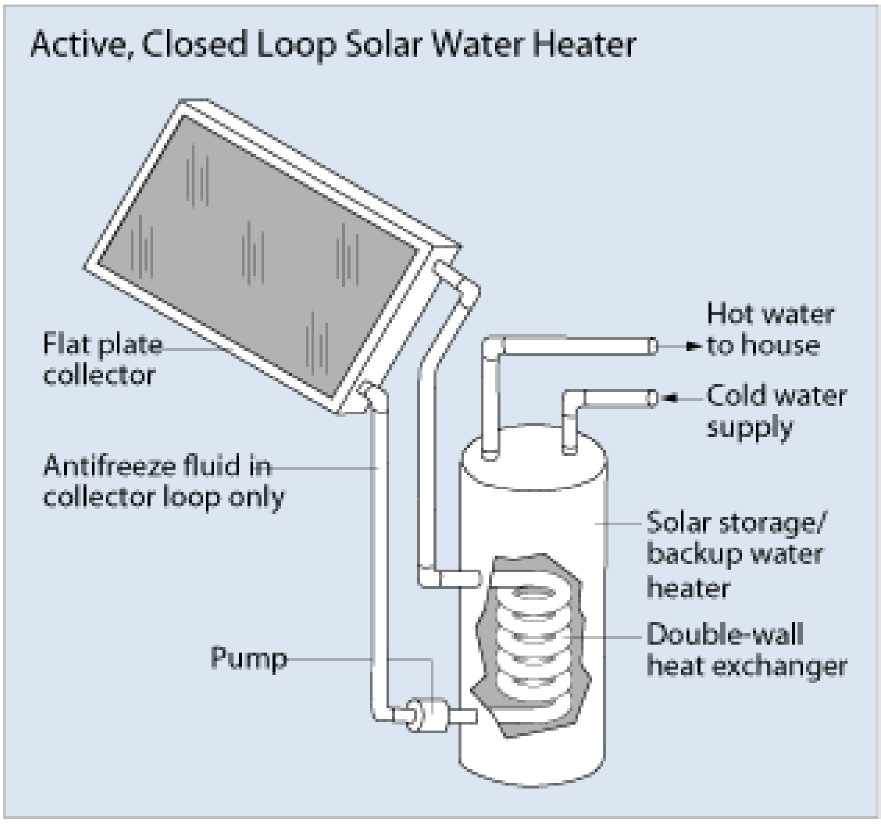

Figure 1: Closed Loop System (From US Dept Of Energy Website)

3.4 Manufacturers, Retailers and Installers

The NZ Solar Industries Association (SIA) lists 270 installers supplying 12 different types of system to NZ. Of these systems, most are flat plate collectors, although the proportion of evacuated tubes entering the market is increasing, with importers taking advantage of newly-available Chinese technology.

Most of these systems are pumped (>60%), and all comply with the SIA quality and performance stipulations for manufactured products. The SIA has also established a code of practice for their members, which covers manufacture and installation of the SWH units.

3.5 Current industry growth

The area of SWH installations as reported monthly by suppliers has continued to grow for another successive year. Analysis of this data shows that during the year to 1 October 2004 growth of the collector area installed increased by 48% over the same period for the previous year. This represents a cumulative increase since 2000 or more than 500%.

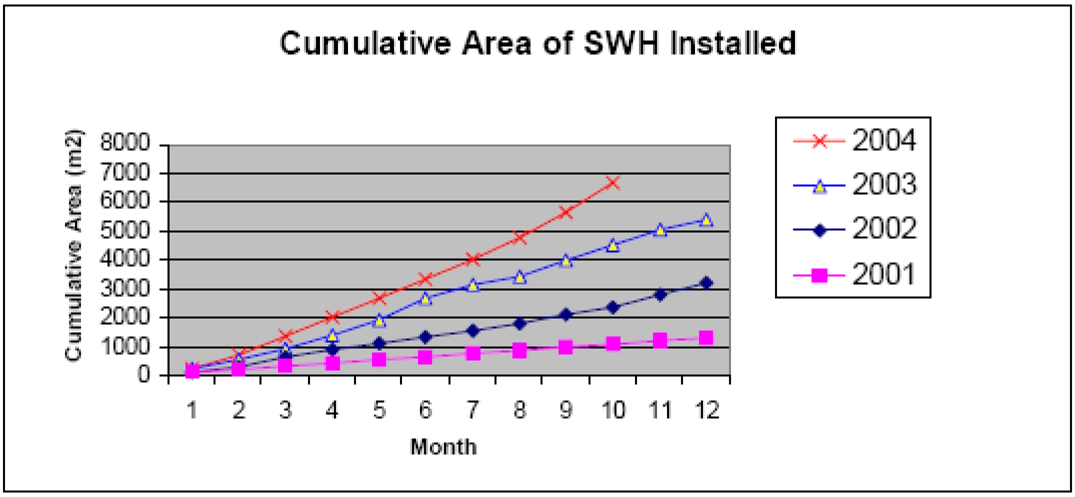

Figure 2:Solar industry growth in New Zealand – 2004 figures

This strong growth is not least due to the current Government support for SWH installations. The new interest-free loans scheme means that homeowners can purchase a solar unit with no upfront payments, and spread the payments over up to three years. The current scheme is based on the Government funding the interest for a loan taken out to purchase and install an SWH system. Loans of up to three years are available from accredited suppliers. According to the SIA newsletter (2005) funding for 2005-06 has increased to $400,000, compared to $200,000 when the full scheme started in 2003-04. (EECA, 2005/6)

SWH units vary in price, but generally range between $4,000 and $7,000 installed. Under the programme, depending on the term you choose, the homeowner is able to borrow all or most of this amount. However, the loan also depends on their length and the actual cost of the unit chosen. The finance assistance helps offset the cost of finance on a loan for an SWH unit. EECA contributes up to $300 towards the cost of finance.

A 2001 EECA report estimated that by 2010 their wider adoption has the potential to create employment for over 400 people. (EECA, 2001). An updated estimate of this, (EECA, 2005) suggests that on the current growth path, the number of residential installations in 2012 will be of the order of 60,000 per year, which is a significant compound increase on the 2,500 installed in 2005. Under this scenario, the total savings would be 150 GWh pa.

3.6 Some common New Zealand systems

According to the NZ Solar Industries Association, New Zealand has a fair representation of global products on the market and available systems include the latest technology. The 12 current complying solar systems available in New Zealand are listed below. These systems are largely available as modular units, and come as standard installation packages for residential applications. Other systems are available, although they may not comply with the SIA requirements for listing in their material.

- Apricus (evacuated tubes)
- Azzuro Solar (evacuated tubes)
- Beasley Solar
- Broady's Solarpower
- Chromagen
- Dux Sun Pro
- Edwards
- Solahart
- Solar 60
- Solar Max
- Solitaire
- Sunz
- Thermocell

3.7 Future market direction

In Australia, each state has a range of government measures based around a subsidy or grant. In Australia, electric hot water storage systems will be banned in all new houses in South Australia from 1 July 2006 as part of the campaign against climate change. The move was announced earlier this year by Premier Mike Rann. Under the new hot water system plan, all new homes or homes undergoing renovations in areas where gas is available must have solar, gas-powered or heat-pump hot water systems. Any householder who decides to replace their existing electric system with a solar hot water system will be eligible for the State Government rebate of up to A$700. There are also federal rebates available.

In New Zealand it is expected that a voluntary approach through the review of the Building Code will be taken. A possible initiative is that SWH will be included as an Acceptable Solution to meeting the sustainability performance target of the NZBC. A possible option is a home energy rating scheme (HERS) which may allow tradeoffs between different sustainability features including thermal insulation and solar water heating.

3.8 Performance

Stoecklein's work (2005) included comprehensive performance simulations (using the RETScreen programme) for a range of system types in a range of climates and orientations and has shown that the theoretical performance (renewable energy delivered per house per year) of a range of systems. Analysis of this type is well beyond the scope of this report, however for the purposes of establishing some indicative cost/benefit values, the range of theoretical values is from 2,005 kWh to 2,359 kWh. For the purposes of the C/B analysis, the upper figure is used.

3.9 Technical (Design) Considerations

3.9.1 Hail resistance

Hail resistance is of concern in some countries, including parts of Australia. In Australia this means that many evacuated tube systems, which are more prone to damage due to hail, do not meet the relevant Australian Standards import test unless covered by a hail guard (i.e. chicken mesh). This is not the case in New Zealand where hail stones are usually smaller. In this respect the New Zealand solar water industry operates under different business conditions, and evacuated tube systems are expected to become more common.

Several New Zealand and Australian industry members suggested that the Australian import regulations are to some degree driven by the need for self-protection by local industry, and that evacuated tube systems are generally sufficiently resistant to mechanical impact from hail. The insurance industry, and concerns about the insurance claims in large hail events, may have also influenced the Australian situation. In Australia, individual manufacturers are eligible to sit on standards committees, whereas in NZ only industry bodies are permitted. In light of this, it may be beneficial to investigate more closely the technical stipulations regarding resistance to hail damage to ensure that the playing field in NZ is a level as possible for all technologies.

3.9.2 Frost protection

Frost protection is a significant issue in many New Zealand climate regions. In regions with risk of severe frosts, systems need to be employed which have features to prevent damage to the panels. Such systems include reversible pumps, which pump small amounts of warm water through the panels during extreme weather conditions, or indirect systems using anti-freeze heat-transfer fluids in the primary circulation loop. Some frost protection measures lead to small reductions in solar panel efficiency. Informal discussions with tube manufacturers in China (Kane and Collins 2005) indicated that there were rarely problems from frost alone in mainland Chinese installations, provided that the panel array was connected to a vented storage tank.

3.10 Emerging Technologies and Developments

Combined liquid photovoltaic/thermal collectors (ie a standard flat plate SWH, with integrated PV cells on the absorber) are now available. They produce both electricity and hot water, and take advantage of the fact that much of the inefficiency of PVs is because they turn incident light into heat – which is then captured by the SWH unit. This has the further additional benefit of cooling the PV and increasing its efficiency.

4 Photovoltaic microgeneration

4.1 Introduction

The Photovaltaic (*photo* denotes light, *voltaic* denotes the generation of electricity) effect was first observed by Becquerel in France in the 19th century. Since that time, much effort has been devoted to the creation of energy technologies based on this. (Eiffert and Kiss, 2000)

Essentially, photovoltaic electricity is generated in the boundary layers of certain semiconductor materials when they are illuminated, the incident photons (discrete “packets” of light energy) causing electrons in the semiconductor to absorb sufficient energy to escape their atomic constraints and flow as current in an electrical circuit.

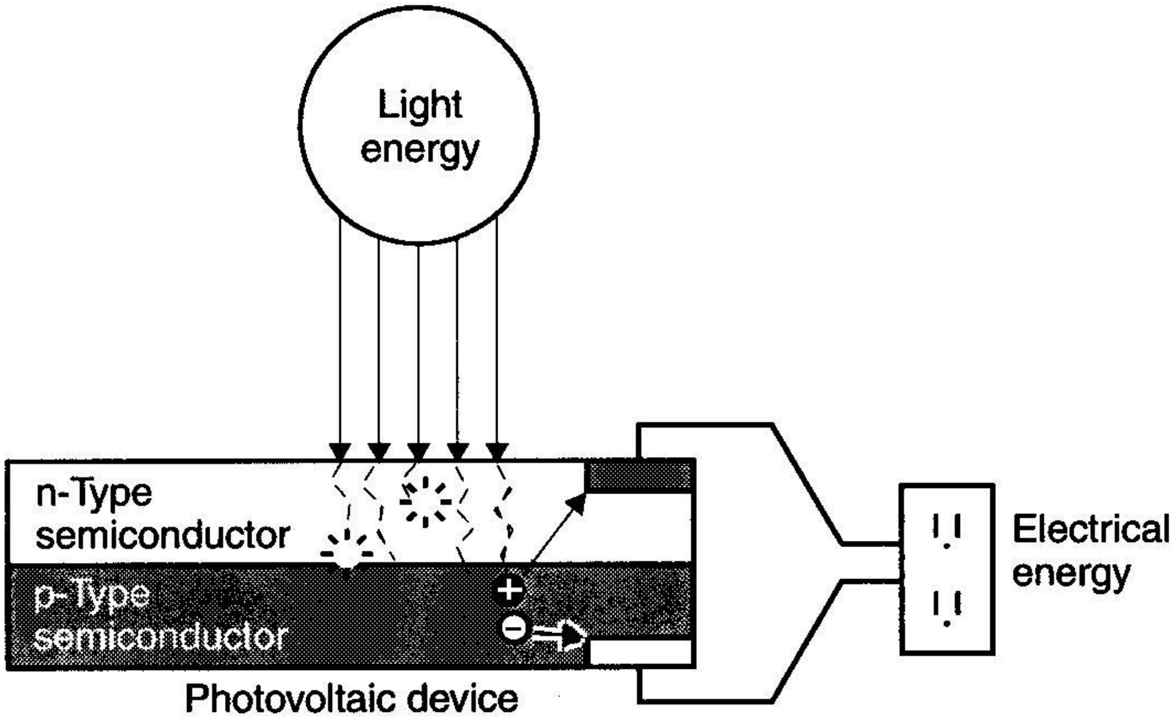

Figure 3: Electron/Photon interactions in PV (From Eiffert & Kiss, 2000)

The semiconductors in use today include silicon (Si), gallium arsenide (GaAs), cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS) Such materials can be classified by their form as either crystalline, polycrystalline, or thin-film.

All of today’s commercial PV products are built from these three technological forms, and over 90% of them are based on silicon. In its raw form silicon is very abundant, making up more than a quarter of the earth’s crust. When refined into PV cells, it can be had in crystalline, polycrystalline and thin-film amorphous forms. Each technology form is distinguished by its conversion efficiency rate, manufacturing process, and hence manufacturing cost. This report focuses primarily on the silicon-based technology, as it is not only beyond the scope of Beacon's resources to develop new materials in competition with multibillion dollar multinationals such as Shell and BP, but is also now an established technology which is increasingly being integrated into buildings (Built-In or Building-Integrated Photovoltaics – BIPV).

BIPV arrays have the cost benefit of fulfilling a building related function in addition to being a solar array – the most common examples of BIPV arrays are as canopies, roofs, or walls on high-insolation parts of the building. They keep the sun and rain out, and generate electricity as well.

4.2 Potential Energy Savings (best case)

In the case of PV, it is comparatively easy to determine the energy savings as they are presented directly in kW. However, given that the amount of energy the array will produce is a factor of its size and efficiency, it's not possible to produce an "average" figure for the performance of a PV array. Hence, it has been assumed that the target power output is 1 kWp (peak power at standard conditions). For illustration purposes, this is enough to power a typical one-bar electric heater.

If a commercially available array such as BP Solar's 3125 (BP, 2004) is used, 8 units will be required to achieve the required 1kWp delivery (each array producing 125 Wp), giving a total area of cells required of 8.1 m^2. These cells are stated by BP to be 12.3% efficient.

Insolation figures derived from NIWA data (NIWA, 2006) indicate that there is sufficient radiation available for this 1kWp array to operate at or near maximum efficiency in most of New Zealand on sunny days.

4.3 System Types

4.3.1 Single Crystal Silicon

Single crystal silicon cells are extremely thin wafers of silicon cut from a single silicon crystal. These are the most efficient silicon cells and if not damaged typically have a life expectancy exceeding 25 years. The cells are fragile so they must be mounted in a rigid frame.

4.3.2 Polycrystalline Silicon

Polycrystalline (or multicrystalline) silicon cells are also extremely thin wafers of silicon but are cut from multiple crystals grown together in an ingot. They are similar to single crystal cells in life expectancy and fragility. However, they are slightly less efficient than single crystal cells and require more surface area to produce a given amount of electricity

4.3.3 Thin Film Silicon

Thin film (or “amorphous”) silicon cells are made by depositing a micro thin layer of silicon directly onto a sheet of glass or other suitable substrate. They can also be mounted on a flexible backing, making them ideal for portable use. They are less efficient than polycrystalline silicon cells. Typically, these are the types of cells used in BIPV systems, where they are adhered to a building element (roof, wall etc).

4.3.4 Combining Cells

As is evident from the above, cells are the basic building blocks of PV modules. Most commonly they are made of silicon doped with a few rare earth metals, and each generates approximately 0.5V. The amount of current generated is proportional to the size of each cell, it’s conversion efficiency and the intensity of the incident light.

For historical reasons, apparently linked to the charging of 12V batteries, cells are packaged together to create standard modules of 12V nominal, 18V maximum output. Each of these modules comprises 36 cells, connected in series. To obtain the desired output for the particular application in question, modules are combined in series and parallel – much as batteries are. When modules are fixed together in a single mount, they are called a panel. When two or more panels are combined, they are called an array.

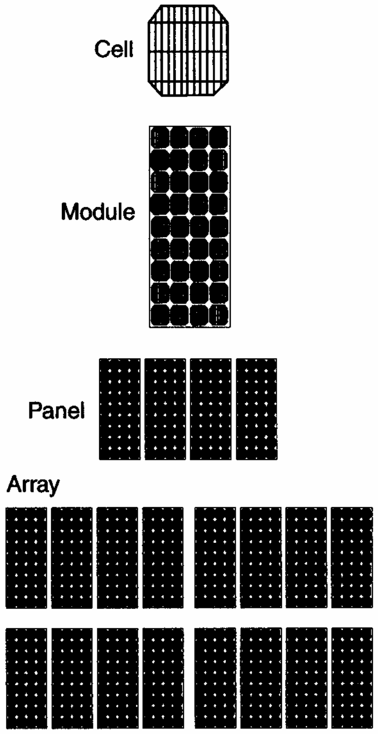

Figure 4: Creation of an array from cells. (From Eiffert & Kiss, 2000)

4.3.5 Regulators, inverters and storage systems.

PV arrays generate direct current, usually at lower than line voltages, and to a level that depends on the amount of sun the array is receiving. This automatically limits their direct applications to equipment where those limitations are not an issue. In common use solar-powered calculators are a good example; if there is no light, the LCD display is unreadable in any case, so there is no need to power the calculator continuously.

In all other applications, some form of power conditioning and storage is required.

4.4 Considerations for a residential system

As mentioned, guidance is available from a number of sources to design a PV system for virtually any application.

For residential houses, the first choice to be understood is whether the house is to be disconnected from the grid or not. If disconnected, then the house must be set up with the PV array itself, a bank of batteries to store energy for when the sun isn't shining, and an inverter to convert the battery's DC power into AC, for those appliances which cannot be driven from low-voltage DC. From this point it is then possible to determine the likely load given the appliances used, the incident solar radiation for that particular site, and hence determine the size of the PV arrays needed.

If the house is to be connected to the grid, and the PV system used to reduce load, then the situation is technically more complex, but because in this situation, there is no need for a battery bank (as the network acts as the battery) making such a system considerably less expensive. An inverter is required to be able to export unused electricity at 230V AC, and also to run mains appliances from the PV array. One of the complications in retrofitting a PV array to an already existing house with the expectation of exporting power to the network is that the wiring will be inspected by a network company rep, and must meet their requirements, and those of the 1997 Electricity Regulations. This is not a problem in itself, but for the additional cost involved.

An agreement must be in place with an electricity supplier if you are to export surplus power from the PV array. In 2005, Contact Energy agreed with the NZ Photovoltaic Association that they will purchase exported power from NZPVA's member's houses at the retail rate. At this time, this is the best offer yet seen for PV system owners, especially in light of there being no need to have an electricity supply agreement (for the supply TO the house) with Contact.

4.5 Manufacturers, retailers and installers.

PV Array manufacturers are predominantly large, multinational companies such as Shell, BP Canon, GE, Sharp and Sanyo. There are no local manufacturers of the actual cells themselves, although there is a significant research effort being expended in increasing their efficiencies and uptake at Industrial Research Ltd, Otago University (under Assoc. Prof Bob Lloyd) and Massey University. Major work at the latter is focused on increasing cell efficiency, under the guidance of Assoc Professor David Officer.

The industry mainly comprises the distributors of imported modules and a network of equipment installers, although the support electronics (inverters, chargers, and batteries) are made locally.

As with all “new” technologies, the NZPV Association is small and underfunded, despite occasional EECA funding of specific activities, and hence marketing is ad-hoc and largely at an individual level. The Association does undertake training for its members however.

4.6 Industry Growth

The PV Association last undertook a survey of the number of installed PV systems in late 2004, and estimated at that time that there was installed capacity of 1.4 MWp (Peak megawatt). Their estimation at that time was for continued growth at the 35% level of the past three years. It is apparent that internationally, PV technologies have reached a critical level in economies of scale, such that large-scale manufacture is now leading to some degree of pricing structure and commonality, in turn further stimulating demand.

However, despite the good alignment to the classic trickle-down model of technology takeup, prices have not fallen as far as they need to for the technology to begin replacing hydro as a fundamental renewable source of energy. European uptake of the technology has been strong, but perturbations have begun to appear in the supply of cells and modules. (Diefenbach, 2005).

“Yet despite slightly differing interpretations of the various aspects of the market, one is more or less agreed upon: industry has gone crazy. Economists speak of an overheated market hitting module manufacturers from both sides. On the one hand, they can’t make proper deliveries to their customers, while at the same time, in their role as buyers of solar cells and other semi-finished products (like laminates, glass and frames), they consistently overwhelm their suppliers. More modules are being produced than ever before , yet there is no end to the shortage in sight.” *From Diefenbach 2005.*

Whilst there are a number of module assemblers, the basic cells are manufactured in limited places and – importantly – from silicon, which is short in supply. Prices per W are therefore increasing, at between 5 and 10 percent.

This semi-stability has however enabled primary producers to sensibly begin making investment decisions, and the consensus is that expansion is required at every step of the value chain. It will take some years for this increased capacity to come on-stream, and unless regional manufacturing bases are established, it is unlikely that the NZ market will see the benefit for 5 years at the very earliest.

4.7 Future Market Directions

Off-grid applications for PV have been well-established across NZ, mainly in remote areas. However, lacking the government-backed incentive schemes of overseas economies (Japan, US, Australia), uptake here is not at the exponential level enjoyed in those nations. Their increased traded volumes will assist in driving the price down, however other factors may act to perturb the local market:

- Although it is changing (see Heat Pumps), NZ's daily load curve is still heavily biased towards peak loads during low-insolation hours
- Retail electricity prices in NZ< although higher than 18 months ago, are still not at an international footing with the relative price of PVs.
- NZ has lower insolation values than many other nations (slightly more than half in some cases when compared with the US), reducing the return and extending the payback period *cf* the US.

4.8 Performance

The conversion efficiency of each particular PV system is specified by the manufacturer. These efficiencies range from 5% up to 18% for current commercially available material. An example was chosen from one manufacturer's data sheets, (BP, 2004), illustrating this well. The polycrystalline cells are on a printed circuit board with integrated diodes, to create a 125W array with an efficiency of 12.3%. (see "best case" above)

Using cost info published by EECA, and by the NZ PV Association (Shaw, 2006; EECA, Feb 2005) a grid-connected 2 kWp system can be expected to cost between $37,000 and $47,000 depending on the exact specifications of the system. The PV association suggests that half of this cost is in the PV arrays themselves at about $10 per Wp, and half in the installation labour and associated rectifiers and wiring needed.

Assuming that such a system contributes 2kW per hour of operation at its peak (design) efficiency, NIWA and NZ PV Association solar radiation figures suggest that the peak insolation is close to the design level (1kW/m^2) for about 5 hours per day in January. This would equate to a daily contribution of 10kWh, or 3,650 kWh per year – slightly more than 1/3rd of the average annual domestic energy use. By applying the recommended derating factor (Sandia, 1995) of 20% to capture transmission losses, collector dirt etc, this suggests a daily contribution of 8 kWh from the PV system, or 2,920 kWh per year.

4.9 Technical (Design) Considerations

Photovoltaic systems are now sufficiently commonplace that standardised design information is beginning to appear (Eiffert & Kiss, 2000; Energy Alternatives 2006; Sandia, 1995).

4.9.1 Sunshine and Shading

PV modules produce electricity in proportion to the amount of sunlight falling on them. In full overhead or 'peak' sun (1000 watts/m^2) they will produce their rated power. Reduced sunlight caused by clouds or location will diminish the amount of electricity generated. Modules will produce electricity even when there is no direct sunlight. A cloudy sky with an occasional blue patch will often be equivalent to approximately 50% peak sun. A cloudy day with rain in the forecast will be about 10 to 20% peak sun.

It is very important to note that shading even one cell of a module will reduce the output of the entire module (apart from in more recent, more costly models with integral diodes), as the individual cells are wired in series to create modules.

4.9.2 Temperature

It is a common misconception that heat is required for PV modules to produce electricity. High temperatures actually increase resistance and reduce the voltage within the silicon cells. Warmer climates require PV modules with a higher maximum voltage than those used in cold climates. Cold temperatures decrease resistance and increase voltage. Modules with a low voltage rating are ideal in colder climates such as Canada because more of the power produced is available as charging current, rather than voltage.

4.9.3 Power Rating

PV modules from the main manufacturers are of similar quality and should provide years of reliable power. Most people base their buying decision on the cost of the module and its power output. However, power ratings for PV modules can be misleading and this can lead to disappointing performance. PV modules are rated at their peak power point. This is measured on a curve showing voltage and current. It is the point where the panel will produce the maximum power in watts, usually with an incident light (artificial) radiation of 1000W/m^2. (Eiffert & Kiss 2000) PV modules seldom operate at their peak power point.

For example: under standard test conditions, the peak power point of the BP 3125 is at 17.3 volts and the panel will produce 7.23 amps at this voltage. Since **volts x amps = watts**, the rated power for the BP3125 is 125 watts.

Rated power is a measurement of ideal performance. However, it is important to note that a panel may produce less than its rated power when charging a battery. Battery voltage averages about 13.5 volts when charging

4.10 Emerging Technologies and Developments

4.10.1 High-efficiency cells

A solar cell that can convert sunlight to electricity at a record-setting 37.3 % efficiency has been developed in space by the National Renewable Energy Laboratory (NREL) and Spectrolab. The record-setting efficiency gained by adding an active germanium junction might be what's needed to inspire the market to bring these high-power solar cells down to Earth. Such high-efficiency cells are well suited for concentrator systems that use relatively inexpensive lenses or mirrors to focus sunlight on the cells.

4.10.2 Concentrating PV

The concept of concentrating the sun's energy has been around since ancient Greece, when some historians believe that Archimedes used mirrors and the sun's energy to set attacking Roman ships on fire. Similarly, CPV concentrators use optics to concentrate sunlight onto a small area of solar cells.

Most concentrators follow the sun as it crosses the sky, either through single- or dual-axis tracking. This tracking capability allows concentrators to take advantage of as much daylight as possible from dawn until dusk. However, many other permutations of CPV exist. Some static CPV technologies use mirrors to reflect and concentrate all the sunlight they can capture onto small high-efficiency PV cells. Other CPV technologies use lenses to concentrate the sun's light. CPV technologies also differ in how strongly they concentrate sunlight, whether they concentrate light to a line or a point, the type of solar cell that they use, and whether the cells are actively or passively cooled.

Figure 5: Parabolic troughs, like those used in this Euclides-Thermie installation in Spain, concentrate sunlight onto a strip of high-efficiency solar cells positioned above the troughs.

The three primary benefits of CPV are: 1) high efficiency, 2) low system cost, and 3) low capital investment to facilitate rapid scale-up. Concentrating optics focus the light so that the semi-conductor or solar cell is much smaller than for flat-plate systems. Because fewer solar cells are needed, the costlier, very high-efficiency solar cells can be used. Some current CPV technologies feature cells with efficiencies as high as 26%. The Spectrolab CPV cells mentioned above have achieved 37.3% efficiency, and efforts are under way to integrate these into commercial systems. The reduced use of semiconductor material provides a pathway to lower cost, as expensive semiconductor material is replaced with inexpensive mirrors or lenses.

A recent Arizona Public Service study shows that CPV is competitive compared with some other PV technologies. For every NZ$2,000 that Arizona Public Service invested in CPV, an average of about 300 kilowatt-hours (kWh) is generated annually. This exceeds the number of kWh obtained each year from a similar investment in fixed flat-plate systems. Although this study shows that single-axis tracked flat-plate systems currently deliver the most electricity per dollar invested, flat-plate systems are mature compared with the CPV systems. In a few years, after the technology has moved further along its learning curve, the CPV systems may deliver the best value. After the technology has integrated today's high-efficiency CPV cells, a NZ$2,000 investment could yield 450 kWh per year. (NREL, 2006).

For micro/domestic installations, CPV is not yet as practical as flat plate BIPV systems, because the latter also function as building elements, rather than as the sort of add-on that most solar water heaters currently are. Except for the lowest-concentration designs, concentrator systems must track the sun in order to keep the light focused on the solar cell. A standard concentrator design mounts a large system on a pedestal, then pivots the system on the pedestal. It is difficult to adequately support such a pedestal on a rooftop, and most people would question the aesthetics of a high-profile system on their roof. Structural issues would also need to be addressed to ensure that adequate seismic resistance is provided for the pedestal support. Low-concentration CPV technologies—systems of less than 10 suns (ie that offer a less that 10x intensification factor) —are being developed for rooftops. Some of these systems don't have trackers and they look a lot like flat-plate PV. Some low-concentration CPV is now being incorporated into existing flat-plate technology using clever optics.

Japan's largest PV manufacturer, Sharp, is developing a high-efficiency concentrator for rooftops (see Figure 5). Japan's densely packed population centers are filled with large apartment buildings that have limited roof space to serve a high density of people. CPV makes sense because, compared to flat-plate PV, concentrating PV can produce more energy in less space. This is important in a country where the cost of electricity is well over 20 cents per kWh.

Figure 6: Daido Steel's Toyohashi 200-watt module is lightweight and uses high-efficiency multijunction cells—perfect for rooftop installation in population-dense places like Japan.

5 Heat pumps

5.1 Introduction

Heat pumps as they are now broadly familiar have been available commercially since the early 1950s. The most familiar heat pump is the common refrigerator, which pumps heat from the inside of the fridge to the outside – which is easily detected by feeling the radiant coils/fins on the back of the unit.

The heat pump is based on the Carnot cycle, so named for its original proposer in 1824. Carnot was a mathematician and physicist, and laid the foundation for the second law of thermodynamics. In a general sense, the second law says that the differences between systems in contact with each other tend to even out. Pressure differences, density differences, and particularly temperature differences, all tend to equalize if given the opportunity. This means that an isolated system (or body) will eventually come to have a uniform temperature.

A thermodynamic engine is an engine that provides useful work from the difference in temperature of two bodies. Since any thermodynamic engine requires such a temperature difference, it follows that no useful work can be derived from an isolated system in equilibrium, there must always be energy fed from the outside. The second law is often quoted as the reason that we cannot build perpetual motion machines.

Every thermodynamic system exists in a particular state. A thermodynamic cycle occurs when a system is taken through a series of different states, and finally returned to its initial state. In the process of going through this cycle, the system may perform work on its surroundings, thereby acting as a heat engine.

A heat engine acts by transferring energy from a warm region to a cool region of space and, in the process, converting some of that energy to mechanical work. The cycle may also be reversed. The system may be worked upon by an external force, and in the process, it can transfer thermal energy from a cooler system to a warmer one, thereby acting as a refrigerator rather than a heat engine.

The Carnot cycle is a special type of thermodynamic cycle. It is special because it is the most efficient cycle possible for converting a given amount of thermal energy into work or, conversely, for using a given amount of work for refrigeration purposes. Conversely, and the reason that “reverse-cycle” heat pumps work, the energy liberated from the “cold” reservoir can be emitted as heat thereby heating a room or water in the most efficient way possible.

In practical terms, most heat pumps are very similar to refrigerators, and operate using a compressible “refrigerant”. (See Figure 7 below). When this is compressed, it releases heat to its environment – when it is decompressed, it absorbs heat from the environment (ie cools the surroundings).

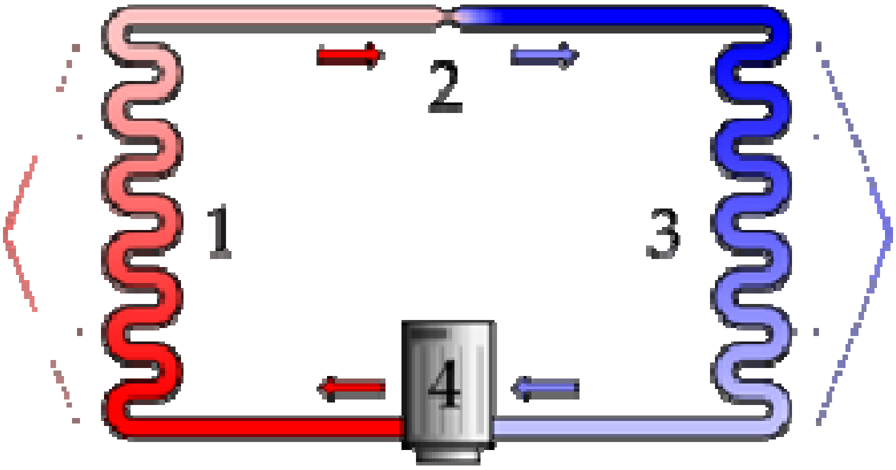

Figure 7: A simplified diagram of a phase change heat pump: 1) condensor coil, 2) expansion valve, 3) evaporator coil, 4) compressor

5.2 Potential Energy Savings (Best Case)

5.3 System Types

Three basic sorts of heat pump exist, defined mainly by the source of energy they are using. In each case, the thermodynamic principles above apply, and the main differences are to be found in the equipment required to capture the energy from its environment. The descriptions below apply to heat pumps used in buildings.

5.3.1 *Air Source Heat Pumps*

The air source heat pump exchanges heat between the outside air and the inside air, (or water – see below). These units tend to be most efficient at between about 4º C and 32º C, and become less efficient outside of that band. They are also less efficient when the temperature difference between the outside and inside environments increases. To overcome this, resistive heating elements are often fitted when the unit is to be used for heating the inside air – further reducing the efficiency of the units.

5.3.2 *Water Source Heat Pumps*

As the name suggests, these units exchange heat between water, and the inside air. These systems are most commonly used in commercial buildings, in conjunction with a boiler and cooling tower to keep the loop water temperature between 15º C and 32º C. These systems are typically cheaper to run than air source units, but are more expensive to install due to the additional water-side equipment needed. Hence they are more appropriate for commercial applications where the cost of capital is more rapidly recovered.

5.3.3 Ground Source Heat Pumps

These use the earth itself as the medium from which heat energy is extracted. The heat exchange medium (often just water pumped through a maze of buried pipes) is pumped through a heat exchanger in the heat pump where a compressible refrigerant extracts the heat and transports it to the area of the house where it is needed, The water then returns through a closed loop into the ground, where it is again heated by the relatively stable thermal mass of the earth. Ground temperatures at 15m below the surface of the earth are reasonably stable (GNS, 2005), usually between 4º C and 12º C, depending on the actual location. To cool the house in summer, the flow of the refrigerant in the heat pump is reversed, and heat added to the circulating water as it passes through the house. This is then cooled in the buried earth loop (Econar, 1993).

5.3.4 Water Heating

Most heat pumps using a compressible refrigerant are capable of heating water, using the high-temperature (“superheated”) refrigerant gasses exiting the HP compressor. Depending on the heat pump design, and the operating conditions, temperatures of above 90º C can be achieved in this gas, and this can be heat-exchanged to give water temperatures of about 65 - 70º C. In winter (heating) conditions this is not “free” hot water, as it reduces the amount of heat available for space heating, however during summer (cooling) conditions it is a very efficient method of heating water AND cooling the house.

Heat pumps with water heating capability can be configured to make this a priority (over space heating), or as an adjunct to utilise heat unused by space heating requirements. The former tend to have long run-cycles and hence operate slightly more efficiently than the latter.

Two distributors (Ross Chiplan of Energy Plus, and Girard Vangaalen) made contact with the author very late in the preparation of this document, largely in response to a newspaper article suggesting that alternative methods of heating water may be more appropriate than electricity. Both sell air/water heat pumps which are capable of meeting the 65 °C requirement for domestic hot water, and both have indicated that the technology to do this (get to 65 °) is relatively new in NZ, so with limited market uptake as yet.

5.4 Manufacturers, Retailers and Installers

Heat pumps are now sufficiently mainstream in NZ that they are sold through retail outlets and building product merchants. Most air conditioning service or installation agents can cope with heat pumps, as they are identical technologies. The Yellow Pages lists 120 suppliers/installers of heat pumps across New Zealand. A wide range of systems is readily available in NZ, the cheapest found being a 2.5 kW high wall split unit for $785 including GST. No CoP figures were available for this unit.

Mainstream heat pump manufacturers are heavily represented in NZ.

5.5 Industry Growth

Definitive numbers are very difficult to obtain, although EECA should have very detailed numbers as part of the MEPS scheme which covers heat pumps – these numbers do not seem to be available, possibly for commercial confidentiality reasons. However, a number of anecdotal experiences have been reported from colleagues attempting to have heat pumps installed in Auckland, Wellington, Palmerston North and Christchurch.

At the time of writing, installers (air to air – space heating/cooling) have waiting lists of up to six months in Auckland and Wellington, and three months in Palmerston North and Christchurch. As mentioned below, retailers report that the double benefit of a heat pump is the major selling factor, with owners valuing the ability to control summer heat in addition to heating their houses. A more worrying trend is that emerging of houses which dramatically overheat in summer, predominantly due to their large N/W glass areas and insufficient attention to the holistic design required to avoid overheating in those cases.

The heat pumps being installed are all of the air-source variety: three industry savants have commented informally that nobody has yet committed to ground-source, all citing that NZ simply is not cold enough to warrant the “huge” (unquantified) additional investment over a simple air-source system.

5.5.1 Refrigerants

Since 1985 it’s been well documented that the ozone layer surrounding the earth has been diminishing. Research has suggested that man-made chemicals are responsible for creating the hole in the ozone layer and that they were largely responsible for the global ozone depletion.

Ozone Depleting Substances have been used in many products which take advantage of their physical properties. For example, ChloroFluoroCarbons (CFC’s), have commonly been used as aerosol propellants and refrigerants, and also as fire suppressants (ie Halon)

However, since recognising that the chlorine in CFC’s contributes to the breakdown of the ozone layer, the ‘Montreal protocol on substances that deplete the ozone layer’ was negotiated and signed by 24 countries and the European Union in 1987. The protocol calls for all parties to scale down the use of CFC’s, halons and other man-made ozone depleting substances.

ODP - The ODP or Ozone Depletion Potential, is the potential for a single molecule of the refrigerant to destroy the Ozone Layer. All of the refrigerants use R11 as a datum reference and thus R11 has an ODP of 1.0. The less the value of the ODP the better the refrigerant is for the ozone layer and therefore the environment.

GWP - The GWP, or Global Warming Potential, is a measurement of how much effect the given refrigerant will have on Global Warming in relation to Carbon Dioxide, where CO2 has a

GWP of 1. This is usually measured over a 100-year period. In this case the lower the value of GWP the better the refrigerant is for the environment.

R11 is a single chlorofluorocarbon or CFC compound. It has a high chlorine content and ozone depletion potential (ODP) and high global warming potential (GWP). The use and manufacture of R11 and similar CFC refrigerants is now banned within the European Union even for servicing. - ODP = 1, GWP = 4000

Note: Although the use of R11 is banned, it was used as the datum for ODP therefore having an ODP of 1. The ODP of all other refrigerants are compared to R11

R22 is a single hydrochlorofluorocarbon or HCFC compound. It has low chlorine content and ozone depletion potential and only a modest global warming potential. R22 can still be used in small heat pump systems, but no more new systems can be manufactured for use in the EU after late 2003. From 2010 only recycled or saved stocks of R22 can be used, as it will no longer be manufactured. - ODP = 0.05, GWP = 1700

> From 1 July 2002 no more cooling only air conditioning equipment can be manufactured that uses refrigerant R22.
>
> From 1 January 2004 no more large-scale heat pump equipment can be manufactured that uses refrigerant R22.
>
> After 1 January 2010 no more virgin refrigerant R22 can be used in existing systems.
>
> After 2015 no more recycled refrigerant R22 can be used in existing systems. R22 manufacture ceases.

There is already a "drop in" replacement refrigerant for R22 with zero ODP - R417A - See below.

R134A is a single hydrofluorocarbon or HFC compound. It has no chlorine content, no ozone depletion potential, and only a modest global warming potential. - ODP = 0, GWP = 1300

R407C is a ternary blend of hydrofluorocarbon or HFC compounds, comprising 23% of R32, 25% of R125 and 52% of R134a. It has no chlorine content, no ozone depletion potential, and only a modest direct global warming potential. - ODP = 0, GWP = 1610

R410A is a binary blend of hydrofluorocarbon or HFC compounds, comprising 50% of R32 and 50% of R125) it has no chlorine content, no ozone depletion potential, and only a modest global warming potential. - ODP = 0, GWP 1890

R417A is the zero ODP replacement for R22 suitable for new equipment and as a drop-in replacement for existing systems.

There are currently no restrictions on equipment or use of the following refrigerants: R134A, R407C, R410A, and R417A

Daikin NZ actually offer the option of being able to purchase either R22 or R410A for their heat pumps, reflecting the fact that R22 is still available from mainstream manufacturers in NZ. Possibly of greater concern is that there appear to be a number of lower price units in the market (author’s personal inspection in three appliance outlets) which do not specify the specific type of refrigerant used – merely referring to it as “HFC” or hydrofluorocarbon. There is possibly therefore a problem in the making with some of these units, as disposal of R22 is becoming more expensive and difficult, the only real option being to return the unit to the manufacturers or their agents for degassing.

As part of the Ozone Layer Protection Act (1996) and the subsequent Ozone Layer Protection Regulations, importation of R22 into New Zealand must be reduced by 75% (from 1996 levels) by 2010, then to cease entirely in 2015. Given that replacements are available, it is recommended that no heat pumps using R22 be considered as part of Beacon’s activities.

5.6 Performance

When comparing the performance of heat pumps, it is best to avoid the word "efficiency", as it has many different meanings. The term *coefficient of performance* or CoP is used to describe the ratio of heat output to electrical power consumption. A typical heat pump has a CoP of about four, whereas a typical electric heater has a CoP of one, indicating units of heat exchange performance per units of electrical power input (resistive electric heat being 100% efficient whereas heat pump heating offering up to 400% efficiency).

Commercial heat pump technologies are currently in a stage of rapid improvement: the CoP for commercially available heat pumps has risen in the last 5 years from 3 to 4 and even (in a few ground-source cases) 5. As a result heat pumps are becoming popular choices for home-heating and cooling – see Industry Growth above.

For an air-source heat pump its CoP is limited by its need to pump the heat into the house from outside - and so they work less well in very cold climates where there is less heat density outside to pump in. Typically the CoP decreases markedly once outside temperatures go below around -5 or -10 degrees Celsius, though this limit varies from one model to another.

Because a ground-source heat pump (GSHP) draws heat from the ground, which at a depth of about 15 m is at a relatively constant temperature year round, its CoP is higher than for an air-source heat pump (the best GSHP CoPs are approaching 5) and its CoP is constant year round. The tradeoff for this improved performance is that a ground-source heat pump is significantly more expensive to install than an air-source heat pump.

From BRANZ HEEP study, the average NZ house uses approximately 30% of its total energy consumption in space heating. Of that, on a national basis, the solid fuel burner (coal and wood) accounts for approximately half of the delivered heat, electricity about a third, and the remainder directly from fossil fuels (gas, oil). If all of the electrical (resistive) space heating component is replaced by air-sourced heat pumps, the equation is very simple: divide the electrical heating energy used by the CoP of the heat pump, and the answer is the potential saving.

From HEEP (Camilleri, 2006), the total domestic consumption of electricity for space heating in NZ is 972 kWh per house, on average. It’s important to realise that this is not evenly distributed across the year, with winter evenings being the time of maximum heating use. By way of comparison, this figure is comparable in magnitude to the baseload (energy used by appliances that run continuously, and those that use power waiting to be turned on) in each house, and also to the standing losses from a hot water cylinder. This is touched on in more detail in the “conclusions” to this report.

972 kWh, for 1.4 million homes is a total annual electric resistive space heating load of 1361 GWh. At a CoP of 3, and assuming that the heat pump is capable of delivering all of the space heating previously supplied, then the load reduction would be 66% (2/3rd) of the above figure – equivalent to an annual saving of 906 GWh.

5.7 Technical and Design Considerations

Heat pumps are available in a number of different configurations; which is preferred is largely a function of the amount of space available, the performance required, and the amenity expected (ie distributed air outlets). (Consumer, 2005). The design of a heat pump system, especially a ground-source or water-source unit, is most sensibly undertaken by an HVAC (heating, ventilation and air conditioning) expert, as the value of the technology can be lost very quickly by mismatching the delivery capacity of the unit to the size of the space being heated or cooled. Design parameters are readily available from both the manufacturers themselves, and generically from the internet.

5.7.1 Configuration Options

3) Combined – these are often seen as single-box units which fit into a window opening: the compressor is outside of the building for noise and component cooling reasons. Such units are often used in retrofit installations, although they have largely been supplanted by high wall units.
4) A split system has an exterior compressor unit, connected to an interior ceiling or wall unit (see High Wall) by copper pipes (for the refrigerant) and wiring. The interior unit contains the electrical/electronic controls and a fan which circulates air over finned tubing for either cooling or heating, depending on the setting of the unit. Much of the installation cost of split systems comes from running the pipes and wires from the exterior to the interior locations.

5) In a multi-split system the exterior unit connects to more than one interior unit. Often, one interior unit is located in the living space and another in the bedroom area. The interior units can have separate controllers - but it is not possible to have one interior unit cooling while the other is heating. Multi-split systems can be cheaper than having separate external units for different parts of the house, but there may be extra installation costs from longer piping runs and some extra control complexity.
6) Ducted. These have a single, large capacity interior unit mounted in the ceiling space, or under the floor. The heated/cooled air is pumped through insulated ducts to ceiling or floor outlets in many or all of the rooms in the house. Ducted systems have the least visual impact of any heat pump system - just small flush vents in each room. Because there is some heat loss from ducts themselves, they are slightly less efficient than other systems in absolute terms, although when amenity and convenience are considered as non-energy benefits, they represent an efficient, if capital-intensive, solution to whole-house environment control.
7) High Wall These are currently the most common heat pumps in new Zealand. They are Split systems, mounted close to the ceiling and circulate enough air to heat a room evenly. They should be located so the airflow can reach as much of the room as possible, but this needs to be done bearing in mind the avoidance of draughts.

5.7.2 Earthworks

Ground source heat pumps require installation of the heating/cooling coils underground, and hence require extensive trenching (horizontal, where space permits) or boreholes (vertical, for space-constrained situations). For a 150-180 m^2 house, approximately 100m of buried polyethylene pipe is required. To ensure that the thermal mass of the earth is fully utilised, the pipes need to be at least 5 meters apart and 2 meters deep. To obtain a suitable length of pipe run, a 40-50 m borehole would be required.

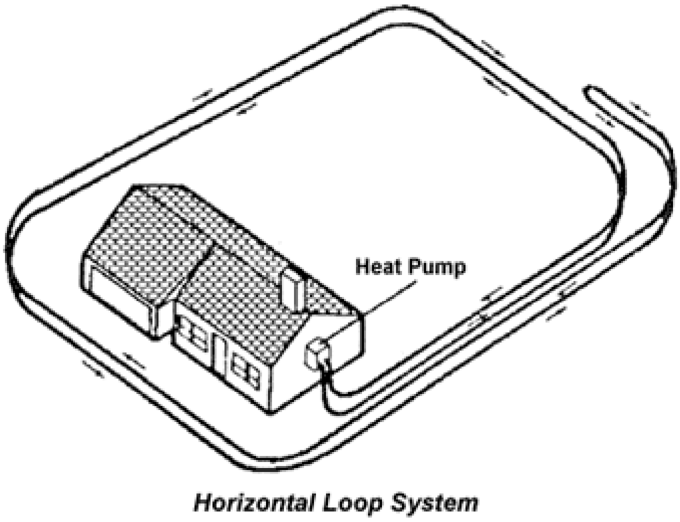

Figure 8: Horizontal Loop system

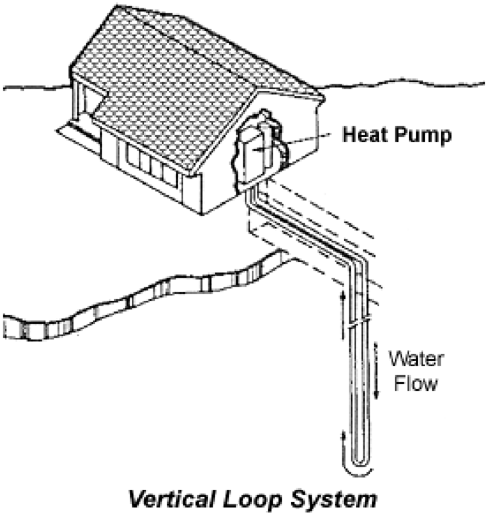

Figure 9: Vertical Loop System

5.8 Emerging Technologies and Developments

The latest commercially-available ground-source heat pumps have extremely high CoPs, up to 5 in a few cases. Incremental improvements are continually happening as manufacturers strive to obtain market advantage.

The most recent significant development is the inverter-based motor controller. These use a variable-speed electric motor which slows down and speeds up as needed to hold a chosen temperature. This has been made possible by developments in both computer control and stepper motors, and has had the side benefit of reduced instantaneous (start/stop) loads on the national grid.

Heat pumps in general are mature technologies, and the last 10-15 years has seen their increasing adoption in domestic situations as manufacturers have turned their attention to packaging and convenience features. It is unlikely that significant technology-based performance leaps will be made in the coming 10 years, meaning that increased production and consequent lower prices will be the mechanism by which greater heating and cooling energy efficiency will occur.

Of particular importance in NZ is the current absence of ground-source units from the market. Personal communications with a number of industry savants have confirmed that GSHP installations are all but absent, and those (less than ten installations) that have been completed were in particularly cold areas with very deep bores, and with costs in the $30-$40K range.

Massey University, under the guidance of Professor Don Cleland, is investigating a number of heat pump systems, some combined with hot water systems. These developments are largely based around high-precision controllers, utilizing very accurate sensors and intelligent control electronics. Commercial companies are involved in these discussions, with an eye to commercialising the technology if successful.

6 Solid fuel burners

6.1 Introduction

The BRANZ HEEP database indicates that approximately 50% of NZ homes employ solid fuel burning as a major source of heating, and on average these homes are warmer than others which employ different energy sources. When these fires are fuelled with timber, the resulting thermal energy release is essentially carbon-neutral. This fact, combined with the level of adoption of the technology, makes a compelling case for closer examination by Beacon.

It is important to realise that the discussion on the use of wood-burners as a renewable energy technology may be considered as left-field by some industry commentators, given ever-tightening controls on emissions levels from such burners. This is being driven by the Ministry for the Environment, which laudably is targeting reduced atmospheric pollutant levels by assisting owners in removing the least efficient solid-fuel burners and replacing them with alternative heating sources, most notably heat pumps. Two factors demand closer scrutiny of the possibilities offered by wood burners, both emerging from the HEEP study. The first, as mentioned above, is the market uptake of solid fuel burners (note – this implies coal as well as wood) is very large – the largest single technology in the heating market. Secondly, is the realisation that many fires are (in some cases by necessity) often run sub-optimally, with the incoming air choked to reduce heat emissions – when run at full efficiency, emissions of fires compliant with AS/NZS 4013:1999 are very low. Two challenges arise from this – appropriate sizing (in many cases smaller) of burners allowing them to be run hotter; and encouraging owners to replace their older less efficient models. For reasons of clear demonstrability of carbon-neutrality, the recommendations made herein apply to wood burners. Arguments on the “sustainability” or otherwise of coal are outside the scope of this report.

6.2 Potential Energy Savings (Best Case)

The argument here is much as for the one made above for heat pumps, with the exception that the electric resistive heating load (1361 GWh) is replaced with wood burning, and hence the electricity cost replaced by wood cost. Given that one of the primary reasons that wood burners are so popular across the country is that fuel is in many cases cheap or free. City prices vary from $290/cord (= 128 cubic feet, or 3.62 m^3) to $440/cord (advertised prices in early May 2006), and are also dependent on the location in the country (ie Auckland is more expensive than Wellington). Depending on the family concerned, the total heating season consumption of wood is between one and three cords. As can be seen, there is a great deal of variability in both availability and behaviour in the use of timber for heating. The Ministry for the Environment home heating survey (see below) determined that about half of the wood fed to the wood burners was self-collected, although the proportions were respectively higher and lower in the country and the cities.

Whilst measures to improve the performance of newly installed units will assist, the largest sustainability benefits will come from replacement of “old” wood burners with high-performance units. Programmes such as Environment Canterbury’s Clean Heat replacement initiative are beginning to deal with this stock, replacing them with heat pumps largely to the satisfaction of the homeowners – although on a wide (national) scale this will have dramatic implications on the national grid.

It is worth pointing out that even heat distribution in a dwelling is more difficult to achieve with a single point source such as a wood burner compared with ducted options such as heat pumps or multiple sources such as numerous small resistive heaters. Many homeowners avoid stratification by installing a ceiling fan to mix warm air in large spaces such as vaulted ceilings with the cooler air from closer to the floor. Simple fans and ducts through the roofspace also work to move warm air from the room with the woodburner into cooler areas such as bedrooms. Note that in this situation the bedroom doors are best left ajar to ensure that the air being moved has a return path.

6.3 System Types

6.3.1 Pellet Burners

The Ministry for the Environment maintains a list of approximately 75 wood burners which are authorised for installation (either they or very similar units have passed AS/NZS 4013:1999 for emissions, and AS/NZS 4012:1999 for thermal efficiency). Of these, 16 are pellet burners. As the name implies, these units burn preprocessed wooden pellets, made of (in NZ mainly) pine waste. MFE have surveyed the country (Wilton, 2005) to assess the degree of uptake of such units, as part of their drive (see above) to reduce pollution – particularly PM_{10} – suspended particulate matter (soot).

The same report concludes that pellet burner uptake is very low, between 0 – 3% nationally, and further, that of the solid fuel burners inspected, approximately 40% of them were more than ten years old. The opportunity for pellet burners is thus apparent, as they burn cleaner than even the newest solid wood burners, although at the expense of some energy used in processing to create the pellets – Scion (Per Nielsen) have been working in this area for some time, and have some elegant solutions to this and other issues relating to pellet burners.

Wood pellet production is increasing exponentially in the northern hemisphere, especially in Sweden at 300,000 tonnes per annum and growing. The recent announcement that the Swedish bio-energy company Talloil will invest about 107 million euro in Canada for manufacturing wood pellets for export to Europe gives the technology even more potential for wider adoption in NZ. The raw material will be pine damaged by bark beetles. British Columbian authorities are desperately looking for solutions to the problem how to deal with their dying trees. The bark beetle has destroyed all pine forests in the province, and local sawmills have no chance of taking care of all that timber before it rots.

One of the main problems (with regard to sustainability and transport energy) is the lack of infrastructure in NZ for creation and distribution of the pellets themselves. This may be a co-dependent (chicken-and-egg) situation related to the lack of uptake of the burners themselves, so an opportunity exists to explore an intervention in this area, if the political risk which will arise from opposing MFE's programme of wood-burner removal can be overcome.

* Pellet burners cannot be tested in accordance with AS/NZS 4013:1999 as they utilise a continuous feeding mechanism to distribute pellets into the fires. Pellet burners are not, therefore, included in the design standard. They do, however, meet both the emission and efficiency criteria.

6.3.2 Log burners

Free-standing log burners themselves have evolved from the once commonplace built-in fireplace, and function by both convection and radiation to heat the home. HEEP has identified that some of the units in use have heating capacities in service of 12kW or more when fully fired and operating without choking. This large heating capacity is in many cases sufficient to overcome the lack of insulation and airtightness in old houses, providing comfort for the occupants even when outdoor temperatures drop into single figures. HEEP indoor temperature measurements suggest that houses heated with solid fuel burners are measurably warmer than those heated by other means (and incidentally that those heated electrically are the least warm).

The HEEP operational records suggest that large-capacity wood burners are often run at only 30-50% capacity, decreasing the efficiency of the combustion process and increasing particulate and other pollution dramatically. A smaller capacity burner may be able to be run at maximum efficiency at all times, without overheating the house.

For both log and pellet fuel burners, there is also the option of fitting a wetback to heat water. For new installations, this is an attractive option as the plumbing can be installed with minimal disruption, and due consideration given to the location of the burner to optimise both its primary heating function and also minimise the pipe runs to the hot water cylinder.

6.4 Manufacturers, Retailers and Installers

The New Zealand market for wood burners is well-served, with both local and imported models available. From the professional body's website:

"The NZ Home Heating Association (NZHHA) was formed in 1985, by a group of wood heating manufacturers and retailers who saw a need to improve the standards of product and workmanship within the industry. Since then it has played an active role in the development of appliance and installation standards both nationally and internationally and has become the industry's mouthpiece. It also plays a major role in the development and promotion of clean air standards, and energy and resource conservation.

It runs a certification for installer and retailer members to help ensure that the appropriate standards are maintained at all levels within the industry.

The Association is affiliated with similar trade groups and organisations through out the world"

This is a reasonably concise summary, with units widely available for retail purchase at a number of outlets.

Installation always requires a building consent, although there is no current requirement for professional installation. It is worthwhile noting that BRANZ's site visit defects database contains a disproportionate number of grossly unprofessional installations of solid fuel heaters, carried out without building consent "under the radar" – which is one of the market conditions that led to the formation of the NZHHA.

6.5 Current industry growth

The NZHHA currently expects steady sales of wood heaters for the next two years, with some growth potential predicated on increasing fuel prices (and knock-on prices of electricity and fuel oil). Sales have been steady for the last three years.

In the USA and Canada, pellet burners are increasingly popular, largely due to their emissions and efficiency advantages in the Environmental Protection Agency –regulated market. If the initial break is made into the market, especially with better fuel supply networks, it is sensible to expect a similar trend in this country

6.6 Performance

6.6.1 National Environmental Standards

The National Environmental Standards are national regulations designed to protect public health by setting 'bottom-line' values. The National Environmental Standards for Air Quality are the first suite of standards and includes the design standard for woodburners in urban areas:

> All wood burners installed after 1 September 2005 must have:
>
> - An emission of less than 1.5 grams of particles per kilogram of dry wood burnt as measured in accordance with AS/NZS 4013:1999; and
> - a thermal efficiency of greater than 65% as measured in accordance with AS/NZS 4012:1999.
>
> From 1 September 2005 the New Zealand design standard for wood burners applies to all units installed on properties less than 2 hectares in lot size.
>
> The standard applies only to wood burners. It does not apply to:
>
> - open fires, multi fuel burners (eg, coal), cooking stoves , pellet burners.

6.6.2 Fit with the Building Code

The National Environmental Standards are regulations made under the Resource Management Act 1991 and may not link to the Building Act 2004. MFE advises that it would be prudent for the Council to inform people that granting of a building consent is not authority to install and operate a non-complying woodburner.

The Ministry suggests that Councils issue an advice note with a building consent for woodburners alerting the owner to the air quality regulations, as these regulations prevent discharge from any non-complying woodburner. The Ministry further suggests Councils liaise with the relevant Regional Council, as they are responsible for enforcement of the regulations. Councils may however, want to consult their own lawyers as to whether there is a link between the two statutes in relation to woodburners.

7 Wind microgeneration

7.1 Introduction

Wind has been used as a source of power for thousands of years, most notably to move sea cargo for the Phoenicians, then to drive windmills and herald the beginnings of the Iron Age. At a NZ domestic level in the new millennia, there are limited opportunities to grind wheat and so modern domestic wind capture technologies focus largely on the generation of electricity.

As with solar heating and PVs, the first factor to be considered when deciding whether to install a turbine is the availability of the resource. NZ is a narrow, insular country with strong and consistent westerly wind run. A graphical representation of the best wind generation sites has been published (EECA, 2005) but it focuses predominantly on large scale network generation. Given the low wind speed required for generation, it is a widely available and free resource across most of the country.

Micro-scale wind turbines are available for domestic installation, however they are all manufactured overseas – barring homebuilt efforts.

Most of the equipment required for the domestic installation of a wind turbine is exactly as for photovoltaic cells – an inverter (or power conditioner), and if the house is off-grid, a storage battery array.

7.2 Potential Energy Savings (Best Case)

This is extremely difficult to estimate for a small scale domestic turbine, since the size of the turbine is directly related to the amount of energy saved, as is the wind speed. EECA (2005) state that even for a commercially oriented wind farm outputs are likely to vary by 25% from month to month.

This points to the capital investment payback model as being a more sensible method by which to determine the economics of a micro-installation. Figures available from the New Zealand Wind Energy Association relate to the cost of delivered energy from wind farms, rather than the setup cost of a micro turbine.

The most relevant figures available come from EECA, who suggest that a moderate stand-alone system will cost between $15K and $25K, of which about 25% will be spent on batteries.

The key variable in calculating national benefit will therefore be the amount of energy saved by each installation, multiplied by the potential number of installations. At this point, it is important to consider that virtually all of the micro turbines currently installed are in non-urban areas, due to planning restrictions imposed by local authorities in suburban areas. This relates specifically to height restrictions, where effective wind turbines are essentially “prohibited” due to the need to mount them on 10m pylons which are unlikely to be welcomed by close neighbours when signing resource consent permission forms.

7.3 System Types

7.3.1 Horizontal Axis

These are traditional windmill-type generators, basically small versions of the large commercial windfarm generators. Their performance characteristics are defined by their rotor diameter, and operational windspeed (torque available at a given rate of revolution).

7.3.2 Vertical Axis

Two types of vertical axis generators are seen:

1) Unlike the more common type of generator which uses a propeller, the Darrieus generator rotates around the vertical axis rather than the horizontal one, and is thus referred to as a *Vertical Axis Wind Turbine* or *VAWT*. Conventional propeller-based systems are known as a *Horizontal Axis Wind Turbine*, or *HAWT*, although typically only when referring to VAWTs. The vertical arrangement has several advantages, notably the generator can be placed at the ground for easy servicing, and the main supporting tower can be much lighter as much of the force on the tower is transmitted to the bottom. The Darrieus type is theoretically just as efficient as the propeller type, but in practice this efficiency is rarely realised due to the physical stresses and limitations imposed by a practical design. In addition, propeller based designs have a wider operating speed range and are self-starting.

Figure 10: A Darrieus Wind Turbine

2) Savonius wind turbines were invented by the Finnish engineer S J Savonius in 1922. Savonius turbines are one of the simplest turbines. Aerodynamically, they are drag-type devices, consisting of two or three scoops. Looking down on the rotor from above, a two-scoop machine would look like an "S" shape in cross section. Because of the curvature, the scoops experience less drag when moving against the wind than when moving with the wind. The differential drag causes the Savonius turbine to spin. Much of the swept area of a Savonius rotor is near the ground, making the overall energy extraction less effective due to lower wind speed at lower heights. Savonius turbines are used whenever cost or reliability is much more important than efficiency. For example, most anemometers are Savonius turbines, because efficiency is completely irrelevant for that application. Much larger Savonius turbines have been used to generate electric power on deep-water buoys, which need small amounts of power and get very little maintenance. Design is simplified because no pointing mechanism is required to allow for shifting wind direction, unlike horizontal axis turbines, and the turbine is self-starting. Savonius and other vertical-axis machines are not usually connected to electric power grids. They can sometimes have long helical scoops, to give smooth torque.

Figure 11: A Darrieus turbine (generating most of the energy), surrounding a Savonius Turbine (self-starting, to get the Darrieus moving).

7.4 Emerging Technologies and Developments

A Building Research Establishment (BRE) article (Dayan, 2006) reports that a number of rooftop-specific systems are now emerging in the UK, some with claimed paybacks of 5 years or less. BRE are establishing testing facilities to facilitate market acceptance by demonstrating noise, vibration and output capacity, in order to demonstrate to the market that the technology is feasible, tolerable and affordable. As mentioned above, NZ is some distance from this point, purely from a market readiness perspective, both for cost and regulatory reasons.

8 Cost/Benefit

For the purposes of this analysis, which is indicative only to demonstrate the potential differences between the various technologies, all figures have been normalised back to a standard energy saving per year – in this case assumed to be that of the best solar water heater performance described (by Stoecklein) on page 11 – 2,359 kWh per year.

This has had to be done as there are too many variables present in the sizing decisions for the various different technologies to make a straightforward comparison possible. These are explained in brief below:

- For space heating systems, HEEP indicates that the average amount of electricity that could be replaced with renewable sources is 972 kWh per year, which is well within the capacity of all of the systems investigated. Because New Zealand homes are (as a very general observation) not well heated, the extra heating offered for less energy consumption would most likely be valued – this is the phenomenon known as “takeback”.
- Photovoltaic and wind turbine systems can be sized to generate any amount of electricity required – for a certain capital cost. The minimum capital required to achieve the 2,359 kWh per year saving is not clear without extensive calculation, however the capital outlays suggested come from EECA advisory bulletins, and performance from assorted overseas references. The capital outlay is for grid-disconnected systems of non-specified size (ie “typical”), so it is misleading to include the internal rates of return in comparison with other technologies where the capital outlay for a given performance can be reasonably accurately determined, and is not sensitive to the presence or absence of a grid connection.
- Heat pump systems can be similarly sized, to deliver whatever energy is required, again for a certain capital cost, although they have input energy requirements to maintain that output, and this has been factored in via the assumed CoP.
- Wood burners are similarly able to be sized as large as necessary, however it seems that the main issue is that the market does not offer emissions/performance-compliant small units which can be run at maximum capacity.

Auckland						**Running**	**Savings in**	**Simple**	
PRODUCTS		**Material**	**kWh/year**	**Fuel**	**kWh**	**cost**	**running**	**payback**	**IRR**
		Cost $	**input**	**$/kWh**	**Savings**	**$/year**	**costs $/ yr**	**years**	
Electric HWC (night rate)		1100	2359	0.145	2359	342	0	-	-
Electric Space heating		500	2359	0.183	2359	432	0	-	-
Solar Water Heating		5000	311	0.183	2359	57	285	17.5	1.3%
Heat pump HWC	(CoP 4.0)	4000	590	0.183	2359	108	234	17.1	1.6%
H/P Space heating	CoP 3.4)	4000	694	0.183	2359	127	305	13.1	4.4%
Wood Burner		3000	2359	0.05	2359	118	314	9.6	8.4%
Wind Turbine		37000							
Photovoltaics		42000							

The Internal Rate Of Return and payback period suggests that the biggest gains are to be made by investigating further the role of the wood burner in providing low-grade energy to heat NZ homes.

From the above table, the input figures were arrived at as follows:

SWH – Cost figures from Page and Phillips work in progress for Beacon

H/P HW – Cost and performance figures from Page and Phillips

H/P SH – Cost and performance from this report

Wood – Capital costs from this report and visit to 4 Seasons, plus fuel costs and efficiency from van Wyk & Neilsen (2004). Note that most woodburners use more wood than this per year (and generate more heat) – this was normalised back to a standard amount of energy generated.

8.2 CBA Conclusions

The primary reason (given stable wood prices) for the good showing of the wood burner compared with a heat pump of similar delivery capacity is its lower capital cost. This is a function of the observed need for smaller capacity units, and hence the price was taken from the advertised costs of smaller units on the market, with installation included. If the cost of firewood increases, this advantage is rapidly eroded. However, it must be recalled that half of the firewood burned is self-collected, so the fuel cost figure used is likely to be high on average.

Similar comments apply to the SWH technologies – until the capital cost is reduced, there is a clear monetary reason to choose a heat pump to heat water – especially with the promise of newer units with CoPs over 5 (by careful siting of the intake heat exchanger) and the current lack of solid information on actual SWH performance.

The Wind and Photovoltaic technologies proved difficult to assign solid figures to. There is no question that both technologies are far more economic when considering whether to connect a remote house to the grid, however in urban situations they currently have very limited traction. Investigation of pricing is difficult, as each system is bespoke – EECA had calculations done for a “typical” system of each, which is assumed to be around 2kW, and in both cases a large proportion of the total cost was batteries and rectifiers, needed for some (but not all) installations. The BRANZ ZALEH research project (Stoecklein 2006) suggests that a combination wind/PV installation is the best compromise for low energy houses in NZ however the prices are still prohibitive for straight payback calculations to show sufficient benefit. In order to not mislead, these have been regarded as special cases and not included.

9 Technology Opportunities

9.1 Solar Industry Installation Capacity

9.1.1 Situation

Although the industry installation capacity is currently fairly well-matched to demand, if the current growth rates continue it is apparent that a severe skills shortage will develop within the next 24 months. The Waikato Institute of Technology (WINTEC) introduced a SWH installation course in early 2005, which will go some distance towards addressing the potential shortfall, but if the predicted growth rates occur, this will not be sufficient. It is also still not possible for the installers to sign off their work.

Introducing a specialised solar water heater installer trade will also have the effect of reducing on-site costs, if it can be agreed that the role of the plumber in the installation process is either in a sign-off capacity, or not at all. The most appropriate model for this is that of the satellite television installer, who is highly trained in the relevant specific aspects of the installation process, rather than a more widely-skilled (and more expensive) master plumber.

The NZ Solar Industries Association currently administer a scheme similar in nature to the one described, but market breakthrough has yet to occur – still needs plumber signoff.

9.1.2 Opportunity

To streamline the installation and compliance process, creating a professional qualification for installers and a SWH-specific compliance path.

9.1.3 Process

1) Working with the NZ Solar Industries Association as advisors and Waikato Institute of Technology as they have already progressed this to some extent, develop an NZQA-recognised tradescraft qualification for the installation of solar water heaters
    - Must include new build and retrofit installations
    - Must enable the installer to sign-off the installation as NZBC-compliant

Cost

Uncertain – as a guide, BRANZ CITE courses cost from $80K-$150K to develop, taking from six to twelve months. Depending on the level of development inherent in the Waikato course, much of the work may be done, requiring only liaison with the DBH and NZQA to conclude.

Potential Suppliers

WINTEC, BRANZ CITE, Plumbing and Gasfitting ITO, other NZQA-registered training bodies.

2) Liaising closely with the DBH, PGITO, and other stakeholders, develop an agreed path through the NZBC to enable quality SWH installations to be made quickly and reliably.
    - Must ensure that homeowner's needs (reliability, timeliness of service, understanding of the technology) are met first to ensure that the installation adds and retains value
    - Must ensure that regulatory control for the DBH is not compromised, enabling their support.

Cost

Tasks include development of briefing papers and proposal, with key liaison role with DBH, PGITO, SIA, NZQA etc. $15K. Timeframe – dependent on the DBH and PGITO – may be up to 1 year due to political consultation cycles, but will depend on the ability of the contractor to engage with DBH (and more importantly MED) and PGITO.

9.2 Solar Water Heater Performance

9.2.1 Situation

Although performance standards exist for SWH units, not all of the units sold in NZ have been subjected to the full suite of tests which paint the total picture of their performance.

The NZ Building Code require SWH systems installed in buildings covered by the code to be compliant with AS/NZS 2712:2002 Solar and Heat Pump Water Heaters - Design and Construction, and installation to be in terms of AS/NZS 3500.4. AS/NZS 3500.4: 1997 Hot Water Supply Systems - Acceptable Solutions.

SWH hot water storage tanks are to meet NZS 4606.1 unless exempt for Minimum Energy Performance Standards (MEPS) under the Trans-Tasman Mutual Recognition Act.

The performance testing is an interesting point; Gleb Speranski of EECA, who is on the SWH standards committee, has advised that it is likely the performance test method to be used in the future will be ISO 9459-3.

AS/NZS 2712 requires system performance testing using either by outdoor testing to AS2984 or in a solar simulator test method toAS2813, so it appears likely that this will be superseded by the ISO Performance test.

No reliable data currently exists for the actual performance of the units installed in NZ, other than small localised surveys. A project is currently underway within BRANZ to acquire data on 42 units across the country, funded jointly by BR and EECA.

9.2.2 Opportunity

To establish the performance of SWH units sold in NZ, in the lab and in the field.

9.2.3 Process

1) Establish agreement with EECA and the SIA on which performance testing regime will be used to accompany the existing AS/NZS 27132 testing. Once agreed, subject each unit currently on the market to performance testing via the Consumer's Institute.

   Costs

   Uncertain – no organisation in NZ is currently set up to undertake ISO 9459 testing so a cost-share may be appropriate for the capital equipment, with a guarantee of the work to follow at agreed rates.

   Potential Suppliers

   BRANZ, Opus, IRL.

2) Support EECA/BR field research, with the aim of expanding the sample size and increasing the robustness of the results. Additional input into the occupant's questionnaire may also be possible, within the next month. The funder's agreement is structured to accept additional sponsors without disrupting the process.

   Costs

   For each additional unit surveyed, $5-7K, depending on analysis required.

   Potential Suppliers

   BRANZ only.

9.3 Photovoltaic Opportunities

9.3.1 Situation

Whilst any life-cycle analysis of PV systems is outside the scope of this report, their 25-year serviceable life and zero-emissions energy generation promise to make the results overwhelmingly positive. However, manufacture of PVs involves the use of toxic and environmentally damaging chemicals, and recycling/disposal of the complex composite modules is problematic. At the current level of PV use, this is not a major problem – however reducing manufacturing costs and increasing efficiencies, coupled with escalating oil process will result in more PV deployment and force further consideration of the LCA issue.

9.3.2 Opportunities

None immediately apparent, other than to maintain a watching brief on the development of PV efficiencies and continuing integration of PV modules into building elements. Given the price per delivered Watt of power, this technology is promising on a macro (grid) scale if distributed generation becomes a necessity in areas such as the East Cape, but does not currently offer value on an individual house basis unless the house is also off-grid. For Beacon, the biggest impact on the achievement of the Goal does not lie there, so the recommendation at this point is that no interventions are undertaken to increase PV uptake with current technology/price.

9.3.3 Process

Make and maintain contact with Massey University, and EECA's renewables team, with an eye to revisiting this report in 12-18 month's time.

9.4 Wind Turbine Opportunities/Risks

From the scarcity of available credible information, lack of local manufacturing base, and TLA bylaws regarding height, it appears that domestic micro-wind installations will be limited to rural areas for some time to come. Their ability to effect a large swing in national energy usage patterns is therefore marginal at best at this time. Many of the comments made about PVs (above) also apply to microturbine wind generation, mainly due to the cost arguments.

9.5 Heat Pump Opportunities/Risks

9.5.1 Situation

The current growth rate of heat pump installations is beginning to concern some energy analysts (Camilleri, 2006), primarily due to the apparent prime use of the heat pumps in question: for summer cooling. This introduces the possibility of high summer electricity loads. The BRANZ HEEP survey does not include heat pumps in any meaningful fashion, as their rise in popularity coincided with the conclusion of the survey. Consequently no sensible population data is available. Anecdotal evidence suggests that there are similar problems emerging in the UK.

Indisputably, heat pumps use less energy when operated as coolers than traditional air conditioners. Whilst the latter are still considered somewhat of a luxury, the ability of a heat pump to also function as a low-cost heater during winter months has led to accelerated sales during the last 18 months. Heat pumps are also a viable technology for heating water, as mentioned in the body of this report.

9.5.2 Opportunities

Understand the current and potential size of the market for heat pumps, and the factors currently affecting uptake.

Determine, via observed heating and indoor temperature patterns, the likely national impact on the electricity distribution system of continuing the uptake trends. Understand these impacts for both space and water heating.

Determine CoPs for units most popularly on sale.

Determine the effect of new technologies (increased CoP, GSHP) on these figures.

9.5.3 Process

0ata\ C:\Documents and Settings\ Conduct market-size research into heat pump sales for the last three years, and tie it into energy/electricity prices, and disposable income indicators. EECA MEPS figures (from Terry Collins on the first instance) may be able to help with this, and would substantially reduce the cost.

Cost

$30K, two months duration.

Potential Suppliers

Market research firms.

2) Model the potential energy use impacts of continued increase in heat pump sales (see 1 above), using HEEP heating profile, temperature, and input energy data. Relate this to increased/decreased loads on the grid, for heat pump use in both space and water heating.

Cost

$40K-$100K (depending on data accessed), two month’s duration subsequent to 1 above.

Potential Supplier

BRANZ only.

3) Working with EECA, assemble MEPS-mandatory information on heat pumps currently for sale in NZ subject to the MEPS programme. For units not covered (specifically, ducted air or three phase units) but which still feature in the sales figures obtained in 1 above, undertake a measurement programme to AS/NZS 3823.1.1 in conjunction with the Consumer’s Institute, in order to provide supporting information to complete the spectrum of expected performance and its impact on national energy consumption.

Cost

$3-5K if no testing. Testing not quantifiable at this time. One week.

Potential Suppliers

Energy Options, BRANZ, Victoria University School of Architecture and Design

4) Using actual results from new technology (Don Cleland at Massey University, for example), feed these CoPs into the models developed above in 2

Costs

$5K, 1 week.

Potential Suppliers

BRANZ

9.6 Solid Fuel Burners Opportunities/Risks

9.6.1 Situation

Currently sold fuel burners are present in about half of New Zealand’s houses, and because of their large capacity for heating, those houses are the warmest during the heating season (both from HEEP results).

Wood burners (of any description) are basically carbon-neutral in operation, liberating CO_2 into the atmosphere which is then taken up by trees as part of their growth cycle.

Cost of burners is largely dependent on size and sophistication, from less than $1k up to about $4K, plus installation of $1-2K, making them capital-competitive with both heat pumps and SWH units, and with an operating cost which may be less than both if the wood burned is self-collected.

9.6.2 Opportunities

Understand, what the potential impact would be on electricity use (both total load and time of load) if current resistive heating was replaced with wood burning. Similarly, understand the impact of replacing the current wood burners with heat pumps.

From the results of this, determine the optimum size of wood burner to be run at maximum capacity, and match this with models currently available in the market (if any – currently it appears there are few small enough in capacity).

Create a specification for a high-efficiency small/medium output wood burner, which can be run at maximum efficiency at all times, without overheating the house, to replace older technology burners or resistive heating in houses.

Develop new technology with a suitable manufacturing partner.

9.6.3 Process

1) Via analysis of HEEP data on heating patterns and energy consumed what the potential impact would be on electricity use (both total load and time of load) if current resistive heating was replaced with wood burning. Via similar methods, understand the impact of replacing the current wood burners with heat pumps.

   Cost

   $30-$70K, depending on data accessed. Three months duration

   Potential Suppliers

   BRANZ only.

2) Via energy modelling, determine the thermal output required from a wood burner in order to heat homes to comfortable levels during winter – when the burner is running at maximum capacity (and max efficiency). Using HEEP figures for heating energy currently produced by wood burners, determine the increased electrical loading which would occur if they were replaced by heat pumps (derive CoP from EECA MEPS figures).

   Cost

   $20-$50K depending on data accessed, and partners involved. 1-2 months.

   Potential Suppliers

   BRANZ (for HEEP data refining) and either BRANZ, VUW Architecture School, Building Workshop (Wgtn), Energy Options or private contractors for the energy modelling.

3) Create a specification for a high-efficiency small-sized wood burner, designed to be run at or near maximum capacity at all times to reduce emissions. There are a number of experts in this area, outside of the manufacturers – Per Nielsen at Scion has a lot of expertise in pellet burning and the issues that need to be addressed, and Grant Murray or Hamish Trolove at CRL’s Gracefield research site are very experienced in the testing of the burners.
4) If there are no suitable candidates already in the market, the opportunity is available for Beacon to proceed with its own technology development.

   Costs and potential suppliers –

   Unknown for 3 and 4.

10 Summary and Conclusions

This report considers two main types of energy (as commonly referred to by energy analysts). Low Grade energy is used to heat the home, and heat water – it does not have to conform to any particular delivery specification (Amps, Hertz, Voltage, power factor, etc) but simply has to be available in a form which can be utilised most effectively. Frequently, this involves the use of heat exchangers (ie solar water heaters, heat pump input and output matrices) to harvest and direct the energy.

High Grade energy is the type which would run a computer, DVD player or microwave oven. It must meet strict standards when delivered, including freedom from spikes (too much energy) and brown outs (too little energy). Electricity, when properly conditioned and delivered, meets these specifications. As can be appreciated, the process of providing high grade energy is expensive, both from a generation and distribution perspective, so it makes sense to reserve this type of energy (specifically electricity) for end uses specifically requiring it, and to look to satisfy low grade energy.

It is important to consider exactly where the biggest wins will be achieved. HEEP suggests that baseload and domestic hot water standing losses are virtually the same (annualised) as the electric space heating load. Baseload is composed of all of the appliances that run constantly, and includes standby load. Given that this is high grade energy, and we are looking to utilise low-cost or free low grade energy, it is sensible to consider the hot water standing losses and electric space heating as our primary targets (best bang for the buck).

Solid fuel burners, in 4-6kW size, appear to offer a sensible route to reducing overall electricity consumption, by substituting electricity for low-grade heat. When combined with a wetback for heating water (unexplored in this report, as the performance of the wetback units is not well understood) the benefits in reducing energy become even greater, although this option is less economically viable in a retrofit situation where pipe runs are more difficult to organise and install. The major detracting factor is the issue of atmospheric pollution, which can be largely dealt with if the burners are designed to run hot and combust completely at a relatively low total output (ie small burners, running flat-out). Wood burners are today’s and yesterday’s technology and as such have a wide installation base and well-demonstrated effects.

Heat pumps appear to offer the best simple “plug and play” opportunity to reduce energy usage across the board. With CoPs now between 3 and 4 for the best units and more performance promised soon, capital costs in many cases directly comparable with both solar water heaters and wood burners, the flexibility offered by air source heat pumps is sufficient to recommend that they also be targeted for further study. The main area of uncertainty is the current level of market uptake for these units, followed by an appreciation of the actual CoPs that the units being sold offer. The almost total lack of domestic ground-source heat pumps is further opportunity for development. Heat pumps will become “the” low energy technology of the next few years.

Solar water heating continues to be an attractive option if cost of capital is not a problem. It appears that the Solar Industries Association is doing a solid job of promoting the technology and responsible installation practices, although the result seems to be high prices. Whether more vigorous competition in the SWH market will lower prices is unclear as there are no “rogue” retailers operating successfully outside of the SIA to make the measure possible. Widespread adoption will not happen until process drop and installation is easier. This technology is on the five year horizon.

Wind power and photovoltaic arrays offer “free” electricity and as such are very attractive when off-grid. In these circumstances, the cost of rectifiers and batteries is acceptable when compared with the potential costs of becoming grid-connected. For houses that are already on-grid, and/or in a neighbourhood, the noise/height issue has yet to be surmounted in NZ for wind turbines and PV arrays are still very expensive due to the silicon shortage. These technologies are on the ten year horizon or beyond for widespread adoption.

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