Little Greenie – Get the Facts

A report prepared for Little Greenie Design and Build, The Hikurangi Foundation and the Energy Efficiency & Conservation Authority (EECA).

LITTLE GREENIE DESIGN & BUILD

hikurangi Ko te kete aronui

EECA Energy Efficiency and Conservation Authority Te Tari Tiaki Pūngao

Little Greenie – Get the Facts

By Verney Ryan, April 2011

About This Report

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Little Greenie – Get the Facts

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Data relating to costs of construction, for Little Greenie and the Quality Basic Build to Code house, was kindly provided by Lawrence and Antje McIntyre with further, much appreciated assistance, from Grant Collings.

For more information about Little Greenie, as well to book accommodation and experience the high level of performance first hand, please visit: **www.goldenbayhideaway.co.nz.**

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1 Executive Summary

This report, which has been commissioned by the Hikurangi Foundation, the Energy Efficiency and Conservation Authority and Little Greenie Design and Build, outlines some of the key features, costs and benefits of the Little Greenie house built in Golden Bay by Lawrence McIntyre. The dwelling, which has achieved the highest energy efficiency rating in New Zealand under EECA's Home Energy Rating Scheme (HERS), provides an extremely warm, comfortable and low cost living environment. For a copy of this HERS report, please contact Lawrence McIntyre.

This report provides an overview of energy and thermal performance within the house. It is based on available data, as well as identifying gaps in the data set, that need to be filled. The analysis includes a comparison of the Little Greenie Passive Design approach with a similar house built to current building code levels.

A summary analysis provides indications of the potential return on investment for the added features of the Little Greenie. These straightforward and practical details provide for increased levels of performance and reduced maintenance costs over the lifetime of the building. An indication of payback periods for certain features of the design and the potential for added capital value are explored.

The Little Greenie house provides the following key benefits compared to an equivalent size and design of house built to current building code standards.

- ☑ A 9 star Home Energy Rating (HERS) rating as compared to a 4.5 HERS rating for a code compliant house.
- ☑ Little Greenie delivers a comfortable indoor environment that consistently meets World Health Organisation (WHO) recommended indoor temperatures year round with minimal reticulated energy input.
- ☑ Only marginal additional costs to build (at $2,136/m^2 compared to $1,766/m^2 for the code level equivalent), which provide a return on investment in less than 21 years and have the potential to add to the capital value of the house.
- ☑ An estimated return on investment in excess of $77,000 over a 50 year period when lower maintenance costs are also taken into account
- ☑ Little Greenie provides a practical and achievable method of building to a higher level of performance through well crafted passive solar design techniques and high levels of insulation, that deliver a unique opportunity to educate and inspire the residential construction sector in New Zealand.

The report concludes with an analysis of the lessons learned, discussions for future potentials, and a summary of recommendations for further work.

2 Introduction

Lawrence McIntyre, a hands-on practical builder with a variety of construction experience[1], built 'Little Greenie' in 2008/9 with the intention of showing what could be achieved when you set out to make a simple, comfortable, easily maintained and 'green' house in New Zealand using accessible techniques and materials.

His motivation is both to earn income from the house and also, through education, to improve New Zealand housing for the good of all. Little Greenie has been set up as guest accommodation, so that people can experience what it is like to live in such a house – with the aim that this might inspire them to follow similar techniques.

Little Greenie has already received many commendations as well as good feedback from visitors, guests and experts in the building industry. The house achieves a 9 star HERS that, at the time of writing, makes it the highest rated house in New Zealand, as well as highlighting the Little Greenie as one of the most energy efficient houses built to date in this country.

This report has been commissioned by The Hikurangi Foundation, EECA and Little Greenie Design and Build to collate and analyse available data from Little Greenie in order to start the process of documenting how the house actually performs in terms of building and maintenance costs, resource use, running costs and comfort. The report presents an overview analysis of the information and relevant available data from the house. The aim is to collate and assess data relating to the performance of Little Greenie according to a range of sustainability, liveability and practicality criteria in order to have verifiable facts as the basis for any future work in promoting the house and the philosophy behind it.

[1] Lawrence McIntyre claims that a variety of experiences have been drawn on in the approach taken with 'Little Greenie'. Lawrence's background in the chicken farming industry where ventilation, insulation, temperature control and air flow are crucial to success, through to his management of construction projects in Papua New Guinea and Africa, and then involvement in the Passive Haus industry in Germany, have all helped to inform the design and construction of the key features of Little Greenie.

3 Little Greenie – Construction Overview

Little Greenie was constructed in accordance with five guiding principles of:

- Energy efficiency
- Low maintenance / longevity
- Ease / simplicity of construction
- Value for money
- Craftsmanship

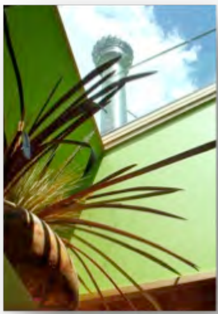
The house is essentially a super insulated lightweight timber frame construction built on a fully insulated concrete slab and utilising elements of passive solar design and thermal mass through adobe wall construction. Full construction techniques are well documented on the Little Greenie website: http://goldenbayhideaway.co.nz/design_build/construction

The following are some of the key features of the design:

Orientation – the house is angled within 15 degrees north for optimal solar orientation. Eaves have been designed to allow sunlight to penetrate in winter whilst providing shading in summer.

High Performance Glazing
The stunning view of Little Greenie is framed with high efficiency low e, argon filled, thermally broken double glazed windows and doors which also provide controlled ventilation to the dwelling.

Airtight Construction
Lawrence McIntyre's attention to detail is arguably most evident in the airtight nature of the construction. All significant air gaps were sealed within the house to allow for very little leakage of air warmed through the passive solar design.

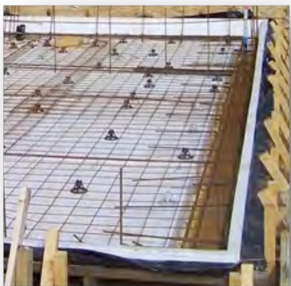


Controlled Passive Ventilation
The house utilises controlled passive stack ventilation. Fresh air is drawn in through controllable trickle vents in the high performance windows and then out of the house through the composting toilet system via a passive vent above the house topped with a 'whirly-gig' wind cowl.

Highly Insulated
Construction is based around a traditional New Zealand timber-frame house with ex 150 x 50 mm framing, ex 100 x 50 mm dwangs (nogs) and exterior 50 mm battens. Three layers of high-density wool insulation minimises cold bridging throughout the structure providing an R-value in the walls of 5.1. Insulation in the standard truss roof is provided with two layers of high-density wool insulation laid in a blanket across each other, achieving an insulation R-value of 7.4. In addition, the construction techniques mean that wall and ceiling insulation butt up against each other, further reducing the cold bridging. This results in a well-sealed, cosy and consistent high performing thermal envelope.

Picture Source: http://goldenbayhideaway.co.nz

The concrete slab of Little Greenie is based around a 'raft' floor pod system which has had additional insulation laid between the pods as well as under the main slab. 60 mm of high-density polystyrene around the perimeter completes the floor and results in a highly insulated structure with minimal thermal breaks. The careful detailing in the floor results in no concrete coming in direct contact with the soil – thus keeping the heat stored in the thermal mass within the thermal envelope of the house.



The insulated floor system provides a robust foundation for the house. In the words of the building engineer who worked on Little Greenie the floor is a ***"****simple, high strength, well insulated raft floor and foundation system which can be used at sites with different ground conditions including those with good ground or cut and filled sites or those with poor ground conditions requiring piles. The reinforced concrete perimeter beam and reinforced concrete ribs within the slab provide a* *very strong floor and foundation system suitable for earthquake prone areas. The foundation system is on the ground and the requirement for trenches is eliminated. This greatly reduces labour costs and the amount of excavated material on site."*[2]

Thermal Mass
The insulated concrete floor slab and the internal adobe wall construction provide a high level of thermal mass (also insulated from the outside). This has the effect of acting like a heat store as well as moderating temperature within the building to provide comfortable year round conditions.

Simple 'no fuss' design
The design of Little Greenie minimises complicated roofing angles, internal gutters or superfluous detail. This reduces the overall costs of building as well as the potential for failure. This 'simplicity' also provides a range of maintenance benefits, such as the elimination of frequent painting or repairs. In addition, through the use of mostly passive systems for heating and ventilation, the need for expert occupant control is reduced, meaning a better performing building with no fuss – and somewhat independent of user behaviour.

Renewable electricity as well as renewable space and water heating – with minimal CO_2 emissions over the life of the building

Picture Source:
http://goldenbayhideaway.co.nz/abodes

Relatively small footprint
As is evident by its name, Little Greenie is of a modest size (104 m^2 footprint including garage and covered area). This reduces the impact of both the materials used in the build process, the amount of permeable land covered, as well as the operational requirements for inputs like energy needed over the lifetime of the house.

[2] Personal Communication, Richard Walker, Consulting Chartered Professional Engineer, Engineering Sustainable Solutions Ltd, 2011

Figure 1: Solar Panels

Figure 2: Latento Hot Water Cylinder

Picture Source: http://goldenbayhideaway.co.nz

4 Energy and Thermal Performance

Little Greenie is designed using classic passive solar and low energy design concepts. The house utilises orientation and thermal mass to capture the heat energy from the sun to warm the primary living space. The high levels of insulation, and attention to detail in reducing air leakage, provide a very well insulated and airtight structure to keep the captured heat in.

The most appropriate method of assessment of the energy performance of the house, in the New Zealand context, is provided by the HERS rating. In the case of Little Greenie the house received a 9 star rating - the highest rating currently given to a dwelling anywhere in the country. More detail regarding the HERS rating is provided in section 7.

Space and Water heating

The primary water heating is provided through a solar thermal system installed on the roof. This consists of solar evacuated tubes (2 x 30 tubes) supplying heat energy to a German designed 500 litre 'Latento' hot water cylinder. This cylinder stores the heat energy like a thermal battery – providing a very reliable and robust system.

The Latento cylinder utilises a series of closed loop system heat exchangers, which take the heat from the solar panels and the wood boiler (when required) to charge up the cylinder. When hot water is required fresh water flows through a separate heat exchanger. This has the added benefit of reduced storage losses as well as minimised risk of legionella developing. A further closed loop system provides heat via the cylinder for the underfloor heating - then piped through the top 50 mm of concrete in the floor when needed. Efficiency within the cylinder itself is further increased through the use of a phase change material (a water/wax mixture). As described in a recent BUILD article "it's a sophisticated, trustworthy system that delivers on demand"[3]

[3] Build 114, October/November 2009

Figure 3: Wood Boiler

Figure 5: Low Energy LED lighting

The house is also equipped with an external wood boiler to supply heat for hot water and underfloor heating in the winter. This uses approximately 10kgs of wood to heat the 500 litre tank, up to optimal temperatures, and provides heat to the underfloor. However, the well performing passive solar design of Little Greenie means that the house only required this a handful of times last winter.

Figure 4: Solar Photovoltaic array

Electricity Generation

The house runs on a dual 24 volt and 240 volt system fed by a 12 panel solar array with battery back up and storage. This sophisticated set up essentially performs as an 'off grid' photovoltaic installation. This system is impressive, and functions well but the success of Little Greenie, from the perspective of this report, is not dependent on an off grid supply of electricity. It is an expensive 'nice to have' feature, that would probably be out of reach financially for most potential customers considering the Little Greenie concept. Therefore, this report does not dwell on this aspect of the house.

Energy Demand

The house has been designed to minimise electricity demand throughout – with provision of 24 volt low energy lighting (21 LED lights), a super efficient fridge, few other appliances and gas cooking facilities.

4.1 Thermal Performance

Temperature has been monitored on-site utilising an Omni log data logger, and nine separate thermocouples, reporting individual temperature data. The thermocouples are placed strategically throughout the house and over the site outside, as indicated in Table 1 below. Data was captured and stored at ten-minute intervals.

Location of the thermocouples was designed into the construction of Little Greenie to achieve a rounded modelling set up. However, this was based more on common sense than a standardised monitoring protocol. The positioning of the thermocouples seems reasonable. However, it is a recommendation of this report that if a second Little Greenie house is commissioned it would be useful to involve a building scientist in the design of a suitable monitoring regimen.

Table 1: Temperature probe locations and descriptions

Code	Main Name	Location Description
INS FL:PNT M FLOO:PNT	Main Floor Temp	Located down a purpose built pipe in the main concrete floor. This thermocouple malfunctioned providing incorrect readings at 242.8^{o}C
CMPST:PNT C TOIL:PNT	Compost Toilet	Located in the chamber of the compost toilet – this temperature reading provides an indication of conditions suited to composting action and assists with maintenance of the toilet
UNGR P:PNT UG/UF	Underground	Located under the foundations of the house close to the back of the garage
OUT UN:PNT O UNDE:PNT	Outside Underground	Located at the front of the house and buried underground to a depth of approximately 300 mm.
OUT AI:PNT O AIR:PNT	Outside Air Point	Located in the purpose built 'weather station' plastic bucket
ADBE W:PNT O WALL:PNT	Adobe Wall	Located in the South room of the toilet adobe wall
INS RM:PNT ROOM T:PNT	Inside Room Temperature	Located above the bed in the main room – potentially affected by the proximity to the adobe wall (hence may not be a true reflection of the air temperature)
UND FL:PNT BASE:PNT	Concrete Base Point	Located in the middle of the rib raft floor down a plug in the concrete
ROOF T:PNT ITEMP:PNT	Internal Roof Temperature Point	Located up in the roof above the insulation and next to the data logger unit – this area was subject to some very high temperatures

Consistency of Data

Monitoring of temperature began on 2 February 2009 and continued through to the 27 May 2009 when the data logger developed a fault and had to be replaced. Unfortunately data from the 28 May through to the installation of the new logger on 9 September is corrupted and unreliable. This means that performance data, from the crucial winter months of June to August, is inadequate for the purposes of a full analysis. The winter months are precisely the time when the thermal performance of the building is expected to face its greatest challenges. However, analysis from the shoulder seasons in autumn and spring indicates that the house performs exceptionally well – and it is not unreasonable to assume that this performance continues throughout the winter months.

For example, as can be seen in the representative graph in Figure 6, the upper blue line represents the indoor temperature of Little Greenie. This temperature never slips below 19^0C, despite the outdoor temperatures plummeting below 9^0C.

Figure 6: Indoor and Outdoor Temperatures for a one-week period in May 2009

Little Greenie also exhibits a good ability to moderate temperatures, thanks to its passive solar design and thermal mass. As indicated in Figure 7, where the outdoor temperature (lower green line) appears to fluctuate significantly between lows of 7^0C and highs of above 25^0C, the indoor temperature of Little Greenie stays within a comfortable band between 20^0C and 26^0C.

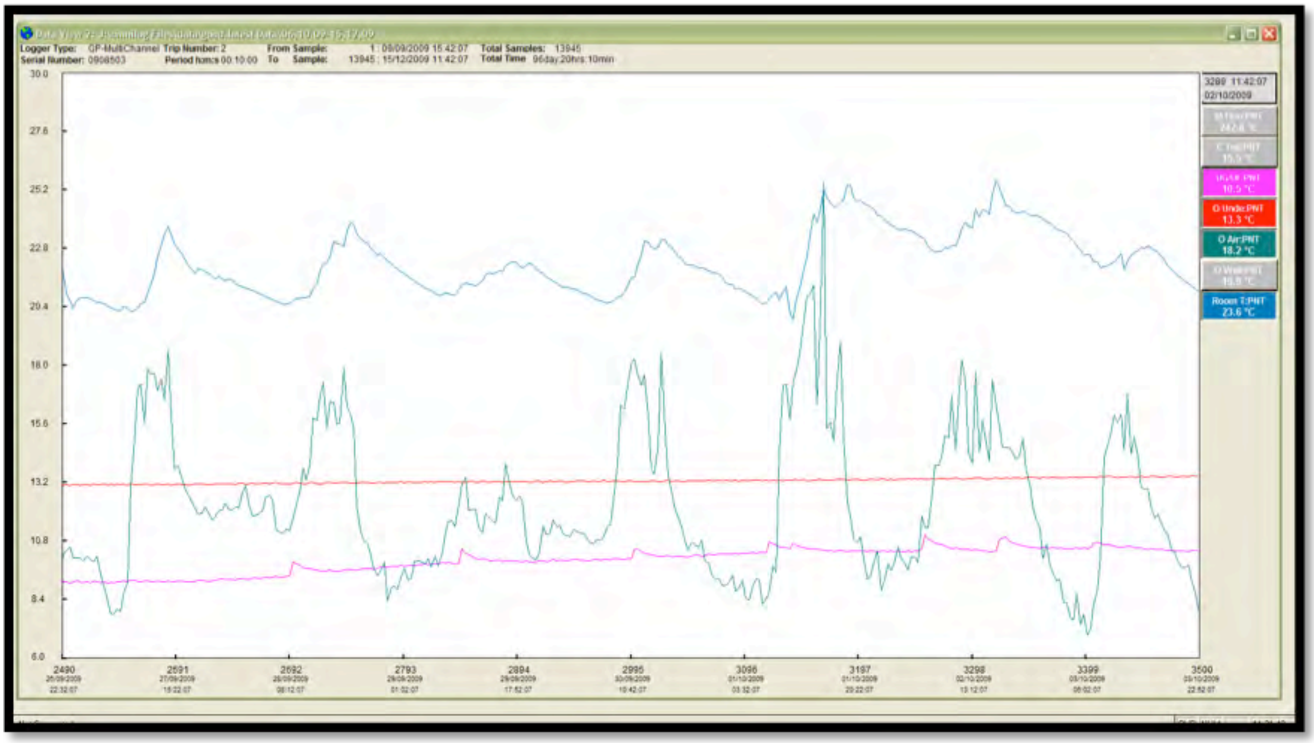


Figure 7: Indoor, Outdoor and In-ground Temperatures for a 1-week period in September 2009

The data across a longer time period indicates good overall performance in relation to healthy indoor temperatures. A single exception is picked up on the chart provided in Figure 8. This shows the indoor temperature dropping to slightly below 18^{0}C around October 10th. This is explained through further analysis of the Little Greenie accommodation diary. It was found that the house was empty and the front door had accidentally been left open for a couple of days following cleaning. In actual fact this shows how well the design of Little Greenie keeps heat in. Even with the front door ajar for this period of time, the temperature was maintained at a level that most New Zealand houses struggle to reach with active heating.

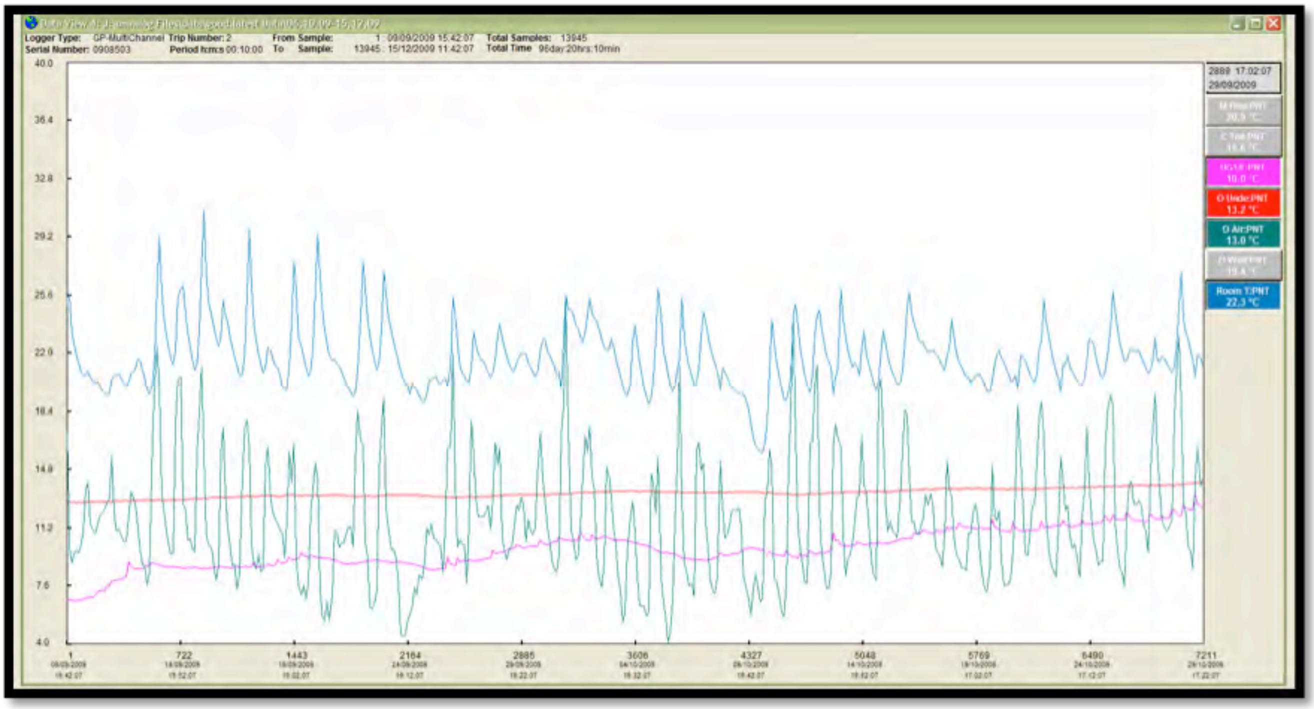


Figure 8: Indoor, Outdoor and In-ground Temperatures for September and October 2009

Despite the promising results above, a full year's worth of data and commitment to an well structured monitoring programme would ensure that robust data exists to make the case for promoting the design of Little Greenie. One of the biggest data gaps, at this stage, is a clear differentiation between the two space heating contributions - active heating versus the passive space heating - provided as a result of the building design (particularly the thermal mass, insulation and passive solar gains). In winter the wood burner was used to drive the underfloor heating only minimally, indicating that only very limited heating was required to top the house up to comfortable temperatures through active means. Fortunately, from June 2010, a pulse meter has been added to the set up to provide data on the actual number of times that the underfloor heating is used. This should allow a more robust analysis of the success of the passive thermal aspects of the design in the coming months.

5 Indoor Environmental Quality

5.1 Indoor Temperatures

Analysis of the indoor temperature readings from the data logger, outlined in the previous section, indicates a very satisfactory performance in regard to internal comfort (and health) conditions. Only on a very few occasions in the data-set does the indoor temperature slip below 18^{0}C.

The following charts provided in Figure 9 and Figure 10, are adapted from a study by a student from Victoria University[4]. These indicate that, for some of the winter months and the shoulder heating season, temperatures in Little Greenie remained inside the World Health Organisation's (WHO) optimum comfort range of between 18 and 24°C.

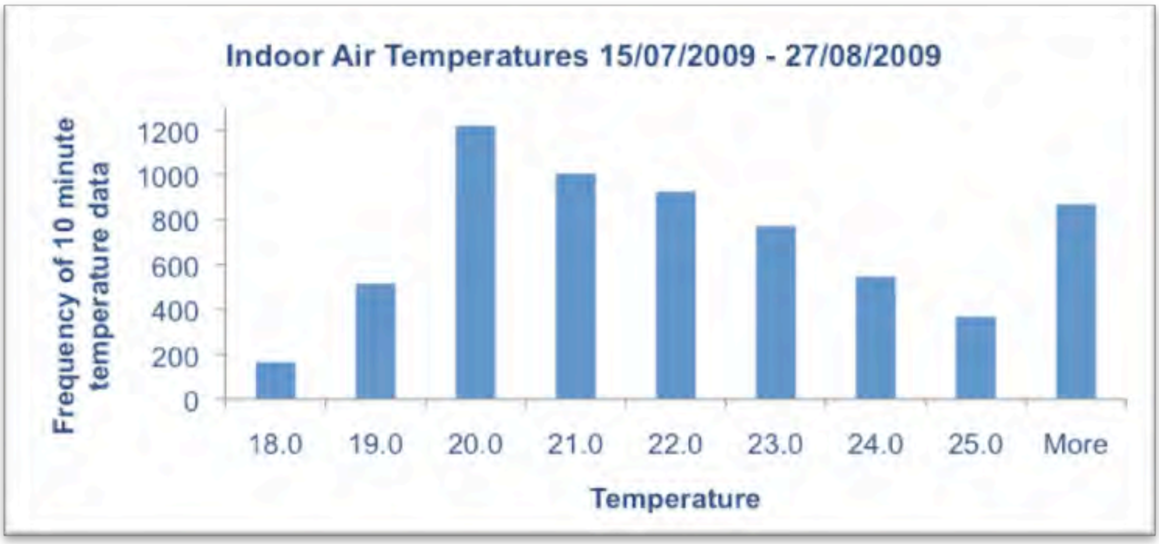


Figure 9: Chart showing indoor air temperature ranges in June/July 2009

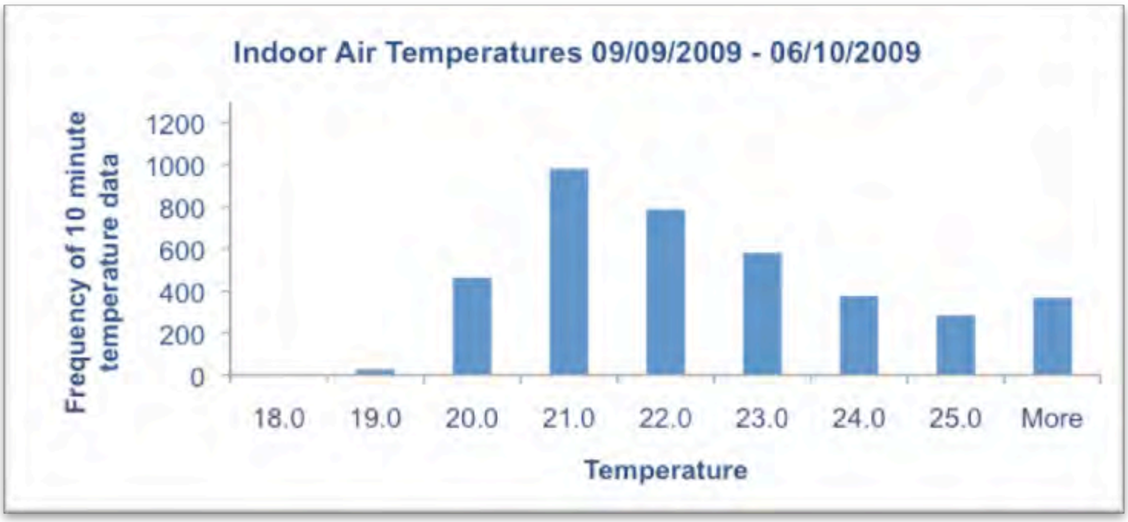


Figure 10: Chart showing indoor air temperature ranges in September/October 2009

[4] Jake Osborne, Data Analysis With The Microsoft Excel Data Analysis Tools Package – Little Greenie, BBSc 403 Assignment 3, September 2009

Note to charts above: The data in the ranges 15/07/2009 – 27/08/2009 (shown in Figure 9) came from the dataset that was corrupted following the initial malfunction of the data-logging equipment. So whilst the air temperature ranges should be robust enough for this analysis, full comparative analysis utilising all thermocouple data points in the house is not possible. Therefore, Figure 9 should be treated with some caution. However, Figure 10 is based on more reliable data and provides further evidence that the house performs very well in relation to comfortable indoor temperatures.

5.2 Humidity

No data has been captured relating to humidity levels within Little Greenie.
It is recommended that humidity and temperature be logged together using at least two independent monitoring devices (Hobo data loggers may be suitable – see http://www.onsetcomp.com/ for more details). The ventilation strategy of the house draws fresh air in through vents in the windows and out via stack ventilation drawn through the composting toilet. This appears to be a good strategy for removing potential pollutants and moisture in the house as well as effectively heating the compost to operational levels. The location of the shower, with the opening into the toilet area, assists with dispersal of moisture in the bathroom area. However, humidity sensing would allow closer scrutiny of this strategy to ensure that it is working effectively. The house had no obvious signs of mould nor did it have any of the mildewy smell typically associated with houses that exhibit poor indoor environmental quality.

6 Water

Little Greenie utilises water from a plentiful nearby stream, therefore, water saving was not a particular focus of the overall design. However, in keeping with the ecological selling points of the house, Little Greenie is equipped with a number of water saving features.

The most significant water saving device in the house is the composting toilet, which, given a standard occupancy of two people in the house could save as much as 40 litres of water per day[5]. In addition to this, the shower is equipped with a low flow Methven Satin Jet showerhead (less than 9 litres/minute), which would provide further water savings as compared to a conventional showerhead.

Currently no overall water consumption data is being collected and the nature of the supply means that this is probably not a priority in respect to monitoring of the house. However, given the importance of water in the wider New Zealand context, rainwater collection and use could easily be incorporated into the basic design of Little Greenie. If the concepts of Little Greenie are taken further, it would be worthwhile noting that this should form part of any new ‘mass market’ design.

[5] The BRANZ WEEP study found that as an approximation the toilet is flushed about five times per person per day throughout the year, using an average volume of 11.3 m^3 per person annually (6.2 L/flush)

7 Costs and Benefits

The following section provides a headline analysis of the main costs and benefits of designing and building Little Greenie. Obviously, Little Greenie is a bespoke house design with the following 'untypical parameters' -

- Built primarily as an accommodation unit
- Relatively small internal conditioned space area (52.1 m^2)
- Built in open plan 'studio' style with no separate bedrooms
- Oriented to the main view – but also oriented well for passive solar gains (which in not always optimised in NZ homes)

These features mean that providing comparisons with other '*typical'* homes presents a challenge. Therefore, for the purposes of this report, Little Greenie's basic design has been modelled against a similar layout of house built to the current New Zealand Building Code. This is used in the following analysis to illustrate some of the costs and benefits.

7.1 Comparative Building Costs

Data relating to the costs of materials used in construction was collated from the main set of accounts held by Lawrence and Antje McIntyre. This information was scrutinised to remove expenses that are not traditionally included in quotes for houses, as set out by the majority of volume builders (such as consenting fees, site earthworks etc).

One of the main difficulties in accurately assessing the final costs of the house relates to the input of sweat equity by the McIntyre family, and the various friends, who assisted with construction. To overcome this problem Lawrence McIntyre worked with a professional builder/roofer, Grant Collings, and several other tradespeople, such as plumbers and electricians, to provide a robust estimate of the labour costs of construction. This was based on a thorough evaluation of the construction methodology in order to fully capture the care and attention to detail involved in building the house (for instance outlining the labour and material costs for the additional insulation and careful installation to achieve the high level of air tightness in the dwelling).

The figures outlined in Table 2 below provide a headline breakdown of the basic build costs for three house types based on the Little Greenie model. These are summarised as follows:

1) The first '**Quality Basic Code Level**' is a house of the same proportions and basic dimensions as Little Greenie but built only to current building code standards and not incorporating any of the 'above code' specific passive design features evident in Little Greenie. An assumption is made that the house is 'well built' by a self employed builder to a good standard and following quality procedures (i.e. not a cheap volume build house)
2) The second house, called '**Little Greenie Passive Design'** provides costs for a basic design of Little Greenie incorporating the passive solar elements such as higher

levels of insulation in the walls, under the concrete slab and in the ceiling, as well as the addition of the adobe thermal mass.

3) The third house type '**Little Greenie Plus Options**' outlines Little Greenie as built with the additional options of the efficient hot water system, solar hot water array and wood boiler heating set up (but not including the off grid photovoltaic installation).

The costs of each house are provided in Table 2 below, but in summary:
The total area of each house type, including garage space, is set at 104 m^2 (with an internal conditioned space of 52.1 m^2)

1) **Quality Basic Code Level** price = \$183,655 total costs or \$1,766/m^2
2) **Little Greenie Passive Design** price = \$222,180 or \$2,136/m^2
3) **Little Greenie Plus Options** price (not including PV array) = \$249,629 or \$2,400/m^2

This breakdown provides the ability to assess the passive solar and thermal envelope advantages of the house in isolation to the options that may, or may not, be required if the Little Greenie design concepts were taken up in new buildings throughout New Zealand. Importantly, the application of Little Greenie design concepts in warmer climates throughout New Zealand may obviate the need for the underfloor heating and the high performance Latento system, with wood boiler. *HERS Accurate* analysis, provided in Table 5, indicates that in at least half of the country's climate zones the Little Greenie passive solar design would provide suitable temperatures year round with an input of less than 300 kWh per annum – or around \$70 worth of heating at today's energy prices[6]. The analysis suggests that even in Golden Bay the money invested in the underfloor heating system, whilst providing high levels of comfort for guests, may not be required.

Little Greenie also utilises a variety of top quality, and hence expensive, equipment not found in ordinary houses. These include the photovoltaic array, super efficient low power consumption fridge, Latento hot water system and custom built kitchen joinery. In a comparison with traditionally built or volume built houses it is suggested that these features skew the costs of the building inappropriately. Therefore, these have either been removed from the analysis of costs or are priced separately as options that could be installed based on individual requirements. However, the basics of the little greenie design, including the additional insulation, high performance windows, LED lighting, etc, are integral to the performance of the building and these features are included in the costs provided below.

As indicated in Table 2, the additional costs of building Little Greenie come to \$38,524 which, based on a gross floor area of 104 m^2, indicates a guide price of \$2,136 m^2. This additional cost is attributed to the extra insulation and labour to fit it (\$10,777), the high performance windows (\$27,221, which is \$12,786 more than standard aluminium double glazing), the adobe wall construction (\$9,606) and the concrete slab detail incorporating additional perimeter and sub floor insulation (\$6.677).

[6] Calculated using an average 24.3c/kWh average taken from Ministry of Economic Development Energy Data File series 'Quarterly Residential Electricity Prices to 15 May 2010' and assuming heating is provided through standard electric heating with 100% efficiency.

Table 2: Build Cost Components

	Quality Basic Build to Code Level			Little Greenie Passive House			Little Greenie plus options		
	Materials	Labour	Total	Materials	Labour	Total	Materials	Labour	Total
Basic Build Components									
Labour Costs		$38,691	$38,691		$38,691	$38,691		$38,691	$38,691
Materials Costs	$86,982		$86,982	$86,982		$86,982	$86,982		$86,982
Plumbing Costs	$12,000	$8,000	$20,000	$12,000	$8,000	$20,000	$12,000	$17,000	$29,000
Electrical Costs			$10,500			$9,178			$9,178
15 % Contingency on Materials	$13,047		$13,047	$13,047		$13,047	$13,047		$13,047
Main Little Greenie Features									
Windows	$13,985	$450	$14,435	$25,871	$1,350	$27,221	$25,871	$1,350	$27,221
Concrete Slab Detail				$4,247	$2,430	$6,677	$4,247	$2,430	$6,677
Extra ceiling and wall insulation includes fitting and battens				$8,002	$2,775	$10,777	$8,002	$2,775	$10,777
Adobe Walls				$3,550	$6,056	$9,606	$3,550	$6,056	$9,606
Little Greenie Plus Options									
Latento Hot Water								$6,980	$6,980
Solar Hot Water System							$8,565		$8,565
Underfloor Heating							$2,905		$2,905
TOTAL COSTS	$126,015	$47,141	**$183,655**	$153,700	$59,302	**$222,180**	$165,169	$75,282	**$249,629**
Costs per m^2 (104 m^2 incl. garage)	**$1,766**	**per m^2**		**$2,136**	**per m^2**		**$2,400**	**per m^2**	
Price difference (compared to Code Level House)			0			$38,524			$65,974

These prices can be compared to standard construction costs for one off speculative houses sourced from the Department of Building and Housing (DBH) and provided below in Table 3. Given the relative difference between the large house costs, and the small house costs provided in Table 3, one would expect the small size of Little Greenie (at 104 m^2) to be reflected in slightly higher per m^2 price than those provided by DBH for their 'small house' (145 m^2). Therefore, the proposed $1,766/$m^2$ for the Quality Basic Code Level price seems reasonable (if not relatively inexpensive). For example, the differential between the large house and small house costs in the Golden Bay area work out at approximately $5.10 per m^2 in terms of size difference. Therefore, a house with a smaller 104 m^2 footprint might, on the same basis, would be expected to cost around $210/$m^2$ more to build than the example DBH 145 m^2 'small house'. This would indicate a cost of $1975/$m^2$ for a 104 m^2 build, which is in effect closer to the costs of the Little Greenie Passive Design House than a 'basic built to code' house of that size. This suggests that the cost of Little Greenie Passive Design house may not be that much more expensive than a standard build speculative house.

Given the unique design and high quality construction of Little Greenie it may be fairer to compare the house to architect designed houses or those specialising in 'eco-buildings' – which are often charged at a premium price in comparison with 'standard' house packages[7].

[7] It should also be noted that the costs used in this report do not include design or engineering fees for the Little Greenie design.

Table 3: Estimated Costs by building type from DBH, (January 2010)

Region	Building type	
	Small house* 145 m² $	Large house* 202 m² $
1	1,698	1,396
2	1,596	1,320
3	1,661	1,370
4	1,626	1,347
5	1,682	1,383
6	1,660	1,369

Source: DBH (http://www.dbh.govt.nz/bofficials-estimated-building-costs)

It should be noted that at this headline level of analysis, only an indicative comparison is possible. Further detail of the assumptions sitting behind the DBH figures would need to be aligned to those provided in the Little Greenie analysis. For instance, transport costs of materials have been removed from the costs provided in Little Greenie, as these will vary based on location. Further to this, the unit construction costs provided by DBH are based on a regional analysis and built up from current commercial prices of materials and labour, along with current allowances for contractors' overheads and margins. There may be potential to explore the basis for the DBH costs in more detail and align the cost comparison of Little Greenie to this more closely in further work.

7.2 Comparing Performance

A comparison of the performance the different build options can be extrapolated based on the HERS Accurate modelling undertaken by Christian Hoerning, Senior Advisor with EECA.

This modelling uses the base accurate file from Little Greenie's HERS assessment, and helps to illustrate the performance benefits of building to Little Greenie's higher thermal envelope standards.

In the following analysis the Little Greenie Passive House was compared to the quality basic build to code levels exploring the following key differences:

Table 4: Key parameters between NZ Building Code House and Little Greenie

Parameters	Quality NZBC House	Little Greenie Passive House
Floor Area	52.1 m^2	52.1 m^2
	Construction R Values	
Ceiling	R 2.9 – R 3.3 + attic space (climate zone dependent)	R 6.9 + attic space
External Walls	R 1.9 – R 2.0 (climate zone dependent)	R 3.4
Floor	R 0.5 (+ground)	R 3.8 (+ground)
Slab design	Concrete slab on ground with carpet + underlay, no insulation	Concrete slab + 50 mm Polystyrene + RibRaft
Windows	Aluminium, IGU clear/clear	Wood, IGU clear/low-e, Argon
Window u-value	3.89	1.93
Solar heat gain coefficient (SHGC)	0.69	0.6
Air Tightness	Post-1960, simple design, <120 m^2, airtight window joinery default	Assume 1 ACH @ 50 Pa (Blower Door test)

The table on the following page indicates Little Greenie's performance across a range of New Zealand's climates. The Nelson-Marlborough area where Little Greenie is located is indicated in light blue.

Table 5: HERS modelling for Little Greenie and NZBC House

AccuRate NZ v1.3.1 modelling results			Little Greenie as built			NZBC Minimum (H1/AS1 Replacement table 1)		
Zone code	Climate Zone	% Population	HERS Building Rating (Stars)	Heating load MJ/(sqm*yr)	Total Heating+Cooling load MJ/(sqm*yr)	HERS Building Rating (Stars)	Heating load MJ/(sqm*yr)	Total Heating+Cooling load MJ/(sqm*yr)
NL	Northland	3.6%	9.5	1.5	5.5	4.5	72.7	97
AK	Auckland	34.3%	9.5	2.4	7.5	4.5	100.5	119.3
HN	Hamilton & Waikato	7.5%	9.5	14.3	22	4	175.7	214.3
BP	Bay of Plenty	4.8%	9	5.2	10.9	4	122.5	154.5
RR	Rotorua	1.6%	9	20.4	22.6	4	266	279.7
TP	Taupo, King Country	1.4%	8.5	35.6	42	4	308.1	323.1
NP	New Plymouth & Taranaki	3.5%	9.5	8.5	13	4.5	171.4	181.9
EC	East Coast	4.6%	9	10.8	19.6	4	171.3	208
WN	Wellington	8.1%	9	29.7	29.9	4	282.3	282.8
MW	Manawatu	4.4%	9	16.9	17.8	4.5	220.9	223.5
WI	Wairarapa	2.3%	9	30.5	39.5	4	279	309.9
NM	Nelson-Marlborough	3.3%	9	19.6	21.3	4.5	210.7	214
WC	West Coast	0.8%	8.5	39.6	43.2	4	318.2	325.2
CC	Christchurch & Canterbury	12.7%	8.5	52.7	56.3	4	363.5	380.2
QL	Queenstown-Lakes	0.6%	8.5	78.4	80.4	4	483.8	485.5
OC	Central Otago & McKenzie Country	0.7%	8	86.9	90.4	3.5	504.7	516.3
DN	Dunedin & Coastal Otago	3.5%	8.5	58.8	59.5	4	413	413.8
IN	Invercargill, Southland	2.2%	8.5	73.8	74.4	3.5	487.8	489.6
NZ average house (population-weighted)		100.0%						

Note to Table[8]:

HERS uses defined thermostat settings for the development of the modelled data. For the analysis provided here the following standard HERS heating/cooling schedule has been used:

- *Heating Regime: Conditioned area (52.1 m^2) to achieve year round minimum temperatures of 20°C between hours of 0700 – 2300 (daytime and early evening); and minimum of 16°C between the hours of 2300 – 0700 (overnight)*
- *Cooling regime: House achieves a maximum temperature in the conditioned area (52.1 m^2) of 25°C at all times (24 hours).*

In addition, it should be noted that for the modelling undertaken for the New Zealand Building Code *(NZBC) minimum house scenarios, all thermal mass was removed, resulting in a modelled scenario of a standard build without adobe walls and carpet covering the concrete slab.*

Table 5 above indicates the benefits in terms of HERS star rating between Little Greenie design and NZ Building Code minimum. It also shows the potential for the design of Little Greenie to gain higher star ratings in warmer climates, whilst maintaining high ratings in colder ones. Comparing costs of heating and cooling loads in the table above allows a headline analysis of the performance of Little Greenie in reduced running costs, compared to the upfront investment in the higher specified thermal envelope provided in Table 2. This is explored in more detail in the following sections of this report.

[8] Figures provided by Christian Hoerning, Senior Technical Advisor Buildings, Energy Efficiency and Conservation Authority (EECA)

7.3 Operational Costs/Savings

7.3.1 Operational Space Heating Energy and Paybacks

The house mainly relies on free passive solar gains to maintain comfortable indoor temperatures, which it does this very efficiently (see temperature tables in section 5.1). Top up heating is supplied via hydronic underfloor heating, using hot water from the Latento system, which is boosted via the solar and/or biomass boiler. Accurate data, relating to the frequency and costs of additional heating energy being applied to Little Greenie, was not available. However, Lawrence McIntyre reported that the underfloor heating was used only minimally – the system being activated for only a few days per year.

This corresponds well to the HERS analysis, which indicates a total heating load for the house of 19.6 $MJ/m^2/year$. Extrapolating this figure by the 52.1 m^2 of conditioned space and converted to kWh/year, results in a figure of 284 kWh of heating required per year with an approximate value of $69 at today's energy prices[9]. This compares to the NZ Building Code house, which requires approximately 3040 kWh/year to heat with a cost of $739. Thus, Little Greenie provides savings of about $670 per annum[10].

Set against the additional expenditure of $38,524, required to get the thermal envelope to perform to a 9 star HERS rating, this provides a crude payback of 57.5 years. Further economic analysis has been undertaken to set these figures against an increasing energy price of 3% (adapted from Ian Page, 2009). This indicates a payback period based on heating costs alone of about 34 years. Further analysis could be undertaken to provide indicative savings and payback in colder regions in New Zealand. For instance, in the coldest region, Central Otago, the payback reduces to only 19 years.

7.3.2 Appliance and Lighting use

A robust analysis of operational electricity costs is problematic due to the unique set up of Little Greenie. Electricity is provided through the photovoltaic array, which has battery storage and back up. The overall energy supply/demand has only recently been individually metered and a lack of historical data prevents in depth analysis. However, as has been discussed in the energy section, the additional electricity required by the house is minimal and the PV array provides most of this easily. A month prior to the author's visit a separate meter had been installed on the local grid-power connection. This provided roughly one month of energy demand data and indicated that the house used approximately 117 kWh/month (for November). Extrapolated to yearly use (ignoring seasonal use for lack of data) this indicates that the house uses approximately 1,400 kWh of electricity per year, or about $340 worth of energy at today's prices[11]. Compared to the New Zealand average of

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[9] Calculated using an average 24.3c/kWh average taken from Ministry of Economic Development Energy Data File series 'Quarterly Residential Electricity Prices to 15 May 2010' and assuming heating is provided through standard electric heating with 100% efficiency.

[10] For this analysis only heating energy has been considered rather than the combined heating and cooling energy

[11] Calculated using an average 24.3c/kWh average as above

7,800 kWh electricity use per year[12] with a potential annual cost of $1,895, this represents significant savings. However, Little Greenie is a small accommodation unit without the full range of ordinary household appliances and subject to occupancy fluctuations. In addition, space and water heating are largely taken care of through passive solar design, solar hot water heating and the wood boiler – and those benefits are considered elsewhere.

For the purposes of a basic comparison of appliance and lighting costs, electricity use per occupant can provide some insights into overall electricity use in the house. Household Energy End-Use Project (HEEP) (Issacs et al, 2007) indicated that household electricity use per person on average is 2,690 kWh/yr. If we remove the amount of electricity that might be used for hot water (34%) and space heating (12%) then that would leave an annual 1,452 kWh per occupant of electricity use, for appliances, lighting, refrigeration and cooking. Based on a standard occupancy of two people in Little Greenie then it would be reasonable to assume that, in an average New Zealand house, they could be using closer to 2,904 kWh/yr for these end uses, indicating potential savings of over $365 per annum for the little greenie setup. However, the other important point to note is that Little Greenie does not have a 'typical' array of appliances that a standard domestic dwelling would have e.g. large screen television, clothes dryer, washing machine, etc. Undoubtedly, this is one of the main reasons for the small energy demand on the house – making comparisons with 'typical' dwellings problematic.

It should also be noted that, for the purposes of this report, and in examining the potential for the Little Greenie design to be taken up elsewhere, the expensive PV array has been removed from the cost/benefit analysis. It is likely that in most of the country connection to the grid would be the norm and despite the dropping price of photovoltaic panels it is unlikely that many people would currently invest in the technology at this scale.

The lack of end-use monitoring data makes deeper analysis of operational energy difficult. It is a recommendation of this report that electrical end use monitoring for the major circuits be considered and set up alongside the more detailed temperature and humidity monitoring programme. This could cover lighting, pumps (for the hot water and underfloor heating set up), and main appliances.

[12] Isaacs et al, 2006

7.4 Payback, Savings and Value

A comparative analysis of *Little Greenie Passive House,* with a standard house built to the current NZBC, is dependent on the scenario chosen to illustrate the various features of the house. Taken in isolation, individual systems (such as the LED system or the high levels of insulation) can suggest lengthy payback periods. However, considered from a whole house perspective these systems work together to provide a high performance environment and after some time, do yield a return on investment. Significantly, once the payback period is reached, the ongoing savings provide a reasonable rate of return compared to a standard house. Headline analysis of the comparison between *Little Greenie Passive House* and a standard NZBC house provides the following simplified illustrative scenario:

- Little Greenie's passive solar design approach costs $38,524 more than a standard house built to code, but performs well enough to make savings of 2,756 kWh per year compared to the NZBC house ($670 per annum at the Ministry of Economic Development (MED) price of 24.3 cents /kWh).
- Assuming that the NZBC solution to the requirement for heating, is to install a heat pump with costs of $3,000 in the standard house and needs replacing on average every ten years (guarantees of 5 years are common for many models)
- Assuming that the heat pump selected has a coefficient of performance (COP) of three – reducing the level of savings from $670 to $223 per annum.
- Add to this scenario the expected savings on total household energy use of $365 per annum from low energy lighting and appliances.
- Assume a 3% increase per year in the price of electricity in real terms (this is somewhat conservative in relation to the actual residential electricity price increases over the last decade which have been much higher)

The breakeven point under this scenario occurs in year 30 – but at year 40 the cumulative return on investment is $18,950 and by year 50 the house has provided a return on initial investment of $43,298 compared to the standard NZBC house[13].

The terms 'payback' and 'cost benefit' indicate that a pure economic analysis provides a picture of the benefits of the house. However, what should not be forgotten is that the house provides a significant level of comfort – which cannot be accurately priced through pure economic models. Data from users of the house, provided in section 9, indicate that users value the warmth and comfort of the house highly. Arguably, those who have experienced it would be prepared to pay extra for this level of quality. Exactly how much extra is the million dollar question but the added value of a higher performing home and user satisfaction should not be underestimated.

Homeowners often make decisions to install additional bathrooms, toilets or fancy kitchens. None of these systems, which provide relatively little additional practical functionality to a home, are expected to match the rigorous cost benefit exercises that thermal envelope

[13] It should be noted that no net present value or discounted cash flow analysis is provided in this simple example and that this will effect the rates of return dependent on the discount rate

upgrades have to. Thus, the benefits of Little Greenie should not be constrained to an economic cost benefit ‘proof’ of concept but should more widely expand on benefits to health, comfort and user experience, look and feel, touch and warmth.

Recent studies from overseas indicate that a well performing, highly rated home can help to add value to housing that has been upgraded to meet higher standards. For instance, a study in Australia found that there is a statistically significant relationship between house price and the energy efficiency rating of a home[14]. In addition, some factors underlying the energy efficiency rating add value to a house for reasons other than the energy efficiency itself (and possibly relating to comfort and notions of performance).

A recent Seattle based study in 2008 found that environmentally certified homes sold for 5.9% more and stayed on the market for 24% less than comparable homes which were not environmentally certified[15]. With the high 9 star HERS rating, and the ability to score well in respect of Homestar™ – New Zealand’s Residential Rating tool, there is a potential for Little Greenie’s higher performance to command a premium in the market. For instance, if a 5.9% premium could be charged for the Little Greenie Passive House design this could add in the region of $13,000 ‘profit’ to the base price of the construction, raising the value of the house.

Provided this premium added a realisable capital value to the house, this would have the effect of markedly reducing the payback time for the high performance features – reducing the breakeven point from 30 years down to approximately 20 years. However, attaining an enhanced capital value as a result of a good environmental (or energy) rating has yet to be researched and proven in the New Zealand context. Therefore, somewhat conservatively, this potential to increase return on investment and improve the cost benefit scenario is not carried through into any of the further analysis set out in this report.

[14] Energy Efficiency Rating and House Price in ACT: Modelling the relationship of energy efficiency attributes to house price: the case of detached houses sold in the Australian Capital Territory in 2005 and 2006.
[15] GreenWorks Realty Analyzes Green Homes Compared to the Rest of the Market
refer www.greenworksrealty.com

8 Materials and Maintenance Benefits

Life cycle analysis of the systems and materials used in construction of Little Greenie is outside the scope of this report. However, the house utilises some innovative design techniques to reduce the need for ongoing maintenance common to most new housing. These are outlined briefly below:

Use of steel cladding – the exterior cladding system has a number of advantages from a maintenance and product lifecycle perspective. There is no need to paint the surface as with timber claddings. It only requires a simple wash down once per year with light detergents. The screw fastening system means that individual panels can be removed and sent for recycling if damaged, or at the end of their life, or if a new colour scheme is desired.

Functioning Passive Solar Design – this reduces the need for technical solutions for providing heat and represents a maintenance free, low cost and environmentally benign way to heat the home. This should not be underestimated as the NZBC minimum house described above would in most instances have a heat pump installed – which may need to be replaced every 10 years (indicating an average cost of between \$15,000 - \$20,000 during a 75 year lifespan).

Bargeboard flashings – For a minimal extra cost the Colorsteel flashing covers the whole bargeboard – meaning that no additional painting is required for the life of the building. This represents a significant time and paint saving if one considers the job needing to be done every 5-7 years.

Stainless Steel Perimeter flashings – This long lasting innovation provides highly finished detailing and neatly resolves the issue of how the perimeter concrete slab insulation meets the window and wall cladding. The nature of the stainless steel, and the construction of the concrete slab, means that the house 'floats' above the ground on a highly insulated pad. There are few, if any, materials in contact with the ground that will be susceptible to deterioration.

Wide sloping gutters and downpipes – these provide for maintenance free gutters, as any leaves big enough to enter the gutter are small enough for the downpipe. The guttering also protects the rough sawn timber fascia from sunlight and the elements. This further reduces the maintenance required in this area of the house.

Wool Insulation – this was relatively easy and pleasant to install, meaning that extra handling required for a 'tight' thermal fit was no problem. The breathability of wool and its capacity to absorb and release moisture may assist with improved Indoor Environmental Quality (IEQ) in the house as well as providing good lifetime performance.

These 'low maintenance' features provide a range of labour, environmental and cost-saving benefits. Several have the potential for commercial development - although patenting or licensing these 'systems' may prove challenging as in most cases they simply use commonly available technologies that are applied in a practical way.

In addition to the obvious benefit of having a low maintenance house, which allows you to get on with other aspects of life without having time tied up in repairs and ongoing touch-up to paint work etc, there are cost savings too. By just isolating one aspect of the Little Greenie design, the cladding, and comparing the Little Greenie to a typical build clad in fibre cement weatherboards, cost savings become evident.

The outside steel 'shell' of the house is designed as the protective covering for the cosy thermal envelope. It is totally recyclable as well as being easy to remove and put back. According to common repairs and maintenance schedules a standard timber, or fibre cement weatherboard house, would require external painting every 5-10 years depending on conditions. The following assumptions illustrate cost saving potentials:

- On average timber and fibre cement weatherboards require painting every seven years[16]
- Initial painting of the weatherboards (within three months of construction), for a house of these dimensions, would cost $5,925 - including preparation of trims, seals, and accessories.
- Ongoing painting costs of $4,000 would be incurred for every seven year maintenance cycle

[16] Personal Communications with Housing New Zealand staff indicate that the majority of their houses are repainted every 7 or 8 years. In addition, fibre cement manufacturers claim that painting is required every 5-10 years. Costs and timing of painting were derived from a tradesperson known to Lawrence MacIntyre who also indicated that the preferred painting schedule for fibre cement boards would be 7 years – especially given the high sunshine and salt spray potential of Little Greenie's surroundings

This adds up to approximately $34,000 over the 50-year potential lifespan of the cladding[17].

If these figures are added to the previous analysis of Little Greenie's cost/benefit potential, the break even point for the house reduces to 21 years and over the 50 year timeframe a return on investment of $77,223 can be expected, as compared to a standard NZBC house clad in fibre-cement weather boards.

In addition to this there are a range of other potential benefits that deserve further investigation:

- the environmental benefits of not needing to paint every seven years
- the full recyclability of the steel cladding and ease of replacement
- the psychological benefits of a reduced maintenance house, knowing that a once a year wash is all that is required
- The time saved in not undertaking DIY painting or calling for quotes and managing tradespeople.

These benefits may provide further basis for an enhanced capital value of the Little Greenie concept. How much more would people be willing to pay for a house that requires little ongoing maintenance?

It is a recommendation of this report that further in depth analysis of the ongoing maintenance savings would assist in building up a more robust picture of the advantages of building '*Little Greenie style*'. There is also potential to contact a University or research organisation to undertake a life-cycle assessment of the house – which may yield further insights into the benefits of the practical low maintenance approach from environmental and cost saving perspectives.

[17] For instance, according to BRANZ appraisal 446, Linea® Weatherboard installations are expected to have a serviceable life of at least 50 years provided the paint system is well maintained.

9 User Experience

The author spent two days and a night in Little Greenie and from this limited stay all indications are that the house provides an exceptional living environment. The house is not only warm and comfortable but the evenness of the temperature throughout the dwelling space provides a unique level of relaxed comfort. This is remarked upon in the recent build article *"Coming in from the cold was more than just physical. It felt different. There was no overwhelming wave of warmth. Rather it was gently pervading… Here we were in a space where every corner was 20^{0}C or more. The comfort was beguiling"*[18]

Qualitative feedback from guests who stay at the house suggests that Little Greenie performs very well. Comments in the visitor's book include the following:

- *"Great concept, great design, great performance equals great architecture"*
- *"What a great house, loved the concept and appreciated all the thought (and work) that has gone into it. We will be taking home some new ideas"*
- *"…A wonderful inspiration to build a sustainable house in Oz… we'll be asking your advice…"*
- *"Fascinating house… works brilliantly"*
- *"A very comfortable house to stay in with no hot or cold spots. All new houses should be built to this standard"*

Whether this feedback counts as post occupancy evaluation is somewhat debateable, however, it is clear that the house is providing comfortable temperatures and living conditions and is also acting as a inspirational source of ideas for those embarking on building their own homes.

[18] Des Molloy, Build 114, October/November 2009

10 Lessons Learned and Future Potential

Obviously a design and build project such as Little Greenie yields a number of lessons learned, as well as developing an understanding of what should be considered if building similarly constructed dwellings in the future. This section of the report briefly documents these from discussions with Lawrence McIntyre. Many of these aspects have potential for exploration in future phases of the Little Greenie project.

Lessons Learned

- **Plumbing systems -** some of the elements of the design such as the Latento cylinder and the solar hot water system meant that tradespeople were working with systems that were new to them. This inevitably meant that installation took longer and potentially cost more than 'standard' approaches. The availability and use of 'heating engineers' common to European countries would have been useful in implementing solutions for Little Greenie.
- **Control Systems** – the control systems that were available and installed in the house were complicated and not as user friendly as they could have been. Future design should incorporate more straightforward control systems (if available – and availability is often a problem)
- **Adobe wall heat recovery system –** the high levels of insulation and thermal mass, as well as airtight construction, meant that the extra time and effort spent on the adobe wall heat recovery system at the rear of the house was probably unnecessary.
- **Resistance to craftsmanship around insulation** – significant time and attention was spent getting the insulation installed correctly and this challenged the tradespeople on site, who continually questioned the necessity for the extra work. Creating the high performance thermal envelope appeared to slow the job at a critical time when builders are used to seeing fast progress (between finishing the framing and closing up the house).
- **Basic shape and aesthetics** of the house means that the benefits of the simple design have reduced the level of interest and publicity in the house (which for the highest energy efficient rated house in New Zealand one would expect to be significant). Aspects such as the colour, traditional shape, single roofline and the basic appearance are all designed to start a conversation about performance <u>over</u> style. Notably a leading magazine in New Zealand decided not to feature Little Greenie as it looked too 'shed like'.
- **Craftsmanship** – tradespeople enjoyed working on a house that valued high levels of craftsmanship. Many were excited to work on a job that inspired them to perform at their best rather than producing the quickest and cheapest result.

Further considerations

In addition to the lessons learned, there are a number of features that Lawrence McIntyre has stated he would look into if building more houses based on the Little Greenie concept including:

- More work on airflow systems and ventilation in the house (depending on size and overall design strategy).
- Potentially reducing the adobe wall component and seeking provision of thermal mass through other design elements such as increases in the mass of the floor.
- Refinement of some design elements to further cut costs of construction and reduce time spent on site.
- Consideration of appropriate heating set-up depending on the climate and site exposure (with the potential to avoid the installation of fixed heating systems altogether in milder climate areas).
- Optimising the amount of thermal mass depending on climate zone and site aspects.
- Exploring a range of different sizes and layouts, including provision of a three/four bedroom Little Greenie design.

11 Concluding Discussion

This report has provided a synopsis of Little Greenie's design as well as detailing the available data to support promotion of the Little Greenie concept. Little Greenie was not set up as a scientific experiment to 'prove' a particular construction methodology – and, hence, the available data is not as complete as is required for a full and detailed comparative cost benefit analysis to be undertaken.

What we have got:

- ☑ Detailed building techniques, descriptions and pictures – a documented construction process
- ☑ HERS rating of 9 stars with information relating to HERS ratings throughout the country
- ☑ Price and comparative costing of Little Greenie set against a similar size and design built to the current New Zealand Building Code and using standard building components
- ☑ Internal and external temperature data for a range of dates (although not a full year of consistent data)
- ☑ Evidence from the monitoring that does exist showing that the thermal envelope and passive solar design are working well
- ☑ Anecdotal reviews of the comfort and performance of the dwelling from users of the accommodation

Where the gaps are:

- ☒ Accurate temperature *and* humidity data for a full year with comparative climate and occupant data
- ☒ Energy supply and demand data (and an overall energy balance for the house)
- ☒ Hot water use data and monitored performance of the installed solar thermal set up and the relationship with the use of the wood boiler
- ☒ Life Cycle analysis/data for the major systems and materials used in the house

One of the key benefits of the Little Greenie design is that it has been built using an approach that will be very familiar to the majority of New Zealand builders. The lightweight timber frame construction utilises systems and materials that current craft based builders in this country are already used to. This should be an advantage in promoting the adoption of similar construction processes, as it is more about fine-tuning an approach than introducing new techniques or complex technological systems.

The high performance of Little Greenie is achieved through application of simple good passive thermal design and an ethos of attention to detail and pride of workmanship. This ultimately results in job satisfaction for the builder involved, as well as potentially high level of satisfaction for the house occupants.

In order for passive solar design to work effectively, well-installed insulation and air tightness are key features. These are common areas of failing in modern New Zealand construction. The design does not rely on complicated technologies or fancy expensive systems to provide a better performing home and this reduces costs and headaches over the lifetime of the building.

Part of the concept of Little Greenie's design was to challenge our way of thinking about the level of performance in houses that we are used to in New Zealand. Lawrence McIntyre built the house to be a practical, achievable and cost effective construction that delivers high levels of satisfaction and performance. The high level cost benefit analysis, provided in this report, gives an indication of some of the benefits that accrue from building and designing according to Little Greenie principles. Having said that, there are many other values enshrined in higher performing houses that go beyond traditional cost benefit analysis to encompass comfort, health, social and environmental aspects – and in many instances these can provide very effective drivers for change. In short, "*Not everything that counts can be counted, and not everything that can be counted counts.*"[19]

The real promise of Little Greenie may lie in utilising the passion and dedication of Lawrence McIntyre as a 'training tool' to up-skill builders and designers in how to build under a different paradigm. Whether this is undertaken through the development of a specific Little Greenie training programme, or through expansion of the Little Greenie concept to design and build more examples around the country, the house itself still has plenty of scope for inspiring action and promoting the benefits of good passive solar design and fine workmanship. The direction of that action could form part of the scope of phase two of The Hikurangi Foundation's Little Greenie project.

[19] A quote attributed to a sign hanging in Albert Einstein's office at Princeton University

12 Recommendations

This report has highlighted a number of specific recommendations for more detailed analysis and data collection based on an initial screening of the available data. These are outlined below in addition to some specific ideas for further exploration.

Key Recommendations

1) Independent temperature and humidity monitoring (using Hobo device or similar) should be installed in at least two strategic locations within the dwelling.
2) Electrical end use monitoring of the major circuits should be set up alongside a more detailed temperature and humidity monitoring programme.
3) Consider utilising a building scientist to help design an effective monitoring protocol for the current house. Could be facilitated through a university (see below)
4) If, in developing the Little Greenie concept, a second house is commissioned, involve a building scientist to implement a suitable monitoring regime at the design stage.
5) Consider using a thermal imaging camera to get pictures of how well constructed the house is, as well as to highlight the absence of thermal bridging compared to a standard build of today.
6) Consider a blower door test to provide data regarding the air tightness of the house to give an indication of benefits of 'tightening up' the house during the build process.
7) Consider a more in depth analysis of the ongoing maintenance savings, through calculation of whole life costs of specific system designs such as the bargeboard flashing detail and steel cladding.
8) Contact a university to explore funding for a PhD student to utilise Little Greenie as a thesis project. Data gathering and analysis should be conducted in close association with Lawrence McIntyre. EECA may wish to consider provision of a scholarship to facilitate this.
9) Consider utilising the passive solar design features and 'quality craftsmanship' approach incorporated into a new design for a 3-bedroom model show home. This could be facilitated through an organisation such as Unitec in Auckland – and the construction used as a method of teaching for building and design students.
10) Conduct further analysis into the market potential of the Little Greenie concept, including willingness to pay, motivational drivers for key target segments of the market, as well as acceptance, understanding and unique selling points of the key features of the Little Greenie approach.
11) Consider professional development and other avenues of industry training utilising the benefits and potential of Little Greenie design and build techniques, concept and features in order to stimulate change in industry practice.

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