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Zero Energy Buildings
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1 Introduction

This research project has been undertaken as part of the Energy Efficient Control of Indoor Environment (EECI) Research Program. This is an extensive program involving research groups from Aalto University, VTT, Helsinki University of Applied Sciences, and others.

The aim of the research is to achieve a good and healthy indoor environment in Zero Energy Buildings.

This project has looked at different aspects of Zero Energy Buildings focusing on three regions, with a view to finding solutions for Finland from the regions. The regions are:

- USA
- Canada
- Australia & New Zealand

2 Definitions of Zero Energy Buildings

Essentially a Zero Energy Building is one that generates as much power as it consumes over a given period, usually one year. When it comes to energy generation the main sources today are solar, wind and geothermal. When it comes to energy consumption there is an emphasis on smart building techniques, materials and technologies to minimize heat losses and improve energy efficiency. In Finland good insulation is a key way to keep energy consumption down.

2.1 Current Terminology

There are currently many terms used in the general area of zero energy buildings. Below is a list of some of the more common terms.

- Low Energy Buildings
- Ultra Low Energy Buildings
- Zero Energy Buildings
- Net Zero Energy Buildings
- Net Zero Site Energy
- Net Zero Off-Site Energy
- Net Zero Source Energy
Net Zero Energy Costs
Net Zero Energy Emissions
Zero Carbon Building
Near Zero Energy Building
Zero Emissions House
Passive House
Plus Energy
Hybrid Buildings

With so many terms some simplicity and consistency is needed, within Finland, Europe and internationally.

2.2 Example Definitions

With so many different terms and so many ways to look at zero energy buildings there are inevitably many different definitions available.

A net zero-energy building (ZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies...we lack a common definition, or even a common understanding, of what it means.

U.S. Department of Energy (DOE) Building Technologies Program

buildings that over a year are neutral, meaning that they deliver as much energy to the supply grids as they use from the grids.

http://www.iea.org/g8/2008/Building_Codes.pdf

energy use of 0 kWh/(m² a) primary energy

Kurnitski, J. (2011). How to define nearly net zero energy buildings nZEB
2.3 Confusing for the Consumer

A more simplified definition is needed for the consumer as there is too much confusion now with all the different classifications, categories and lack of common definitions. The consumer could be forgiven for ordering an nZEB, a ZEB or a PH without really understanding what it means. This could lead to disappointment when for instance the ZEB does not equate to zero energy costs, i.e. a monthly energy bill of zero euros. For the concept of zero energy buildings to be accepted and embraced they need to appeal to a wide an audience as possible, not just the urban professional.

Zero Energy can be a misleading term itself, as at face value it could seem to the average consumer that a zero energy building is one that uses zero energy. Using a number (i.e. zero) also implies that there is a scale with zero being the target – “if I cannot attain zero energy, what is sufficient - ‘one energy’, ‘2.5 energy’, ‘twenty energy?’”

2.4 Building Energy Efficiency Rating System

One option is to rethink and redefine the whole terminology using a measurable scale with a ‘high’ target rather than the current ‘low’ (i.e. zero) target. The current terms could be kept and built into a measurable scale, or phased out over time.

- Zero Energy ≈ 100% energy efficient
- Nearly zero ≈ 90% or higher
- Plus energy ≈ over 100%

With a system similar to what is used for electronic goods this 100 scale will give an immediate and clear idea of the performance of any dwelling, and will encourage home owners to take steps to ensure their homes reach and maintain a high score on the scale.

An easy to understand and consistent scale will also simplify the design, construction, installation, manufacture and sales of buildings and building systems.

One of the main benefits of this proposed energy efficiency system is the simplicity. For a calculated value the formula for the scale is very simple:
When it comes to passive solar space heating for instance, exact measurements of the energy produced are hard to make. Therefore to get the measured values for a building already in use, the formula is slightly different:

\[
\text{B. Energy efficiency rating} = \frac{\text{Energy generated} + (\text{Normal usage} - \text{Energy consumed})}{\text{Energy consumed}}
\]

The normal usage is pre-defined according to building type, location and other relevant factors. So in practice if a building of a certain type and size, in a certain city is expected to use 20 kWh for space heating, and the building uses 6 kWh, then that building is effectively generating 14 kWh. The normal value can be customised in many ways – for instance space heating may be included, whereas lighting and appliances will not be, or according to building usage, type, size, even according to season.

These formulas will give a percentage rating with a score of one hundred per cent meaning the building is generating as much energy as it consumes, i.e. the building is a Zero Energy Building. All units (kWh, kWh/m², etc.) are removed from the final rating making it easier to understand for the people using and living in the buildings. Also the system is flexible in the units used to calculate the rating, as long as the units are consistent the same result will be reached using kWh/year, kWh/m² or kWh/year/m² for example.

Products, technologies, appliances and building systems can be assessed and rated according to their energy usage and generation capabilities so when buildings are planned these can be figured into the equation to calculate the buildings potential energy efficiency rating. In the design stages if a building has been calculated to use 10,000 kWh/year, then you can shop around and find products and systems to achieve the desired rating. Finding better or worse renewable energy sources (solar, wind, geothermal, etc.) would have a direct bearing on the final energy efficiency rating of the building.
With a system such as this in place, the next decade in Finland could be managed easier with realistic and measureable goals set out. For example we could say that by 2014 the target is to have new buildings built to 70% efficiency rising 5% per year to hit 100% by 2020. Likewise, existing buildings could also be assessed and action taken to improve their energy efficiency.

This scale will also help with assessing and evaluating buildings upon completion and during their lifespan. If a building is initially rated at 90% then measurements can be made 5, 10 and 50 years after the building has been completed to see how close to the goal the building’s performance is.

Using this system some buildings, including the example buildings featured in this report have been rated.

Riverdale NetZero Project in Canada has used calculated values (formula A, above).

<table>
<thead>
<tr>
<th><strong>Riverdale NetZero Project, Canada</strong>¹</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy produced*</td>
<td>63.00</td>
</tr>
<tr>
<td>Energy consumed*</td>
<td>61.50</td>
</tr>
<tr>
<td><em>(kWh/m²)</em></td>
<td></td>
</tr>
<tr>
<td><strong>Building Energy Efficiency Rating:</strong></td>
<td>102%</td>
</tr>
</tbody>
</table>

The Little Greenie project has been rated using measured values (formula B, above) and using ‘normal values’ from the same source below.

<table>
<thead>
<tr>
<th><strong>Little Greenie, New Zealand</strong>²</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy produced*</td>
<td>0</td>
</tr>
<tr>
<td>Normal usage (excl lighting/appliances)*</td>
<td>3955</td>
</tr>
<tr>
<td>Energy consumed (excl lighting/appliances)*</td>
<td>284</td>
</tr>
<tr>
<td>Energy consumed (total)*</td>
<td>3188</td>
</tr>
<tr>
<td><em>(kWh/year)</em></td>
<td></td>
</tr>
<tr>
<td><strong>Building Energy Efficiency Rating:</strong></td>
<td>115%</td>
</tr>
</tbody>
</table>
Kuopas Apartment Building in Kuopio, Finland has been rated using calculated values (formula A, above).

<table>
<thead>
<tr>
<th>Kuopas Apartment Building²</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy produced*</td>
<td>85 600</td>
</tr>
<tr>
<td>Energy consumed*</td>
<td>107 100</td>
</tr>
<tr>
<td>* (kWh/year)</td>
<td></td>
</tr>
<tr>
<td>Building Energy Efficiency Rating:</td>
<td>80%</td>
</tr>
</tbody>
</table>

From these three examples, and using existing terminology we could conclude that the Kuopas Apartment Building could be classified as a Near Zero Energy building, Riverdale in Canada is a Zero Energy Building while Little Greenie is Plus Energy.

3 Example Dwellings

Example dwellings were chosen from the three regions of our study to research in depth. The results follow.
3.1 Canada – Riverdale

Riverdale house (LovinsAmory 2007)

Improving energy efficient of house isn’t very new thing to Canada, it wasn’t named as ‘zero energy house’ or ‘passive house’ Canadian government had concern about energy efficient buildings since 2006 when they noticed that greenhouse gas (GHG) emissions. Searching for renewable energy gradually connected with housing efficiency that the energy consumption of building is generally very large. As a result associated institutes and courses about efficient housing have been established and the market welcomed the experimental new technologies. Designing competitions and advertising about efficiency housing have encouraged the field so there are already quite many energy efficient buildings in Canada but they didn’t use much of assessment to evaluate. EnerGuide is now in development by Canada government but the origin of the assessment was labelling electricity appliances but now they are developing for buildings, vehicles and even HVAC equipment. (CanadaNatural 2010)

Riverdale house general goal was a house can be supply its own heat and electricity and not only for the energy consumption but also water and waste management, construction site and material sustainability. The project is winner of Canada Mortgage and
Housing Corporation’s national net zero energy healthy home design/build competition. The competition was concentrated on health, energy, resources, environmental and affordability. It has branded as Equilibrium Sustainable Housing Initiative. (Gordon HowellP.Eng. 2008)

Location of the project, the climates are very similar to Finland that 6 times more energy has been used for heating the house in the site area compare to other region of Canada. Mostly the project focused on home heating. (Riverdale NetZero Project 2008)

3.1.1 General Summary (LovinsAmory 2007)

<table>
<thead>
<tr>
<th>Building Location</th>
<th>Built</th>
<th>Planned energy consumption</th>
<th>Structures and windows</th>
<th>Electricity production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada Edmonton, Alberta</td>
<td>Urban, new development Dwellings</td>
<td>2008</td>
<td>Heating 43.09 kWh/m² Applying 16.39 kWh/m²</td>
<td>28 module 5.6kW grid-dependent solar photovoltaic(PV) system predicted to generate 200kWh of electricity per year</td>
</tr>
<tr>
<td>Site area 889m²</td>
<td>Ventilation 2.02 kWh/m²</td>
<td>wood frame structure</td>
<td>mechanical ventilation 48.2L/s heat recovery ventilator</td>
<td></td>
</tr>
<tr>
<td>Heated floor area 234m²</td>
<td>total 61.51 kWh/m²</td>
<td>walls: 400mm R-56 (U-0.101) ceiling: 690mm R-100 (U-0.057)</td>
<td>differently designed for each side of the windows</td>
<td></td>
</tr>
</tbody>
</table>

The project house is designed for duplex residential houses which can accommodate two house hold. Mostly the structures are wood but also concrete and masonry have been used for certain necessaries. The House is still on the local grid so if the house doesn’t function the grid energy supports immediately. (AraerO.Ercan 2008)

PV system doesn’t have storage for keeping electrical energy and since the house is on the grid, the surplus energy will be imported and exported freely and remain of energy will be used by neighbour houses. The house has 28 modules, 5.6kW/h of PV system which is designed to generate 6200kW/h annually. (HousingCMHC 2008)
PV Solar System (LovinsAmory 2007)

R-Value is the same type of insulation’s resistance to heat flow with different unit. It uses Britain thermal unit and feet instead of watt and metre. If the value is higher it indicates the effective of the insulation better apposite of U-value system. (The R-Value of Insulation 2011)

3.1.2 Heating Systems (LovinsAmory 2007)

<table>
<thead>
<tr>
<th>Energy sources</th>
<th>Energy consumption</th>
<th>Mechanical systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Heating</td>
<td>14.43 kWh/m²a</td>
<td>Forced air using a solar thermal heated fan-coil with electric backup</td>
</tr>
<tr>
<td>Water Heating</td>
<td>7.74 kWh/m²a</td>
<td>Solar thermal with electricity backup</td>
</tr>
<tr>
<td>Ventilation</td>
<td>2.02 kWh/m²a</td>
<td>Heat recovery ventilator (mechanical ventilation rate; 48.23L/s)</td>
</tr>
<tr>
<td>Lighting/Appliances</td>
<td>16.54 kWh/m²a total; 40.73 kWh/m²a</td>
<td></td>
</tr>
</tbody>
</table>
Heating System (LovinsAmory 2007)

Passive Solar heating; EnerGuide rating: 93 (Electricity efficiency)
Active Solar heating; EnerGuide ration: 96

Most of heating system energy sources will be from direct solar gains and there is another heat system for backup which is ran by electricity. Thermal mass stores the energy from solar heat collect bellow the PV panels.

Thermal mass has been installed below the fire space and it gathers energy from each system through heat pumps. The thermal mass is made of masonry. According to Passive Solar Design Handbook (PSDH), the thermal mass is better to be in direct gain space or at least in bordering, no insulation and having three times more space than glazed area which fits masonry well. The thermal mass generates 1484kWh, when the heat of the water in the tank, at 80°C and the mentioned amount of energy can be stored in thermal water storage tank (Thermal mass heat storage). (AraerO.Ercan 2008)
The fraction of solar energy for domestic water heating is 93.8% and for thermal space heating is 78.1%. The storage tank is also connected with waste water heat recovery system and heat recovery ventilator. Some of heating systems connected with air ventilation system for passive air flow. (Gordon HowellP.Eng. 2008) Grey water heat recovery system also used for inlet water warming for thermal storage. (HousingCMHC 2008)

Energuide is one of energy consumption rating system such as LEED, BREEAM. Most of the values in this project have been evaluated with Energuide and the rating for whole project is 100. (What is the EnerBuide Rating System? 2010)

3.1.3 Technical Characteristics
(Mark BrostromP.Eng., 2008)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>External walls</td>
<td>walls: R-56, 400mm (U-0.101)</td>
</tr>
<tr>
<td></td>
<td>50% fly ash concrete, Expanded polystyrene insulation(R8), Isocyanurate Insulation (AmerongenPeter 2012) (R13; U-0.437), cellulibre insulation(R33; U-0.172)</td>
</tr>
<tr>
<td>Roof</td>
<td>ceiling: R-100(U-0.057, 690mm for attic insulation</td>
</tr>
<tr>
<td>Ground floor</td>
<td>walls: R-54(U-0.105) 600mm</td>
</tr>
<tr>
<td></td>
<td>floors: R-24((U-0.237) 450mm</td>
</tr>
<tr>
<td>Window</td>
<td>3-glazed (S,E,W): South R-7.3(U-0.778), East and West R-8.3(U-0.684)</td>
</tr>
<tr>
<td></td>
<td>4-glazed (N): North R-10(U-0.568)</td>
</tr>
<tr>
<td></td>
<td>(low-e) argon gas</td>
</tr>
<tr>
<td>Air tightness</td>
<td>Air leakage rate: 0.5 AC/hour at 50Pa</td>
</tr>
<tr>
<td>Ventilation system</td>
<td>with heat recovery</td>
</tr>
<tr>
<td></td>
<td>80% efficient</td>
</tr>
</tbody>
</table>

Predicted Heat loss at winter (-32°C) 6.6kW
Building envelope efficiency: 86 (Energuide)

The windows are separately designed by its facing direction and it gathers heat and it goes to the Thermal mass heat storage through pump. 10.8% of the floor area in the house is located in south glazing which also generates lightings during the daytime. (HousingCMHC 2008)

3.1.4 Energy Performance
(Mark BrostromP.Eng., 2008)
In design condition, passive solar gain will cover 40% of house heating, internal sources 28%, active solar 21% and solar photovoltaic 11%. (Mark BrostromP.Eng., 2008)

3.1.5 Monitoring

The project team planned to research further and invest but it seems it hasn’t been going on anymore. I tried to find more information about the real performance and found the web page about the project. On the very first web-site on the bottom there is analysing features but it does not work any longer. (Riverdale NetZero Project 2008)

3.1.6 Technologies and some more which has been suggested (HousingCMHC 2008)

Passive air flow paths
When the heat system is working its most efficiency, heated air will rise up and it causes natural ventilation. The paths are located inside of wall and they are forcing to the indoor air flow circulating. (HousingCMHC 2008)

Thermal storage mass
The idea of the thermal mass is using big or small mass to store heat to keep warmth longer or using less energy for heating. This system with solar energy heating the thermal mass, it will make good energy performance. (AraerO.Ercan 2008)

**Solar PV system**

By heating the surface of in between semi-conductor it causes electron difference. Small anti-conductors combine as cell and a module consists of cells. Amount of cells and modules are depending on the purpose of it. Until now producing PV modules is not matching sustainability and also causes financial problems, because of its high price the project team needed to minimise the PV system. (KnierGil 2002) (Mark BrostromP.Eng., 2008)

There were some more technologies that considered to be installed in the house. Ground source heat pump (GSHP) was one of it and at that time, the actual performance wasn’t clear enough to risk increment of budget. In the report, project team considered to use GSHP combined with solar thermal system but it didn't happen with financial shortcomings. Water source heat pump was also discussed to be installed to enhance temperature of solar thermal heat storage water but they didn't see the benefit out of it. The project team try to use heat recovery system for grey water then they had doubt about how efficient they will be. (Mark BrostromP.Eng., 2008) (HousingCMHC 2008)
3.1.7 Conclusion

Housing system of Canada encourages the consumers to make their house more energy efficiency. Canada Mortgage and Housing Corporation have been established in 2008 and it has organised events such as EQuilibrium Sustainable Housing Competitions about efficient energy building designs and it could be sold and bought easily through the system. It is not only building new houses but also renting, renovating houses. (About CMHC 2012) The atmosphere in Canada is very freely. Market opens experimental projects and the government keeps up with regulations and consumers are getting more and more aware of the benefit of zero energy building in long term. (Housing 2010)

The house I was researching is one of the winning designs of EQuilibrium competitions and it has already built since 2008. As a result, there aren’t much new technologies which haven’t been introduced to Finland. It would have been very good reference to follow if the actual performance of building was available. Main purpose of the design was covering the necessary energy needed for basic function of the building such as heating, cooling and ventilating systems but the project approached about affordability so that the project includes some of appliances which perform high energy efficiency to
reduce usage of electricity at the house and reasonable technologies which can operate with less maintenance attention.

Riverdale net zero energy project is residential building which usually demands heating energy the most. Because of the states of the building the project was focused on heating system. The project categorise as active and passive solar thermal. Mainly the active solar gain will be thermal storage from solar heat collector and passive solar gain will be more about air tightness that preventing heat losses through high efficiency of walls and windows.

Technologies which have been used in Riverdale Project aren’t very new thing but still it shows simulation of the operating such technology in similar climates that tells it could be more developed in many ways to approach reasonable level to apply in practice.
U.S.A. is adopting more the zero net site building followed by LEED. In those buildings the amount of energy provided by on-site renewable energy sources is equal to the amount of energy used by the building.

Since, there are a lot of types of climate in U.S.A. the building are being built using different kinds of technologies like photovoltaic panels, day lightning to reduce the uses of electricity during day time or solar access with large roof area, wind turbines, grey water collection, solar skin, thermal buoyancy, natural ventilation and many more. The technologies used are also depended on the location of the building within America.

In U.S.A. the zero energy building is not only taken as the amount of CO2 it emits or the zero consumption of energy but, also which can be taken in a economic way and the additional cost needed to build it can be payback after certain period of time by the performance of the building\(^3\).

It is a better way to use the energy in the form it is in for the best performance of a building. The energy efficiency should be maximized as much as possible to achieve the zero performance of the building.
Electromagnetic (Light, Electricity) | Lighting, equipment, fans, pumps, heating, cooling
---|---
Kinetic (Movement) | Fans, pumps, heating, cooling
Chemical (Natural gas, batteries, coal, wood) | Heating, direct fired absorption cooling
High Grade Heat (Steam) | Heating
Low Grade Heat (Warm Water) | Absorption cooling, Heating

3.2.1 Zero carbon emission office building, St. Louis, Missouri

Project Type: The Path to net Zero CO₂urt
Two- four story linked by two wide bars.

Largest Zero Emissions Building in North America

“A building that produces and exports at least as much emissions-free renewable energy as it imports and uses from emission-producing energy sources annually.”

St. Louis has four season climate with average low of -6°C in January and average high of 32°C in July and has approximately 150-180 cloudy days in a year. And also the cost of electricity is amongst the lowest in U.S.

<table>
<thead>
<tr>
<th>Building Area</th>
<th>15860 m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daylight Parking</td>
<td>1650 m²</td>
</tr>
<tr>
<td>Parking Capability</td>
<td>438 (with solar roof)</td>
</tr>
<tr>
<td>Photovoltaic Panels</td>
<td>4810 m²</td>
</tr>
<tr>
<td>Solar Thermal Tubes</td>
<td>1390 m²</td>
</tr>
<tr>
<td>Carbon Reduction</td>
<td>76%</td>
</tr>
<tr>
<td>Energy Efficiency</td>
<td>73%</td>
</tr>
<tr>
<td>Payback Time</td>
<td>10-12 years</td>
</tr>
<tr>
<td>Building’s Energy Use Intensity (EUI)</td>
<td>235.7 KTBus /m² per year (before the renewable energy is considered)</td>
</tr>
</tbody>
</table>
1650 m² day lit parking with two level rows structure provides 438 parking capacity with photovoltaic panels topped in the roof and walls. 91.44 m long each building are linked by 18.28 m wide landscaped courtyard.

The north and south facades of the building which has high-performance envelope optimize vision and daylight glazing with insulated opaque areas to leverage natural light. And the east and west facades of the building are solid blocking the sunlight which also helps to the average U-value of the building skin.

Exterior walls of the office bars consist of U-0.025 rain screen construction with tile facades to the east and west. Vision and daylight panels are triple-glazed, double low E with argon fill set in wood frames to provide optimized and controlled daylight into the workspace, views to the exterior and minimum U-value.

On southern facades, evacuated solar thermal tube panels provide both a unique aesthetic and a heat source for the building. The roof is sloped at 10 degrees south and incorporates solar PV and solar thermal panels over U-0.02 insulated roof (U-0.025 walls).
The building emits 76% less carbon than any other building of same capacity and can save tons of CO2 in a year³.
3.2.2 HVAC

Both mechanical as well as electrical ventilation are in use in zero energy building in U.S.A. Phase Change Material (Heating + Cooling) Units deliver conditioned 100% outside air at floor level and at low velocity without the use of refrigerants for proper ventilation and maintaining the temperature inside.
3.2.3 Energy Production

4,810 m² photovoltaic panels used in the roof and walls of the building and 1,650 m² day lit parking with solar roof and the renewable energy make the office building 73% energy efficient.

The building’s energy use intensity (EUI) is 235.7 KTBus/m² per year before renewable energy is considered. Annual energy cost savings through the building’s energy efficiency, solar thermal and photovoltaic system are $184,567 leaving an annual energy cost of $2,418 or 10.7 cents per m² at 2010 utility rates.

<table>
<thead>
<tr>
<th>Tenant premium of $60K/year (modest)</th>
<th>Fuel escalation rate of 7% higher than dis-count inflation rate</th>
<th>Blended electricity costs of $0.12/kwh</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1.2 million more one-time incentives</td>
<td>Solar and PV costs coming down over time</td>
<td>Potential cap-and-trade legislation and other initiatives to restrict carbon emissions</td>
</tr>
</tbody>
</table>

3.2.4 Adapting for Finland
In Finland since the winter is very long, dark and too cold the zero energy building should be focused on highly insulated materials so that the heat from inside the building cannot escape out and the amount of solar energy it can absorb during the sunny summer. Geothermal energy can be used for heating system whereas snow cooling system can be the most efficient for cooling during the summer. Since the building can work as plus energy building during the summer time and energy might be needed to import during the winter the building can also be called net zero cost building.

Solar panels can be very fruitful in summer time while also having wind turbine can be very advantage also for winter.
3.3 New Zealand

When looking into zero energy buildings in New Zealand and Australia a few things tend to stand out. The first is the lack of clearly defined and universally accepted definitions and criteria in the region. One project aimed at understanding low energy housing in New Zealand promotes some houses that actually use more energy than the average home, one house in particular by a factor of five!

Also noticeable is the low number of zero energy buildings that are currently in use. Another key aspect of sustainable building in New Zealand is the emphasis on health and lifestyle as well as energy efficiency, lower costs and other aspects more commonly seen in Finland. A recent study in New Zealand found that by making homes warmer, drier, more energy and water efficient the country could:

- Avoid sending 50 people a day to hospital with respiratory illnesses (saving $54 million a year)
- Cut sick days off work by 180,000 a year (lifting production by $17 million a year)
- Cut household power bills by $475 million a year by using a combination of insulation and double glazing
- Stop households wasting enough water a year to fill 9,200 Olympic swimming pools.

The average New Zealand house is "scarily cold", badly insulated, has huge expanses of single-glazed glass, and is a nightmare to heat. In terms of energy efficient homes we are not very far along. It’s pretty much where the Scandinavians were in the 1960s.

Prof Robert Vale, Victoria University

There are similarities in the situation in Australia and New Zealand when compared to Finland. The main similarities are that completed and in use zero energy buildings are not very common and there is also confusion over the definitions meaning some buildings that may be classified as energy efficient in New Zealand or Australia may not be in Finland, and vice versa.
3.3.1 Little Greenie

Golden Bay Hideaway
Takaka, New Zealand
52.1m², residential

Built in 2008/2009 the Little Greenie project was started by someone passionate about sustainable building, and was designed with four key principles in mind:

- energy efficiency
- low maintenance
- ease of construction
- value for money

Based on buildings and experiences in Germany the building was developed to challenge people, government and industry in New Zealand and to show what is possible with energy efficient buildings. The building is currently used as a holiday home, with the energy efficiency facets of the building being one of its main attractions.

One key factor in selecting this building as an example is the available data on the experience of the building. A comprehensive and independent report covered many aspects of the building, including:
- Orientation
- Glazing
- Air-tightness
- Passive ventilation
- Thermal envelope
- Thermal mass
- No fuss design
- Renewable electricity
- Relatively small footprint
- Composting toilet
- Fancy cylinder
- Extremely low maintenance
- Materials specifications

The building was built as an example and sensors and measuring devices were built in to the house to enable data to be easily extracted to measure the buildings performance.

3.3.2  Energy Efficiency

Little Greenie achieved 9 stars out of a possible 10 on the Home Energy Rating Scheme – a joint venture between the Building Research Association of New Zealand (BRANZ) and the New Zealand Green Building Council (NZGBC). A similar house built to the New Zealand building code would rate 4.5 on the same scale.\textsuperscript{12}

According to Christian Hoerning from the Energy Efficiency and Conservation Authority, the key points which helped achieving such a highly energy efficient house are:

- Compact, simple building layout
- Good solar orientation of windows
- Super insulated roof, walls and floor – more than twice as much insulation as required by the building code
- The thermally best performing double-glazed windows available in NZ have been used
• Thermal mass in the concrete floor and adobe walls collects the sun’s warmth on sunny days and release it overnight and on cloudy days
• Solar water heating for hot water and under floor heating
• Attention to detail in the design

3.3.3 Easy Construction

Little Greenie is a basic rectangular shape and uses proven building practices common in New Zealand. This means labour can be sourced locally which in turn reduces construction costs. To mass produce zero energy buildings in Finland, New Zealand or anywhere this is an important factor that many new technologies render difficult, as they may require specialist work during installation and maintenance.

Floor

The house is built with insulated foundations and uses a RibRaft flooring system. This system uses polystyrene pads, steel reinforcing, plastic spacers and concrete to produce a floor that sits on the ground, not in the ground. The floor is highly insulated with minimal thermal breaks, with no concrete coming in direct contact with the soil keeping the heat stored in the thermal mass of the structure.

Figure 1 Sample Floor Design

Advantages of the RibRaft system include:
• seismically strong
• energy-efficient concrete floors
• time, labour and cost savings (by eliminating the need to dig footings)
• cleaner construction, with far less excavated material and waste\textsuperscript{16}

**Walls**

Construction is based on a traditional New Zealand wooden frame house with triple layer of high density woollen insulation. Walls are 200mm thick with an R-value of 5.1.

Internal adobe walls made from locally sourced materials form part of the thermal mass, acting as moisture and temperature moderators.

**Roof**

The roof is insulated with two layers of high density wool insulation. The truss framing gives access to the ceiling cavity and allows easy servicing of solar, wiring and plumbing systems.
Windows
Windows are double glazed, low e and filled with argon.

Exteriors
The roof and walls are clad in Colorsteel, a long lasting, low maintenance material.

Power supply
The house is off-grid and runs on 240V solar power and battery back up.

Lighting & Appliances
Efficient LED lighting is used, along with energy efficient appliances.
3.3.4 Thermal Performance

Figure 2, below shows how the building moderates temperatures with the outdoor temperature (the lower blue line) varying between 5°C and 25°C, while the indoor temperature (the upper red line) stays between 20°C and 26°C at all times. This is achieved only using passive solar heating, and no other heating source.\textsuperscript{17}

![Figure 2: Indoor, Outdoor and In-ground Temperatures for a 1-week period in September 2009](image)

\textit{Date / Time Series from 26 September through to 4\textsuperscript{th} October 2009}
3.3.5 Other Buildings

**The Pixel Building**

205 Queensberry Street, Carlton,
Melbourne, Australia
840 m², office

Australia’s first carbon neutral building opened in 2010 and scored a perfect 100 on Australia’s Green Star rating system. The building was designed specifically to achieve high ratings not only on the Green Star system but also with LEED and BREEAM.

As well as being carbon neutral the building is water balanced, uses free night cooling, tracking and fixed photovoltaic panels, wind turbines, vacuum toilet technology, and an anaerobic digester utilising methane from waste as an energy source.¹⁸
Meridian Building

33 Customhouse Quay, Wellington, New Zealand
5246 m², office (77%) & retail (16%)
www.meridianbuilding.co.nz

Finished in September 2007 the building was the first completed to receive 5 stars from the NZGBC Green Star scheme. Features of the building include a double skinned façade, chilled beams, thermal mass, solar hot water, rain water collection, lighting and building management systems. The building has good cycling facilities and no car parking, encouraging use of public transport.

No information about the building and its performance since opening was to be found.¹⁹
Zero Energy House

Point Chevalier, Auckland, New Zealand
Approx. 130 m² residential
http://www.zeroenergyhouse.co.nz

As of May 2012 the house is still under construction so no performance data is available. The design and construction period is well documented on a website set up for that purpose. Once again citing the relatively poor housing conditions in New Zealand the project aim is to build a house that is:

healthy, comfortable and pleasant to live in with minimal impact on the environment during construction, throughout its functioning life and in its disposal (and) that suits our lifestyle and reflects our values.20

Passive ventilation, energy and water metering, photovoltaic and solar hot water system, rainwater harvesting and storage as well as provision for grey water treatment and reuse are some of the planned features for the building.

3.3.6 Examples with Regard to Finland

On the face of it Finland seems to already be more advanced in many areas of housing and sustainable building, but there are some lessons to be learnt.

With New Zealand’s focus on health and wellbeing there could be potential for more research in Finland into the effect of buildings on health.
With the requirement for good workmanship to achieve the desired results, especially with regard to air tightness, installation of potential new techniques there could be room for improved teaching and expectations of the work force.

4 Expert Interviews

We planned to carry out some interviews with various experts in the field of zero energy buildings. However, despite contacting quite a few people we had very few replies to our enquiries.

5 Conclusions and Suggestions

Assuming that photovoltaic panels are only advantageous in sunny places might not be correct. In Finland where the summer is so short, have longer sunny days which can produce enough energy. Keeping wind turbines also as a source of energy can produce energy in the night time when there is no sunlight and the energy is used less during the night. The nights are usually windy so the turbines can produce enough energy for night time.

5.1 Building Energy Efficiency Rating System

The system described in more detail earlier in the report is a way zero energy buildings can be made more understandable for the public as well as acting as a tool for expert to evaluate houses easily.

The system can be adapted for different areas and building types, with the so called normal values to be set according to local regulations and resources.

More user involvement can be implemented by including measuring devices in buildings with interactivity available through personal computers and smart phones. Applications allowing users to monitor real time energy data will see users more involved with their buildings and more interested in energy efficiency. With users being actively
involved and up to date with their buildings, they will be encouraged to set targets and
generally improve energy efficiency in their own homes and offices.
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