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Towards Zero Net Energy Schools

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TOWARDS ZERO NET ENERGY SCHOOLS
FINAL REPORT

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Even with the abundance of information available about the benefits of energy conservation and potential for renewable energy generation, few schools in New Zealand have aimed to achieve Zero Net Energy. One of the reasons for such low engagement with ZNE aspiration, is the absence of tools for key decision makers in schools to help them select from a number of energy conservation and energy generation technologies and building features, and assess the costs and benefits of their selections. In this project, we constructed a prototype of one such tool, in the face of the difficulties with complexity, relevance and availability of highly scattered data. The prototype was put in a trial with six schools in Auckland, and the feedback and insights gained have helped to develop the pathway for further development of the tool and strategy for national rollout to all interested schools in New Zealand.

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1. Introduction

Numerous technologies and building features are available these days that help with both reduction of energy use as well as power generation. This has given rise to several strategies for the building industry to significantly reduce their energy footprint. The ultimate goal is to achieve Zero Net Energy (ZNE) by aiming to generate roughly equal amount of renewable energy on the building site as the total amount of energy used by the building on an annual basis. To achieve this, the building owners must select and integrate an optimum mix of energy saving, storage and generation technologies based on the unique requirements of their building and its surroundings.

While use of such technologies in building industry is shown to provide benefits in terms of cost reduction, as well as environmental and health benefits, their adoption and use in commercial buildings in New Zealand, is not very prevalent. The main challenge is to convince the key stakeholders involved in the decision-making process for design of new buildings or retrofit of existing buildings to aim for ZNE, and implement energy reduction and energy generation technologies in their buildings.

One group that we identified as requiring special consideration and support for making such decisions are school boards. Boards of Trustees in NZ schools have governance role in the management of school property projects. They are required to be involved in developing the project brief for major property projects, appointing school representative, and being part of the project control group giving approvals at various stages of the project. However, the boards are mainly built up of parents, staff and student representatives, who are put in charge of making complex decisions associated with trade-offs of long-term environmental and financial benefits against short term financial and budgetary constraints.

Previous efforts by EECA, Ministry of Education and charities such as Enviro School have focused on developing guidelines[1] for educating boards members about energy conservation and providing funded energy audit schemes for schools to develop a better understanding of their energy use and options available for saving energy. Although, these guidelines are very beneficial, they still don't go far enough in engaging the key decision makers in the design and planning process for implementing energy efficiency in the school rebuild or retrofit projects.

In this project, we aimed to facilitate such deeper engagement in the design process by developing and testing an early stage design tool, aimed at enabling the board members and other school representatives dealing with property management at schools to get an early estimate of the costs and benefits of various energy saving and energy generating options available to them. This report outlines the methodology for developing such a tool, followed by detailed explanation of the various aspects of the tool and assumptions made for estimation of costs and benefits. Preliminary results of testing the tool at several schools in Auckland are also presented. Finally, a discussion section is provided about the pathway and challenges for roll out of such a tool to schools in NZ.

2. Methodology

2.1 Tool Design

The main objective of the tool is to estimate costs and benefits of various options available to a school for reducing energy usage or generating renewable energy. The tool will therefore need to have the following capabilities:

- Ability to input information about the specific school
- Ability to select energy saving features (new build and retrofit options)

[1] http://www.enviroschools.org.nz/energy_efficient_schools_large.pdf

- Ability to select energy generating technologies
- Ability to calculate costs and benefits (new build and retrofit)

An iterative design approach was used with Microsoft excel chosen as the first platform for development of the tool since it is readily available, highly flexible and reasonably familiar to our potential users. At various stages, potential users in several schools were given the chance to interact with the tool and their feedback was taken into account for improving the tool.

2.2 Data gathering

One of the most difficult challenges in this project was gathering the cost and benefit data for all the design features and energy saving and energy generating technologies that schools could use to achieve ZNE. An extensive literature review was conducted to gather information about energy saving and energy generating technologies, information about New Zealand schools and universities and New Zealand climate data. Additional information was gathered by consulting experts in the energy field.

Data was gathered, among other things, about the current energy consumption in education buildings, data about the different climates in New Zealand, legislation of the New Zealand Building code[2], as well as estimated savings and costs associated with implementing various energy saving features and changes to building occupant behaviour. Where local New Zealand data was not available, data from other countries was gathered and methods were devised to make appropriate approximations from them. Where such approximations were made, a conservative approach was used to ensure the tool never overestimates the energy savings or underestimates the costs. All sources and assumptions were documented and can be adjusted as more relevant and accurate data becomes available.

Rawlinsons New Zealand Construction Handbook[3] was found to be the best source for estimation of the costs. Unfortunately, they no longer publish new editions, so in order to estimate costs, the Rawlinson data was adjusted for inflation. Where data was not available in the handbook, discussions with industry experts or suppliers were used to arrive at an estimate.

3. Tool Design and Features

3.1 User workflow

The first step is to get the information about the specific school and the nature of the property project (new build or retrofit). The school specific information is divided in to two sections:

- **General Data:** Location, Type of school, Total School Area, Number of occupants, Building shape, Number of storeys, Existence of high buildings in the surrounding.
- **Advanced Data:** Wall height, Window to wall ratio, Skylight to floor ratio, Occupant growth rate, R values, Glazing, Airtightness, Shading, Heating, Cooling, Ventilation, Hot water, Lighting, Energy Monitoring.

The above information is used to estimate the average monthly energy usage in kwh.

Since the underlying philosophy behind this early stage design tool, is to encourage energy conservation as much as possible before exploring opportunities for generating energy to achieve ZNE, the next step is to select from a list of energy saving features/technologies. These include, Insulation, Glazing, Airtightness, Shading, Ventilation, Window opacity, Heating, Cooling, Hot water, Lighting and Energy monitoring. The baseline for calculation of savings in each section is the New Zealand Building Code, and several options for each design decision is provided as incremental improvements from the

[2] https://www.building.govt.nz/building-code-compliance/h-energy-efficiency/h1-energy-efficiency/

[3] Rawlinsons New Zealand Construction Handbook, 28th ed., 2013/14

Building Code. With each selection, the user can see the estimated potential energy savings and additional costs for implementation of the design feature or technology.

Once the energy saving features were selected, the user moves to energy generating options. At this stage the system calculates the amount of energy to be generated to achieve ZNE. The default energy generation technology is PV solar cells. The tool calculates whether the roof footprint is enough for the number of PV panels required. It also provides a cost estimate for installation of the PV cells. In future other renewable power generation options, such as bio-mass can also be provided.

A final summary of the current energy usage, potential costs and savings associated with the selected design features and technologies along with the costs associated with energy generating technologies are presented. Estimated payback period as well as NPV (based on 20 years) are also presented to better aid with the decision-making process.

The following section will describe each of these stages in more detail, outlining how data was gathered, estimated and used to calculate the final outcomes

3.2 System Inputs

If available, it is possible for users to incorporate actual energy data in the tool. Nevertheless, the tool should also be useful when this kind of information is unknown or schools are unwilling to conduct an energy audit to provide this kind of information due to time or cost constraints. Therefore, average energy consumption and average energy end-use of schools are estimated based on the information provided.

Energy consumption

The energy consumption of a school is the total amount of energy a school uses annually i.e. it is the sum of the energy used as gas, electricity or other fuels throughout the year. Needless to say, this depends on numerous factors, for instance the type of school, the climate of the region where the school is located and the age of the building.

Since this is a rough pre-assessment tool only the major factors are considered. These factors are the type of school, the nature of building project, the shape and size of the building, and the regional climate.

For refurbishment projects of existing buildings the database provided by Energy Efficiency and Conservation Authority of New Zealand (EECA), was used, which breaks down annual energy use by type and region[4]. This information was cross referenced with the database of the US Department of Energy (DoE) [5], which contains a lot of information about schools in the USA. This data can be split for different regions, types of school and also contains information about the area of the schools. It is important to select the data of the schools that are relevant for New Zealand. This means data of schools in regions with a similar climate as New Zealand. In order to provide a comparative regional breakdown, the insulation zones[6] (1, 2 and 3) provided in the New Zealand building code were used to differentiate between warm and cold regions in New Zealand. Corresponding US DoE data from ASHRAE[7] zone 5C was used for zones 1 and 2 and ASHRAE zone 5A was used for zone 3. Since the New Zealand data does not differentiate between the type of school, US DoE data was also used to provide a further breakdown of the energy use by school type (i.e. Primary, Secondary or Tertiary).

4 https://www.eeca.govt.nz/resources-and-tools/tools/energy-end-use-database/
5 https://buildingdata.energy.gov/cbrd/
6 https://www.building.govt.nz/building-code-compliance/h-energy-efficiency/h1-energy-efficiency/building-code-requirements-for-house-insulation/house-insulation-requirements/
7 http://www.aashe.org/files/documents/STARS/20081111_cztables.pdf

For new build projects, unfortunately EECA does not provide any New Zealand data. Again, the US DoE provides useful information for this subject. The US DoE, in conjunction with three of its national laboratories, developed reference buildings for new construction building including education buildings for primary and secondary schools. The data can be analysed for all the different climates that are present in the USA.

Appendix C provides the estimated power consumption and end use by school type, region and project type.

Other inputs

Other inputs such as Wall height, Window to wall ratio, Skylight to floor ratio and Occupant growth rates are also requested from the user. For refurbishment of existing building further information is requested such as R values (roof, walls, underfloor), Glazing, Airtightness, Shading, Heating, Cooling, Ventilation, Hot water, Lighting, level of Energy Monitoring. The tool provides a default value as an estimate for each of these inputs in case the user does not know their exact vales. The default values are estimates that have been made based on conversations with architects and construction experts, as well as utilising US data where available. Unfortunately, such data at national or regional level for school buildings were not available for New Zealand.

3.3 Energy Saving Technologies

All the parameters involving energy saving technologies are discussed in this section. There are two groups of parameters in this section. The first group are the parameters used to determine the energy saving per product. Second is the group of parameters used to determine the cost per product. There is a difference in which parameters are used and how for new build and refurbishment thus they will be discussed separately.

3.3.1 Reduce heating requirement

The total energy that goes to heating is determined with the energy end-use of the corresponding school. Then the total energy that is used to generate heat in the building is divided between five different potential places where heat is lost in a building. The roof, walls and floor, windows and airtightness. It is assumed that by designing to the Building Code the heat loss is evenly distributed over the building. This assumption is not validated however the data can be changed when more actual information is acquired. However, the everage data for existing educational buildings is available[8] and will be used for refurbished projects. The heat loss distribution for each section is listed in the table below by project type.

Heat Loss	Refurbishment	New Build
Roof	33%	25%
Wall	22%	25%
Floor	13%	25%
Window	25%	25%
Air leakage	8%	0%

The following heat loss reduction technology or features were included in the tool:

Insulation

The R value represents how well a product insulates the building envelope. There is a converse linear relation between the R value and how much heat is lost through the building envelope. The thickness of the insulation material is an important property especially for the refurbishment case as the insulation material must be fitted in the wall cavity. The thickness of the material also contributes to the R value. If a product of the same material is twice as thick the corresponding R values is twice as

[8] BRANZ, Designing Quality Learning Spaces: Heating & Insulation. Ministry of Education, 2007

high. If skylight is selected as an optional feature, the R value of the roof is adjusted to consider the R value of the skylight.

For new build the baseline R value, called minimum standard in the tool, is based on the Building Code of New Zealand. It is assumed that the energy consumption of the school is also in compliance with the Building Code and hence a fair comparison can be made about energy savings wherein the Building Code R value is regarded as baseline and represents a 0% additional energy saving.

New Build (prices calculated based on Rawlinson Handbook[9])

Zone	Zones 1&2	Minimum standard	Medium standard	Average standard	Best standard	Average thickness per R value	Average initial cost per R value per m2
Zones 1 & 2	Roof	3.2	4.8	6.4	9.6	49	$ 5.7
	Walls	2.2	3.3	4.4	6.6	39	$ 8.7
	Floor	1.6	2.4	3.2	4.8	42.9	$ 16.1
Zone 3	Roof	3.6	5.4	7.2	10.8	49	$ 5.7
	Walls	2.4	3.6	4.8	7.2	39	$ 8.7
	Floor	1.6	2.4	3.2	4.8	42.9	$ 16.1

Refurbishment (prices calculated based on Rawlinson Handbook[10])

Zone	Zones 1&2	Current Average	Medium standard	Average standard	Best standard	Average thickness per R value	Average initial cost per R value per m2
Zones 1 & 2	Roof	0.35	3.2	6.4	9.6	49	$ 5.7
	Walls	0.6	2.2	4.4	6.6	39	$ 8.7
	Floor	0.75	1.6	3.2	4.8	42.9	$ 16.1
Zone 3	Roof	0.35	3.6	7.2	10.8	49	$ 5.7
	Walls	0.6	2.4	4.8	7.2	39	$ 8.7
	Floor	0.75	1.6	3.2	4.8	42.9	$ 16.1

Glazing

Windows are typically one of the worst insulated areas in the building envelope. Installing high performance windows can result in significant energy use reduction. As for the insulation section the energy savings are based on the R value of the different products. The R values of six glazing options were included in the tool, based on BRANZ approved list[11].

Again, one of the differences between refurbishment and new build for glazing is the baseline R value. It is concluded that single glazing is most common in New Zealand education building and hence the R value for single glazing with a minimum frame is the baseline R value for refurbishment. Another difference is the installation price for glazing in case of refurbishment. Since the old windows need to be removed first the costs for glazing are higher. These removing costs are estimated $100 per sqm glass irrespective of which type of frame or glazing[12]

Window	R value	Thickness in mm	Average initial price per m2	VT	Heat enters
Clear/Low e glass(Argon) with best frame	0.53	4/12/4	$ 835	0.74	0.3
Clear/Low e glass(Air) with best frame	0.48	4/12/4	$ 791	0.41	0.55
Double glazing(Air) with best frame	0.36	4/12/4	$ 678	0.8	0.26

9 Rawlinsons New Zealand Construction Handbook, 28th ed., 2013/14
10 Rawlinsons New Zealand Construction Handbook, 28th ed., 2013/14
11 http://www.level.org.nz/passive-design/glazing-and-glazing-units/glazing-options-for-temperature-control/
12 SPON's architects and builders price book, AECOM, Tech. Rep., 2015

Double glazing(Air) with medium frame	0.31	4/12/4	$ 643	0.8	0.26
Double glazing(Air) with minimum frame	0.26	4/12/4	$ 609	0.8	0.26
Single glazing with minimum frame	0.15	4	$ 515	0.9	0.2

Airtightness

Every building has its leaks whereby air and thus heat can escape the building. It is important to ensure that a building is air tight to prevent heat loss by convection. The key metric is the amount of air flow volume in m3h. A blower test can be conducted to determine this parameter and subsequently decide whether the air leakage of the building needs to be handled. The lower the air flow from the inside of the building to the outside the less heat is lost. It is not known how to relate the airtightness of a building to energy savings though. Hence the energy savings in this section are based on experiments instead of calculations. Furthermore, it is assumed that a new build education building, which complies to the building code, already has a sufficient airtight building envelope and thus only refurbishment is discussed.

Millot et al.[13] provide various measures aimed at reducing the leakage of air in a building. A building without any products to prevent air leakage is used as baseline. This corresponds with the baseline in the tool for refurbishment; an uninsulated building. Only the features with the highest savings in the article are combined and included as an option in the tool. These features are airtight membrane, connection strips for windows and tape to seal joints for the membrane.

Airtightness Product	Average initial price per m2 or m	Lifespan (Years)
Membrane	$ 8.7	5
Connection strips	$ 7.5	5
Tape for sealing overlaps	$ 2.1	5

3.3.2 Reduce cooling requirement

All the products to reduce energy used for cooling, do so through directly blocking or reducing the transmittance of sunlight into the building.

Shading

Shading features include awnings, louvres, building overhangs and blinds. The key challenge faced in developing the options for the schools, was that there is no parameter to indicate how well shaded a building is, and how they impact energy reduction. Review of literature identified a number of studies investigating the energy savings of different products or features and compared them with a building without shading products.[14] [15] [16].

[13] M. Millot, D. Loveday, J. White, C. Wood, K. Chmutina, and K. Vadodaria, “Im- proving the airtightness in an existing uk dwelling: The challenges, the mea- sures and their effectiveness,” Building and Environment, vol. 95, no. 1, pp. 227–239, Aug. 2015.

[14] L. Bellia, F. D. Falco, and F. Minichiello, “Effects of solar shading devices on energy requirements of standalone office buildings for italian climates,” Applied Thermal Engineering, vol. 54, no. 1, pp. 190–201, Feb. 2013

[15] http://energy.gov/energysaver/energy-efficient-window-treatments

[16] M. Nielsen, S. Svendsen, and L. Jensen, “Quantifying the potential of auto- mated dynamic solar shading in office buildings through integrated simulations of energy and daylight,” Solar Energy, vol. 85, no. 1, pp. 757–768, Feb. 2011.

For the new build the baseline is considered to be no shading feature as this is optional in the building code. For refurbishment projects, the baseline needs to be specified by the user (default is set as no shading).

Shading Feature	Initial cost per m2 or pc	Lifespan (Years)	% of savings available through shading
Exterior Louvres	$ 602	20	50%
Retractable canvas awnings	$ 452	5	40%
Building overhangs/eaves	$ -	20	30%
Interior blinds	$ 73	20	20%

Visible Transmittance (VT) of Windows

Different glazing options provide varying degrees of VT, which in return impacts the heat load on the cooling system. VT values listed in the Glazing section for reducing heating were used to estimate cooling energy savings with respect to the base-line.

Other influences

There are several other building features that indirectly reduce the cooling requirements. These include insulation [17], skylights [18], roof mounted solar panels [19] and natural ventilation [20].

3.3.3 Provide heating & cooling

After selecting features and technologies to reduce the heating and cooling requirements in the building, it is time to identify opportunities for more efficient methods of providing heating and cooling.

There are 3 different ways incorporated in the tool to provide heating. A gas heater is only added as a baseline option and not as a renewable option, so users cannot select it in the tool. There are two different ways for the three heating options to heat the building, which are underfloor heating and high wall heating. Whereas high wall heating is the more common way these days. Since heating and cooling are a reverse process for heat pumps, they can be used for both processes. The gas heater, however, cannot be used for cooling. In the "provide cooling" section the gas heater is replaced by a standard air conditioner system, which has many similarities with an air source heat pump.

Heating Product	COP	Costs useful heat	Initial cost per m2	Annual cost per m2
Geo HP UF	5	5.8	$ 262.00	$ 4.30
Geo HP wall	5	5.8	$ 291.00	$ 5.00
Air HP UF	3.5	8.3	$ 167.00	$ 3.70
Air HP wall	3.5	8.3	$ 196.00	$ 4.40
Gas boiler UF	0.85	21	$ 111.00	$ 5.80
Gas boiler wall	0.85	21	$ 127.00	$ 6.80

[17] Z. Fang, N. Li, B. Li, G. Luo, and Y. Huang, "The effect of building envelope insulation on cooling energy consumption in summer," Energy and Buildings, vol. 77, no. 1, pp. 197–205, Mar. 2014.

[18] L. Ghobad, W. Place, and S. Cho, "Design optimization of square skylights in office buildings," in 13th Conference of International Buildings Performance Simulation Association, Chambery, France, 26-28 Aug. 2013, pp. 3653–3660

[19] A. Dominguez, J. Kleissl, and J. Luvall, "Effects of solar photovoltaic panels on roof heat transfer," Solar Energy, vol. 85, no. 1, pp. 2244–2255, 2011

[20] I. Oropeza-Perez and P. A. Ostergaard, "Energy saving potential of utilizing natural ventilation under warm conditions," Applied Energy, vol. 130, no. 1, pp. 20–32, 2014

Product	EER	Initial cost per m2	Annual cost per m2
Geo HP UF	5	$ 262.00	$ 4.30
Geo HP wall	5	$ 291.00	$ 5.00
Air HP UF	3	$ 167.00	$ 3.70
Air HP wall	3	$ 196.00	$ 4.40
Standard AC Wall	3	$ 50.00	-

3.3.4 Ventilation

To ensure a good indoor environment, which positively affects performances of the people inside the building, a good ventilation system is required. There are two ways to provide fresh air for a building; mechanical ventilation and natural ventilation. The total energy that goes to ventilation is based on the energy end-use for ventilation of the corresponding school.

A distinction is made between two different type of rooms; normal rooms and special rooms. Normal rooms do not necessarily need mechanical ventilation whereas special rooms such as canteens and science labs always need mechanical ventilation because natural ventilation is not simply strong enough to comply with the Building Code. [22] Since every school has toilets and also toilets require mechanical ventilation this is already included in the energy savings and prices for normal rooms natural ventilation only.

The baseline for normal rooms is a standard mechanical ventilation system. The other options are a mechanical ventilation system with Green Star rating, a system with options for both mechanical and natural ventilation, a system with both options where the mechanical ventilation part has a Green star rating and a natural ventilation only.

For the options with both natural ventilation as well as mechanical ventilation users should fill in another percentage. This is the percentage of the time throughout the year when natural ventilation is possible to properly ventilate the building. The energy savings for natural ventilation only apply for the time of the year when natural ventilation is possible. Since the Building Code only provides a required minimum amount of fresh air per time period for schools and not how this should be achieved this parameter cannot be used to calculate the energy savings. Therefore the energy savings are based on consultations with energy and ventilation experts [21] [22] [23]

Room	Product	Initial cost per m2	Savings natural Against baseline	Savings mechanical Against baseline
Normal	Natural	$ 275.00	90%	0%
	Natural + Mechanical	$ 525.00	90%	0%
	Mechanical	$ 425.00	0%	0%
	Mechanical Greenstar	$ 500.00	0%	25%
	Natural + Mechanical Greenstar	$ 600.00	90%	25%
Special	Mechanical	$ 625.00	0%	0%
	Mechanical Greenstar	$ 700.00	0%	25%

3.3.5 Hot water

Usually the energy that goes to hot water is a small part of the total energy consumption. It can still be useful to try reduce energy here though because hot water systems are not very expensive. Also for hot water the costs of useful heat of a system is the parameter on which the energy savings are

[21] http://www.wsp-pb.com/en/WSP-au-nz/

[22] Natural ventilation in non-domestic buildings, CIBSE, 1997

[23] http://www.aquaheat.co.nz

based. Solar hot water is the only exception because it is unfair to compare the other systems with the costs of useful heat for solar hot water since the sun provides free and renewable energy.

The energy savings for the solar hot water system are estimates from EECA based on the ability of the system over time to provide the required amount of hot water[24]. Sometimes this system fails because of the lack of sun light for example and a back-up system, an electric heater, needs to be used and no energy savings can then be achieved. The baseline option in this category is a gas heater just as for heating. This is only a baseline option and cannot be chosen since it uses a non renewable energy source.

Hotwater Product	COP	Costs 1 kWh useful heat	Initial costs per L	Amount of water in storage L per person	Savings
Solar Hot Water	-	-	$ 5.7	5	50%
Ground source HP	5	6	-	5	71%
Air source HP	3	8	-	5	62%
Electric heater	1	28	$ 7.4	5	-33%
Gas heater	0.85	21	$ 10.5	5	0%

3.3.6 Reduce lighting requirement

There are multiple ways to ensure there is enough light in a classroom but first, options for reducing the required energy for lighting are presented to the user. Among these measures are skylights and occupancy/vacancy sensor. Prices are from Rawlinson Handbook [25].

Skylight	R value	Average area per skylight	Initial costs per m2
Fixed	0.53	0.82	$ 1,434
Manually Opening	0.53	0.91	$ 1,548
Automatic Opening	0.5	1.07	$ 2,241

Sensors and Controls	Range	Initial costs per m2	Savings
Occupancy sensor	37.16	$ 1.64	40%
Daylighting with dimming sensor	127.23	$ 1.94	40%
Combination of products above + scheduling & control	111.48	$ 5.19	70%

3.3.7 Provide lighting

When daylight is not enough to provide the required amount of light in a building artificial lighting comes in. There are 4 different ways of artificial lighting included in the tool. The total available energy savings for provide lighting are the energy endues for lighting minus the eventual overall energy savings of the skylights section and minus the eventual overall savings of the sensors section. The luminous efficiency (LE) of various lighting options are used to determine the potential energy savings that could be achieved with respect to the baseline, which is incandescent.

There is a distinction between two different types of rooms for lighting which affects the formula for the costs. Some rooms such as music rooms, gyms, craft rooms and laboratories require higher levels of luminosity per square meter than a normal classroom (approx. 320 Lumens per sqm versus 240 Lumens per sqm for normal rooms) [26]

[24] https://www.energywise.govt.nz/at-home/water/types-of-water-heating-systems/solar-water-heating/

[25] Rawlinsons New Zealand Construction Handbook, 28th ed., 2013/14

[26] BRANZ, Designing Quality Learning Spaces: Lighting. Ministry of Education, 2007

Lighting Product	Luminous efficiency	Lumen	Decline factor	Life span in hrs	Initial costs per pc	Life span in years (4 hours a day)
LED	90	806	0.88	15000	$ 12.66	10
CFL T2	60	1450	0.95	6000	$ 4.51	4
Halogen	23	1200	0.9	2000	$ 3.63	1.4
Incandescent	15	1125	0.9	1000	$ 0.50	0.7

3.4 Energy Generating Technologies

After selecting mechanisms for reducing energy consumption, it is time to select energy generating technologies. Several technologies are available such as solar, wind, biomass and hydro. However, in order to keep the system simple, only solar and wind energies were included in the tool.

3.4.1 Wind turbines

Since the focus of the wind turbines industry is either around large commercial wind farms or small wind turbines for dwellings medium wind turbines for school projects are a long way off the mainstream. Nevertheless, wind turbines are being seen as the ideal energy generating technology for a showcase purpose. They raise awareness for the teachers and students the current energy problem. Nowadays for a feasible wind turbine the average wind speed must be higher than 7m/s, which is only the case in the Wellington region, Stewart Island and Northland. To produce some energy, however, an average wind speed of 2.5 m/s is sufficient. For the regions with an average wind speed between 2.5 and 7 m/s the wind turbine is seen as a good showcase energy generating technology. The prices for the different wind turbines are determined after consulting with Technico Site Services[27], a company which specializes in wind turbines.

The calculation for wind turbines consists of three different parts. First the energy requirement per month for the wind turbines needs to be calculated. Then based on the average wind speed of a region, the number of required wind turbines can be computed and the total cost can subsequently be calculated.

The total energy required per month is simply the average monthly energy usage after applying all the chosen energy saving technologies converted to kW multiplied with a desired percentage for wind turbines. It is possible for users to adjust this percentage to their preferences. However, it is advised to use as many solar panels as possible especially with an average wind speed below 7 m/s. Based on the ratio between the average wind speed to the rated speed of the wind turbine the actual output power is determined. The rated speed is the average wind speed at which the wind turbine is able to produce the displayed output power. Although it is not completely true, it is assumed that this relation is linear due to simplicity.

Wind turbine	Start-up speed (m/s)	Rated speed (m/s)	Degrade factor per year	Cost	Installation
Rutland 100W	2.5	10	1.6%	$ 2,498	$ -
Rutland 600W	2.5	11	1.6%	$ 5,851	$ -
Windspot 1.5kW turbine	2.5	11	1.6%	$ 23,000	$ 6,400
Windspot 3.5kW turbine	2.5	11	1.6%	$ 34,000	$ 6,800
Windspot 7.5kW turbine	2.5	11	1.6%	$ 57,000	$ 6,800
Osiris 10kw	2.5	9.5	1.6%	$ 72,000	$ 6,800

The number of wind turbines is then simply the energy requirement for wind turbines divided by the actual power of the different wind turbines. An adverse property of wind turbines is that the performance over time degrades. The average degradation factor for wind turbines is considered 1.6%

[27] http://www.futureenergy.nz/

per year[28]. This means that every year the actual power output is 1.6% less. To ensure that schools produce enough energy on-site the required number of wind turbines over 10 years is calculated. This means that from the start on the wind turbines harness more energy than needed but when looking at a time-period of 20 years more or less the total requirement of energy is generated.

3.4.2 Solar panels

Solar panels are considered as the best option to harness renewable energy nowadays. Since the market is constantly developing the prices continue to drop. There are different types of panels available but the monocrystalline cells are considered the most cost effective option. The calculations in the tool for solar panels are based on an average price and power output based on two monocrystalline solar panels. These two panels are from different manufacturers and are widely used in New Zealand for school projects. The estimated prices for solar panels are determined after consulting with Solar City, a company that specializes in solar panels systems for New Zealand education buildings.[29]

The calculations for solar panels consist of the same three parts as for wind turbines. First the total size for solar panels needs to be determined, then the number of solar panels and total costs can be calculated. The total size in kW is simply the total energy requirement minus the power output of the wind turbines. The solar panels have a degradation factor as well.

Ty	Monocrystalline	Polycrystalline	Polycrystalline
Brand	CNPV-200M	REC solar 8.5Amps 60 Cell PolyCrystalline Module	CNPV-250P
Cost	400	379.5	420
Efficiency	16%	15.8%	15.3%
Degrade factor per year in %	0.8%	0.8%	0.8%
Power	200	260	250
Dimension	125mm x 125mm	1665 x 991 x 38 mm	156mm x 156mm per cell *60 cells
Cell Area	1.125	1.504	1.460
Area required	168.34	170.48	176.05
Area required after degrade factor	182.31	184.61	190.65
Total number of panels	162.05	122.72	130.57
Cost inverter	4000	4000	4000
System size in W	32410	31906	32641

3.5 Data output sheet

The output sheet is arguably the most important sheet for decision makers. It displays financial and energy parameters and aids the users in determining the feasibility of their project. It is up to the user of the tool to decide whether the project is achievable. The tool only gives certain estimated outcomes but no further advice regarding the continuation of the project. After using the tool the users can confer about the outcomes and the selected energy technologies with an architect to discuss the follow-up of the project. Again, it should be noted that the outcomes of the tool are averages and hence might differ from the actual costs, energy savings and so on. The outcomes can be used as a rough estimate and guideline for further developing the project during the design phase.

There are three different types of output parameters; financial parameters, energy savings parameters and energy generating parameters. The selected energy saving technologies are omitted on this sheet due to clarity. The output parameters are discussed in the same sequence as they are presented in the tool.

[28] I. Staffell and R. Green, "How does wind farm performance decline with age?" Renewable Energy, vol. 55, no. 1, pp. 775–785, 2014

[29] http://www.solarcity.co.nz/schools/

4. School Trials

This section describes the trial of the pre-assessment tool at 6 schools across Auckland. The results of this trial were used to produce key requirements for further development of the software and a nationwide rollout strategy for the tool. The overall aim of the rollout strategy is to achieve zero net energy across all schools in New Zealand through use of the tool.

The objective for the school trials was to gather feedback and opinions in order to improve the current tool from a functionality standpoint and to assess general attitudes about Zero Net Energy in schools, the intended user base. Schools were selected and put into a preliminary list according to their roll size, age of students, decile rating, and location in Auckland and position in the 5-year school funding cycle. It was preferable to get a range of each of the listed factors to ensure that the tool is applicable in all potential school situations. Where possible, the schools that were selected were nearest to the time that they would receive their capital funding. This is so that they would be actively making decisions about potential rebuilds and renovations. The schools were then contacted by email and followed up with a phone call.

Where possible, the business manager of the board or principal was the person to be contacted. A number of schools did not respond to the email or phone call, or were involved in other existing energy programs and as such declined the invitation to participate.

Six schools positively responded (Appendix B) to the invitation and participated in the trial. During the trials, observations, questions and suggestions that were made by the school representatives were recorded, serving as another form of feedback.

Each visit consisted of three steps:

1. A preliminary presentation which outlined the concept of Zero-Net Energy, the benefits and barriers to its implementation, and the role of the tool in this process. This involved the viewing of a video which was adapted from previously existing videos online. The video contained an explanation about Zero-Net Energy and an overview of Pegasus Bay School, the first school in New Zealand to achieve Zero-Net energy. Presenting the project through this format seemed to be the most ideal method, as some of the school representatives were not previously aware of the concept of ZNE.
2. Tool trial with mock data - The tool was then presented to the school representative with a short explanation of the format of the tool. We then demonstrated how to use the tool using a fabricated set of data. A simplified instruction sheet was also given to the school representative. This step was aimed towards guiding the user through the tool and reducing their time spent reading the introductory material. Initial user feedback suggested that there is a steep learning curve with the use of the tool which this instruction sheet aims to lessen.
3. A discussion then followed regarding questions about the tool, suggestions for modifications and suggestions on how this tool could be made available to them.

4.1 Epsom Normal Primary School

Epsom Normal Primary's business manager was contacted first via email followed by a call immediately following the email to set an appointment. The business manager had previous interest in sustainable technologies and was therefore open to hearing about the tool.

The business manager responded positively to the presentation. The accompanying video worked very well to engage his interest. It enabled him to visualize the technologies being implemented as well as the benefits of Zero Net Energy buildings. He raised a question regarding the compatibility of the tool with Mac computers as the school primarily operates on a Mac based system. He also enquired about what funding schemes are available for schools who are looking to implement zero net energy technology.

He professed that having numbers and projections were useful for convincing upper management about pursuing a project.

4.2 Waiheke High School

The business manager at Waiheke High School was contacted. She was interested in the tool and its potential capabilities and benefits. The school was already in plans of converting their existing lighting systems to LED, but due to budgetary constraints, it did not appear to be feasible at that time.

There were a number of questions and suggestions after the tool demonstration. The business manager questioned the derivation of the technology costs and was concerned that the standards used were three years old (Rawlinson's 2013), noting that they would need constant updating in order to be reliable. Waiheke also incurs extra expenses due to being a remote location. After a discussion, it was suggested that an added factor of 20% may be suitable to compensate for this until it was analysed further. This mainly covers the increased transportation and labour costs. It was also mentioned that the school's plan to upgrade to double glazing didn't progress as expected due to delay in funding from MoE. The business manager was interested in the costs of both the solar panels and the wind turbines. She was surprised that the cost of solar panels wasn't as high as she had previously considered. It was evident that the cost of the technology and the lack of funding was the major barrier to implementing any technology. It was expressed that the chairman of the board was very interested in green technology and she would like the opportunity to share the tool's findings with him.

4.3 Tamaki Primary School

The property manager was the primary point of contact. He responded positively to the invitational email due to his personal interest in sustainability (particularly PV panels). Though he did not seem to have any prior knowledge about Zero Net Energy, he was quite enthusiastic to take part in the trial.

The property manager enjoyed the presentation and was more convinced about making ZNE a reality after looking at the example of Pegasus Bay School. The accompanying video made a good impression on him since it illustrates where they could make technological changes in their school to make it more energy efficient. He was impressed with the "Energy Saving Tips" section of the tool and said that it would be quite useful for the students to learn from this.

He felt that the first three pages of tool have too much generic information and suggested to skip this and instead refer to some internet sources for generic information about ZNE. He also felt that getting the input data for the tool would be a hard task. The data might be available, but they would need to go through a lot of administrative procedures to source it.

Despite the property manager's strong interest, he did not have the sole power to make a decision in adopting ZNE. He suggested to involve people who are higher in the hierarchy, such as the principal, school board and the Ministry of Education. These are the people who had the greatest influence on budget spending decisions for the school.

A further suggestion he gave was to seek out schools that are actively planning to rebuild or renovate. At the moment, consideration has only been given to the five year funding plans for schools and the assumption has been made that schools will spend their budget on renovations as soon as their five year funding cycle has been renewed. However, this assumption might not be true. Instead, sourcing and targeting the specific schools that are actively planning a rebuild or renovation would significantly impact the adoption rate of the pre-assessment tool.

4.4 Glen Taylor Primary School

The school was contacted through e-mail, and a member of the school's Board of Trustees was interested in knowing the benefits of using the tool. Being a part of a sustainable energy company, and the Sales and Marketing representative for the school, he was very enthusiastic and willing to travel to the University for the presentation.

The board member suggested making the tool online based instead of using the excel format. He mentioned that this had an extra benefit of being able to record information of the users. Specifically, who was using it and for what purposes. He appreciated the tools capabilities and its potential to help schools move towards zero net energy. He was also interested in the tool being a learning opportunity for the students.

The board member enquired about the rollout plan for the tool and gave some helpful feedback. He noted that it would be best to supply the tool to both the schools as well as MoE. This was so they can collaborate over the same calculations, while using the same resource. This is preferred as the system for applying for funding is complicated and disordered. The board member recognised EECA as an authority on the subject and recommended to establish contact with them and seek their input as they have the potential to aid in funding either for the project or for the schools. They would also be able to give guidance and insight for the rollout plan. He explained how schools of specific regions form a cluster and share resources, contacts and information between them. This may be one medium for us to distribute the tool. The clusters also apply for funding collectively as they have more influence as a larger group.

The board member suggested to start identifying the schools who are actively making efforts to move towards ZNE rather than approaching less interested schools, so as not to waste time and resources.

He also mentioned, especially in lower decile schools, the Board of Trustees may consist of members who are not experienced in this field. This means that the tool would need to clearly outline what the next vital steps are to make use of the outputs. He also expressed that the tool needs to highlight the positive outcomes such as monthly savings over the information about costs and long payback periods. Putting the initial cost as the top output conveys a negative feel about the results.

4.5 Bayswater Primary School

Bayswater primary school is certified green-gold by Enviroschools. The principal responded to the email with great interest, as they currently run sustainability and energy saving schemes within the school.

The school currently has two solar arrays in operation and uses them for a small amount of cost saving. The kids in the school are involved in a program which aims to teach them about energy conservation. This involves monitoring and calculating the savings from the solar panels and awards for classrooms who have the best energy usage habits. She was also aware of Pegasus Bay Primary School and their achievement of Zero-Net energy. Because of these programs and the school's involvement in energy conservation, she was already aware of many of the concepts that was presented and the presentation was able to move quickly to the discussion of the tool. She showed a positive attitude towards the tools layout and colour coding. She also expressed that she was happy with the walkthrough process from input to output. She seemed eager to start working through the tool in her own time. As the principal already had a substantial knowledge base, the presentation only took around 15 minutes which is significantly shorter than the other school visits.

4.6 Western Springs School

Western Springs College agreed to participate in the trial, however they preferred for the tool to be emailed to them instead of being physically visited. The college is undergoing a large rebuild, funded by the Ministry of Education. Their website has some information regarding the project, which shows they are currently in the planning stage. This made them a perfect candidate for trialing out the tool, and the main contact (one of the deputy principals) expressed interest due to this reason.

The tool was presented by the Deputy Principal to their Sustainability panel, and they expressed interest in using the tool as a guide in the early stages of their project.

4.7 Recommended Modifications

Through the school trials a number of improvements for the tool were identified. These changes are recommended to be implemented before the tool is available for the nationwide roll out. Apart from the general layout improvements and some additional features, the main recommendation is to develop this into an online tool. All of these changes have been condensed into a proposed tool design. The proposed new tool is the basis for the nationwide roll out plan.

4.7.1 Improved Output Information

Once the tool has been used to completion and the user is satisfied with the outputs there is a lack of information about how to proceed to the next stages of the project. In the current tool there is a small amount of information about how the tool's outputs can be passed on to an architect in the introductory notes. The new tool can improve on this by expanding the amount of information and support on how to proceed with the outputs from the tool. This may include a list of expert contacts inthe area or a dedicated consultant who is hired as part of the roll out plan. The layout of the tool can also be improved so this information is more strategically placed at the end of the tools walkthrough process.

4.7.2 Educational Use

A common concern from school decision makers was the potential for the tool to be used as an educational aid for kids. Currently the tool is too complex to be used in the classroom effectively. The information is also presented in a way that would not be entertaining or enriching for children. As part of the roll out plan, raising awareness within the community is key to creating momentum in the zero-net energy movement. Increasing the awareness of energy efficient and energy generating technologies in general with the students is going to raise the profile of the subject and make decision makers more aware of the benefits.

The new tool could potentially include 2 separate modes, a simplified interactive mode for children and a regular mode for use by school decision makers. Keeping these two users' functionality separate is essential as a tool designed for both would have to make major sacrifices in detail and complexity to make it user friendly for the children.

4.7.3 Information Layout

Currently tool users are required to read through 3 pages of dense information before they can begin using the tool. Although aimed at educating the user, it must be recognized that the users have different levels of awareness related to sustainability and energy conservation. A significant amount of this information is then required to be reviewed later as the input stages of the tool are completed. This forces the user to alternate between input and instruction pages.

The new tool would need to address both of these issues, to reduce the barriers of using the tool, and to make navigation easier during the input process. An option to skip this information if the user is already familiar with the initial concepts should be provided. The introductory information should be condensed as much as possible to allow the user to move on to the more engaging sections of the tool. This could be done by summarising all the introductory information into an instructional video. To solve the final issue of having to move back and forth between instructions and input sections, details about each input could be dispersed throughout the input section and explained again as they are required. This may take the form of an explanation which appears when the cursor is hovered over a help box next to the input.

4.7.4 Ability to Save

When using the current tool, the input values and associated outputs cannot be saved and used again reliably. This was a major concern for many of the users in the trial who were pushed for time and not able to complete the entire process in one sitting. This presents a major barrier for use as users felt like they had to wait until they had a large period of free time which could be dedicated to the use of the tool. An ideal situation would be one where users slowly progress through the tool at their own pace and have the ability to put their progress on hold. This would allow them to collect data for the required inputs if required. An additional benefit to a saving function is the ability to archive output results for later use or for sending them forward to other parties for analysis.

4.7.5 Login Functionality

A problem with the current tool is that there is no way of monitoring how it is being used by the schools. Information on who is using the tool, what they are using it for and the extent of their use with the tool are all useful parameters which could be analysed. This could then be used to adapt the roll-out and during cases which need support. This information is hard to recover via written feedback from the users and is more suited for recovery via data logs in the software.

A feature that would allow this information to be gathered most efficiently would be a login system. Before using the tool, users would login to their schools account. This would allow the uptake of the tool to be monitored closely during the roll out process and also provide staff members within a school a means of sharing their results from the tool.

4.7.6 Flexibility

One major barrier for schools in taking on the changes suggested by the tool is the initial cost. During the trial period the majority of the school's concerns were about the costs involved and how these broke down. For most schools spending a significant amount of the budget on a long term investment is a tough decision. With the current tool the outputs are limited to a scenario where the school buys all the technology at once with a large upfront cost and a given payback period. In many cases the output of the upfront cost is too large which is enough to deter any further investigation into the project. The new tool would be able to hold the interest of users which fall into this category if it had the ability to present a wider range of purchasing scenarios. This could include options which aim to cut the net power usage in half or a quarter as a more affordable step towards zero-net.

4.7.7 Cost Breakdown Report

A number of users in the trial expressed concerns and confusion about how the costs broke down. They found it hard to understand how each component of the cost added together to give the final output value. It was also not clear that in a rebuild scenario the cost is the difference between the cost of the baseline standards and the cost of the energy efficient technology. The new tool needs to have a more transparent approach to how these costs are conveyed. Users need to clearly see all of the components contained within the final cost estimate. This is required for them to trust that the numbers are accurate and allow them to compare the costs with quotes they may get from designers.

4.7.8 Data Management

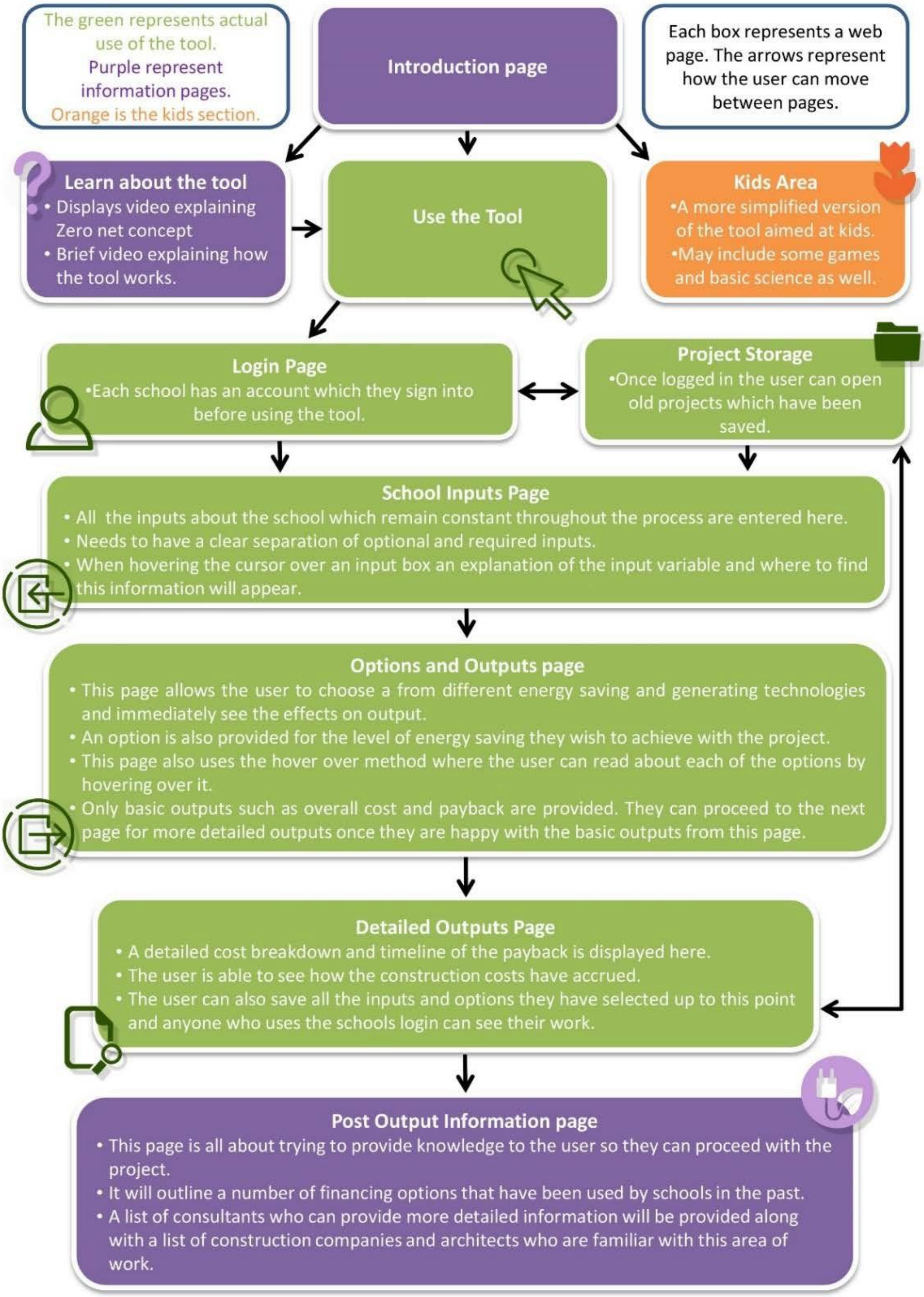
The backend database structure of the tool must allow for updates all the data and some of the underlying assumptions. It should also have features where new technologies are able to be added as the field of energy conservation, storage and generation is developing rapidly and prices for some of the technologies are dropping as they become more mainstream.

4.7.9 Improved Cost Benefit Analysis

Currently the tool allows for inflation, degradation and growth of the number of students over the 20 year lifespan of the installations. However, the rising prices of electricity should also be incorporated in the cost benefit analysis, providing a better outlook and shorter payback periods for generating renewable power.

4.8 Lay Out of the New Web-Based Tool

The following is a proposed layout which incorporates all of the improvements discussed in the previous section and aims to demonstrate how all these recommendations can be consolidated.



The green represents actual use of the tool.
Purple represent information pages.
Orange is the kids section.
Introduction page
Each box represents a web page. The arrows represent how the user can move between pages.
Learn about the tool
• Displays video explaining Zero net concept
• Brief video explaining how the tool works.
Use the Tool
Kids Area
•A more simplified version of the tool aimed at kids.
•May include some games and basic science as well.
Login Page
•Each school has an account which they sign into before using the tool.
Project Storage
•Once logged in the user can open old projects which have been saved.
School Inputs Page
• All the inputs about the school which remain constant throughout the process are entered here.
• Needs to have a clear separation of optional and required inputs.
• When hovering the cursor over an input box an explanation of the input variable and where to find this information will appear.
Options and Outputs page
• This page allows the user to choose a from different energy saving and generating technologies and immediately see the effects on output.
• An option is also provided for the level of energy saving they wish to achieve with the project.
• This page also uses the hover over method where the user can read about each of the options by hovering over it.
• Only basic outputs such as overall cost and payback are provided. They can proceed to the next page for more detailed outputs once they are happy with the basic outputs from this page.
Detailed Outputs Page
• A detailed cost breakdown and timeline of the payback is displayed here.
• The user is able to see how the construction costs have accrued.
• The user can also save all the inputs and options they have selected up to this point and anyone who uses the schools login can see their work.
Post Output Information page
• This page is all about trying to provide knowledge to the user so they can proceed with the project.
• It will outline a number of financing options that have been used by schools in the past.
• A list of consultants who can provide more detailed information will be provided along with a list of construction companies and architects who are familiar with this area of work.

5. Rollout Plan

5.1 Key Stakeholders

The success of any project on this scale is largely determined by how willingly the individuals and groups who are affected by the final solution accept it. Therefore, the first step of the roll-out plan is to establish strong partnerships and sponsor relationships, in order to start developing the web-based tool and proceed with the roll- out. The stakeholders who have an interest in the nature of the solution, or the general concept of sustainability in schools, have been identified below. This was an important step that helped to inform the best-fit requirements of the final roll-out plan.

MINISTRY OF EDUCATION

The Ministry of Education are the primary source of funding for the vast majority (85%) of schools in New Zealand. The Ministry oversees school infrastructure, sets property standards and provides guidance regarding their educational program.

Different types of schools receive varying levels of financial support and guidance regarding their property. State schools are managed in partnership with the Ministry and the school Board of Trustees. Property work is delegated by the Boards of Trustees to Project Managers.

Integrated schools are former private schools that become part of the state system. These schools receive some government funding for maintenance and modernisation of school buildings, and must meet minimum standards as set by the Ministry. Private school properties are managed solely by the school owners, with minimal input from the Ministry.

The Ministry has the most influence on state schools. Their responsibilities include enforcing Government and Ministry spending rules when schools use property funding. They do this by:

- Allocating property funding through various funding programs for state schools to build and maintain school property.
- Providing information regarding management of school property, using the Ministry website as the primary medium.

The Ministry has a high level of influence on the success of the tool roll-out, as they are the official authority for the majority of schools in New Zealand regarding the viability of Zero Net Energy projects. Ministry support regarding the incorporation of sustainable technologies in school property projects will greatly help generate interest regarding the tool.

Currently the Ministry has shown interest in sustainable infrastructure for schools, through pledging NZD 1.14 billion over 10 years to the Education Renewal Programme in Canterbury. The goal is to implement energy-efficient buildings and create innovative learning environments, according to the MoE's 4 year plan report[30].

Additionally, the ministry provides NZD 500 million to school boards to maintain and upgrade school property, as well as advice and funding to 330 state integrated schools in NZ.

Ministry support regarding the roll-out will be crucial to its success. If direct funding cannot be obtained, keeping MoE updated with the roll-out will be necessary, as the MoE will be directly involved in most schools' building projects. They will need to verify the cost estimates and financial viability of the projects, as predicted by the tool.

The MoE will require the roll-out to not disrupt or detract from current funding plans in other areas such as education programs and training. Ultimately this can be done by aligning the roll-out with the Ministry's aims, as found in their 4 year plan document.The project presents an added benefit to the MoE, potentially helping to attract students from overseas through promoting New Zealand's clean and green image and progressive educational system. This image will be enhanced if the tool can be adapted to support student learning regarding sustainability.

[30] http://www.education.govt.nz/assets/Documents/Ministry/Publications/MOE-Four-Year-Plan- 2015-2019.pdf

Building Research Association of NZ (BRANZ)

BRANZ is the original provider of the funds for the development of the tool. They have also developed numerous sustainability fact-sheets for the building industry as well as the very comprehensive http://wwwl.level.org.nz website. Much of the content of this website provides guidance and contact regarding the energy efficiency features incorporated in this tool.

Energy Efficiency and Conservation Authority (EECA)

EECA has been identified as a stakeholder with a very high interest in the roll-out. The concept of Zero Net Energy aligns with their main programs, which are targeted towards energy conservation and the use of renewable energy sources, as well as their mission statement 'to help you make those choices, we provide advice, tools and information you can trust.

EECA currently provides some forms of funding or consulting for businesses interested in implementing energy efficient technology. Funding for the roll-out plan would be ideal, however any support through promoting the tool or helping to distribute it (potentially through hosting it on their website) would be greatly beneficial for a successful tool roll-out. EECA has already expressed support for the project.

Individual Schools(BOARD OF TRUSTEES AND MANAGEMENT)

The individual school decision makers are the targeted users of the tool. The main decision makers have been identified as the Board of Trustees and Senior Management, as confirmed through speaking with schools during the trial. They ultimately make the choice regarding whether to try out the tool, therefore the success of the roll-out plan is dependent their interest level and adoption rates.

To increase awareness of the tool among the individual school decision makers, partnering with some of the following stakeholders would be very beneficial:

NZ School Trustee Association (NZSTA)

Similar to the NZPF, the NZSTA is a membership based organisation which currently represents 91% (2,200 of 2,415) of NZ school board of trustees. Their aim is to allow students the best education, through supporting school governance. NZSTA has already expressed support for the project.

NZ Principal Federation (NZPF)

The NZPF is an organisation which represents more than 2,300 principals from the education sector. Conferences and seminars would be a useful medium in reaching individual school decision makers, to promote awareness and adoption of the tool. Having the endorsement or support from such an organisation also increases trust in the tool. However, NZPF's aims don't always align with the Ministry of Education especially regarding funding. This needs to be managed closely if both partnerships are to be maintained.

Green School Alligance (GSA)

The GSA is an international coalition of sustainable schools, with member schools from 53 countries. Their main focus is on sustainability in action, through connecting individuals and schools in programs to develop sustainability, education and action. They offer training, consulting and online resources to schools to develop their sustainability programs.

A partnership with the GSA can help promote the tool globally for further development. However current influence over NZ schools is unknown, though they may be interested in furthering their membership through the tool roll-out.

Enviro School

The Enviro school program is a New Zealand based program offering support for schools wishing to implement sustainability actions in their community. There are currently 1016 member schools, one of which (Bayswater Primary) participated in the tool trial. The roll-out plan can utilise the Enviroschools network to promote the tool, especially among members who already show interest in sustainability.

They currently have over 100 national and regional partners. Therefore they may be open to forming more partnerships concerning the tool, especially considering that it may be developed as an educational tool for students.

Commercial Entities

Genesis Energy and Solarcity are among many commercial entities who are actively promoting solar energy generation to schools across NZ. Genesis Energy has developed the schoolgen.co.nz program, which has provided PV installations at 92 schools across the country (notably a 30kW installation at Otanga primary in Rotorua).

5.2 Analysis of Variables Influencing Diffusion of the Tool

In order to ensure successful diffusion of innovation, there are certain attributes of a new technology that highly influence its uptake in the market. It is important that the new technology is assessed based on these attributes prior to launching it in the market. This gives a preliminary idea of whether the technology is ready to be introduced in the market or whether it needs further improvement prior to its market introduction. Hence, the pre-assessment tool was analysed based on the following important attributes:

RELATIVE ADVANTAGE

This refers to the degree to which an innovation is better than the idea it supersedes. Since the pre-assessment tool is free of cost and gives impartial recommendations, the relative advantage of the tool is considered high. This has been confirmed by feedback from the school trials, where the majority of the individuals felt that the output of the tool would be useful for their school.

COMPATIBILITY

The pre-assessment tool is currently programmed with Visual Basic in Microsoft Excel and hence is compatible with different operating systems (Mac and Windows) used in computers. Given that most schools have sustainability as a part of their agenda, the pre-assessment tool is also compatible with schools' existing values, norms and practices. As the tool is planned to be converted into a web-based format, 100% compatibility should be ensured assuming all the decision makers have internet access.

COMPLEXITY

As most potential users are able to use Microsoft Excel to a basic level, the pre-assessment tool should be easy to use and understand. At the moment, no specialised skills are required to operate the tool, however the interface is somewhat complex. The tool will likely be available as a web-based platform in future, allowing those who are not acquainted with Microsoft Excel to use the tool. During the trial, a separate one page instruction sheet was developed for reference while using the tool. The instruction sheet includes the key points users need to keep in mind while using the tool. Furthermore, as a part of the tool improvement recommendations, the web-based platform is planned to be more user-friendly. If the user forgets how a specific section of the tool functions, the user can just hover over the section and it will display more information about what is needed.

TRIALABILITY

The tool can be tried an unlimited number of times and there is no obligation to use the results of the tool. Hence, there is no risk associated with the adoption of the tool.

OBSERVABILITY

The output of the tool gives long-term recommendations (several years) and hence it is difficult to observe if the actual results of the tool hold true straight away. As a result, users of the tool might not be completely convinced about the integrity of the output of the tool. However, given enough time, you will be able to observe the results from the adoption of the technology. This will then be observed by other schools, encouraging them to adopt the technology. To compensate for this at the early stages of the roll-out, the online version of the tool must present case-studies of successful implementation of the features and technologies presented in the tool.

5.3 Rollout Strategy

The diagram below outlines the path for a national rollout of the ZNE tool. Critical in this journey, is the development of the online version of the tool and linking it with other online resources to engage with key stakeholders at schools and guide them through a selection process, which helps them develop various scenarios towards ZNE objectives.

6. Conclusions

Even with the abundance of information available about the benefits of energy conservation and potential for renewable energy generation, few schools in New Zealand have aimed to achieve Zero Net Energy. One of the reasons for such low engagement with ZNE aspiration, is the absence of tools for key decision makers in schools to help them select from a number of energy conservation and energy generation technologies and building features, and assess the costs and benefits of their selections. In this project, we constructed a prototype of one such tool, in the face of the difficulties with complexity, relevance and availability of highly scattered data. The prototype was put in a trial with six schools in Auckland, and the feedback and insights gained have helped to develop the pathway for further development of the tool and strategy for national rollout to all interested schools in New Zealand.

7. Appendices

7.1 Appendix A:Tool Screenshots

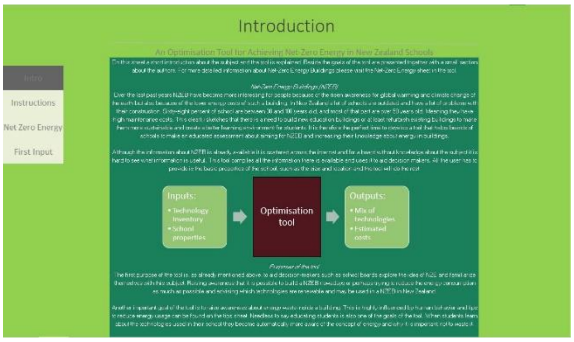


Figure A.1: Intro sheet

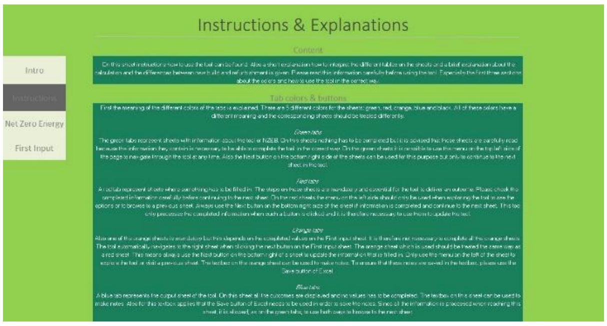


Figure A.2: Instructions sheet

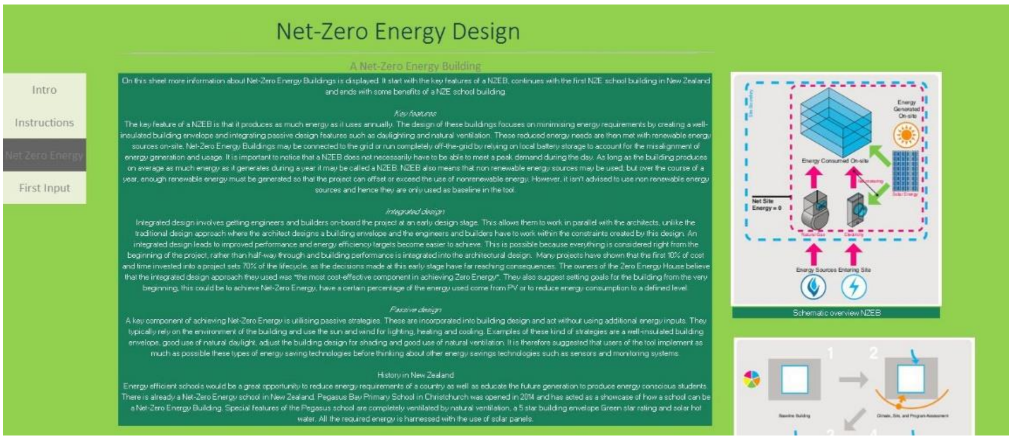


Figure A.3: Net-Zero Energy sheet

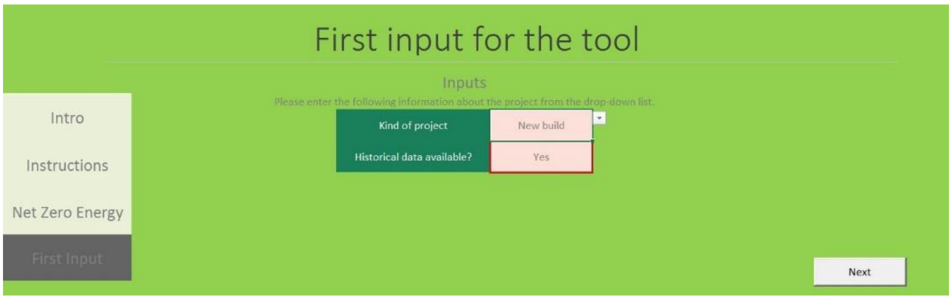


Figure A.4: First Input sheet

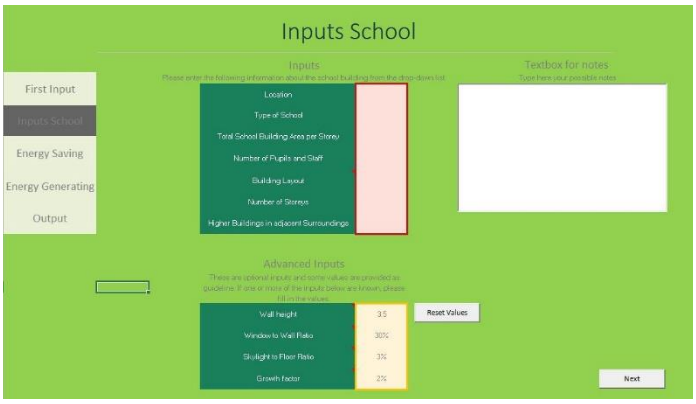


Figure A.5: New build no data sheet

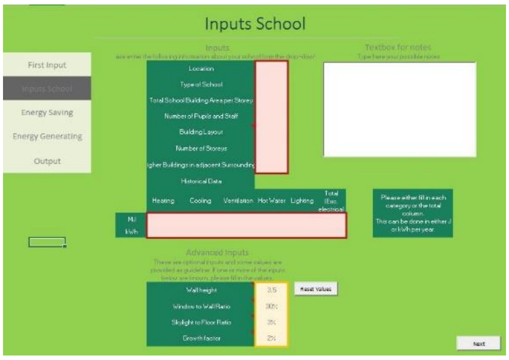


Figure A.6: New build data sheet

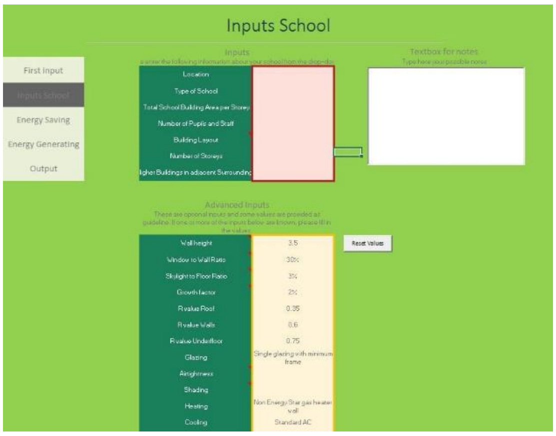


Figure A.7: Refurbishment no data sheet

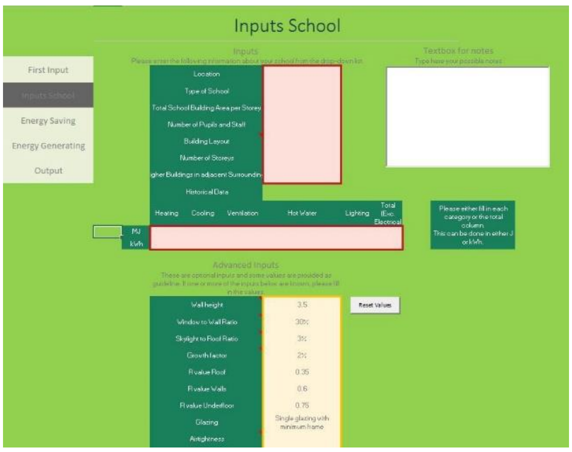


Figure A.8: Refurbishment data sheet

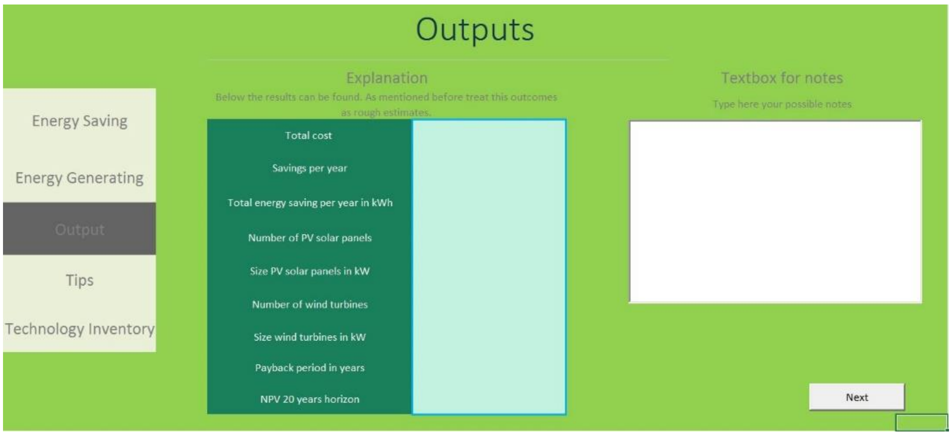


Figure A.9: Output sheet

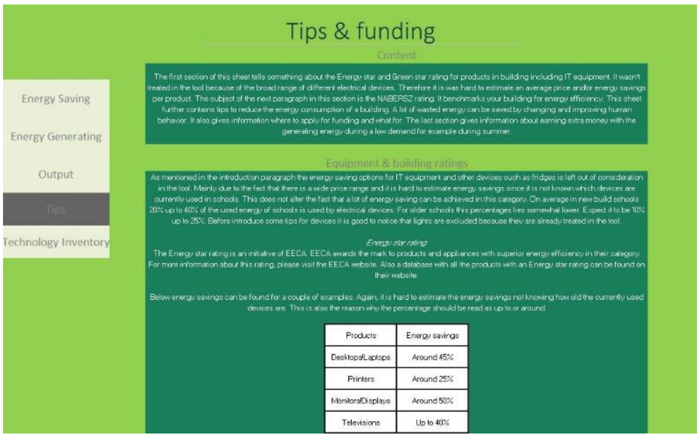


Figure A.10: Tips sheet

Figure A.11: Technology inventory sheet

7.2 Appendix B: School Trial Contacts

	School name	E-mail	Contact Person	Designation	Contact
1	Epsom Normal Primary	office@epsomnormal.school.nz	John Jacka	Property Manager	09 6305144
2	Waiheke High School	business@waihekehigh.school.nz	Trudie Jamieson	Business Manager	09 3719000
3	Tamaki Primary School	gfepuleai@tamakiprimary.school.nz	George Fepuleai Jr.	Business Manager	09 5276345
4	Bayswater Primary School	admin@bayswater.school.nz	Lindsay Child	Principal	09 4456226
5	Glen Taylor School	scottf@glentaylor.school.nz	Scott Fairbairn	Board of Trustees	09 5286325
6	Western Springs College	stimsonk@wsc.school.nz	Karen Stimson	Deputy Principal	09 815 6730

7.3 Appendix C: Energy Use Data by Region, Project Type and School Type

Region	City	Refurbishment or New build	Type	Energy usage in kWhr/2	Heating	Cooling	Ventilation	Hot Water	Lighting	Insulation zone
Auckland	Auckland	New build	Primary	125	37.5%	3.1%	3.1%	6.3%	50.0%	1
Auckland	Auckland	New build	Secondary	150	46.3%	11.0%	8.5%	3.7%	30.5%	1
Auckland	Auckland	New build	Tertiary	180	23.1%	15.4%	7.7%	15.4%	38.5%	1
Auckland	Auckland	Refurbishment	Primary	225	93.9%	0.0%	0.0%	2.9%	3.1%	1
Auckland	Auckland	Refurbishment	Secondary	275	93.9%	0.0%	0.0%	2.9%	3.1%	1
Auckland	Auckland	Refurbishment	Tertiary	325	63.4%	21.6%	0.5%	10.1%	4.3%	1
Bay of Plenty	Rotorua	New build	Primary	125	37.5%	3.1%	3.1%	6.3%	50.0%	2
Bay of Plenty	Rotorua	New build	Secondary	150	46.3%	11.0%	8.5%	3.7%	30.5%	2
Bay of Plenty	Rotorua	New build	Tertiary	180	23.1%	15.4%	7.7%	15.4%	38.5%	2
Bay of Plenty	Rotorua	Refurbishment	Primary	225	90.2%	0.0%	0.0%	7.4%	2.4%	2
Bay of Plenty	Rotorua	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	7.4%	2.4%	2
Bay of Plenty	Rotorua	Refurbishment	Tertiary	325	68.1%	17.5%	0.4%	10.5%	3.5%	2
Bay of Plenty	Tauranga	New build	Primary	125	37.5%	3.1%	3.1%	6.3%	50.0%	2
Bay of Plenty	Tauranga	New build	Secondary	150	46.3%	11.0%	8.5%	3.7%	30.5%	2
Bay of Plenty	Tauranga	New build	Tertiary	180	23.1%	15.4%	7.7%	15.4%	38.5%	2
Bay of Plenty	Tauranga	Refurbishment	Primary	225	90.2%	0.0%	0.0%	7.4%	2.4%	2
Bay of Plenty	Tauranga	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	7.4%	2.4%	2
Bay of Plenty	Tauranga	Refurbishment	Tertiary	325	68.1%	17.5%	0.4%	10.5%	3.5%	2
Canterbury	Christchurch	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Canterbury	Christchurch	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Canterbury	Christchurch	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Canterbury	Christchurch	Refurbishment	Primary	225	90.2%	0.0%	0.0%	3.0%	6.8%	3
Canterbury	Christchurch	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	3.0%	6.8%	3
Canterbury	Christchurch	Refurbishment	Tertiary	325	39.3%	43.2%	1.0%	7.9%	8.7%	3
Canterbury	Kaikoura	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Canterbury	Kaikoura	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Canterbury	Kaikoura	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Canterbury	Kaikoura	Refurbishment	Primary	225	90.2%	0.0%	0.0%	3.0%	6.8%	3
Canterbury	Kaikoura	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	3.0%	6.8%	3
Canterbury	Kaikoura	Refurbishment	Tertiary	325	39.3%	43.2%	1.0%	7.9%	8.7%	3
Canterbury	Timaru	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Canterbury	Timaru	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Canterbury	Timaru	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Canterbury	Timaru	Refurbishment	Primary	225	90.2%	0.0%	0.0%	3.0%	6.8%	3
Canterbury	Timaru	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	3.0%	6.8%	3
Canterbury	Timaru	Refurbishment	Tertiary	325	39.3%	43.2%	1.0%	7.9%	8.7%	3
Gisborne	Gisborne	New build	Primary	125	37.5%	3.1%	3.1%	6.3%	50.0%	3
Gisborne	Gisborne	New build	Secondary	150	46.3%	11.0%	8.5%	3.7%	30.5%	3
Gisborne	Gisborne	New build	Tertiary	180	23.1%	15.4%	7.7%	15.4%	38.5%	3
Gisborne	Gisborne	Refurbishment	Primary	225	93.7%	0.0%	0.0%	2.9%	3.4%	3
Gisborne	Gisborne	Refurbishment	Secondary	275	93.7%	0.0%	0.0%	2.9%	3.4%	3
Gisborne	Gisborne	Refurbishment	Tertiary	325	61.7%	23.1%	0.5%	10.1%	4.7%	3
Hawke's bay	Napier	New build	Primary	125	37.5%	3.1%	3.1%	6.3%	50.0%	2
Hawke's bay	Napier	New build	Secondary	150	46.3%	11.0%	8.5%	3.7%	30.5%	2
Hawke's bay	Napier	New build	Tertiary	180	23.1%	15.4%	7.7%	15.4%	38.5%	2
Hawke's bay	Napier	Refurbishment	Primary	225	93.2%	0.0%	0.0%	3.0%	3.9%	2
Hawke's bay	Napier	Refurbishment	Secondary	275	93.2%	0.0%	0.0%	3.0%	3.9%	2
Hawke's bay	Napier	Refurbishment	Tertiary	325	57.8%	26.5%	0.6%	9.8%	5.3%	2
Manawatu-Wanganui	Palmerston North	New build	Primary	125	37.5%	3.1%	3.1%	6.3%	50.0%	2
Manawatu-Wanganui	Palmerston North	New build	Secondary	150	46.3%	11.0%	8.5%	3.7%	30.5%	2
Manawatu-Wanganui	Palmerston North	New build	Tertiary	180	23.1%	15.4%	7.7%	15.4%	38.5%	2
Manawatu-Wanganui	Palmerston North	Refurbishment	Primary	225	95.4%	0.0%	0.0%	2.9%	1.7%	2
Manawatu-Wanganui	Palmerston North	Refurbishment	Secondary	275	95.4%	0.0%	0.0%	2.9%	1.7%	2
Manawatu-Wanganui	Palmerston North	Refurbishment	Tertiary	325	74.0%	12.0%	0.3%	11.2%	2.4%	2
Manawatu-Wanganui	Taumarunui	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Manawatu-Wanganui	Taumarunui	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Manawatu-Wanganui	Taumarunui	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Manawatu-Wanganui	Taumarunui	Refurbishment	Primary	225	95.4%	0.0%	0.0%	2.9%	1.7%	3
Manawatu-Wanganui	Taumarunui	Refurbishment	Secondary	275	95.4%	0.0%	0.0%	2.9%	1.7%	3
Manawatu-Wanganui	Taumarunui	Refurbishment	Tertiary	325	74.0%	12.0%	0.3%	11.2%	2.4%	3
Marlborough	Blenheim	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Marlborough	Blenheim	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Marlborough	Blenheim	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Marlborough	Blenheim	Refurbishment	Primary	225	90.2%	0.0%	0.0%	3.0%	6.8%	3
Marlborough	Blenheim	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	3.0%	6.8%	3
Marlborough	Blenheim	Refurbishment	Tertiary	325	38.7%	43.6%	1.0%	7.9%	8.8%	3
Nelson	Nelson	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Nelson	Nelson	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Nelson	Nelson	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Nelson	Nelson	Refurbishment	Primary	225	90.2%	0.0%	0.0%	3.0%	6.8%	3
Nelson	Nelson	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	3.0%	6.8%	3
Nelson	Nelson	Refurbishment	Tertiary	325	38.5%	43.8%	1.0%	7.9%	8.8%	3
Northland	Whangarei	New build	Primary	125	37.5%	3.1%	3.1%	6.3%	50.0%	1

Northland	Whangarei	New build	Secondary	150	46.3%	11.0%	8.5%	3.7%	30.5%	1
Northland	Whangarei	New build	Tertiary	180	23.1%	15.4%	7.7%	15.4%	38.5%	1
Northland	Whangarei	Refurbishment	Primary	225	95.3%	0.0%	0.0%	2.9%	1.8%	1
Northland	Whangarei	Refurbishment	Secondary	275	95.3%	0.0%	0.0%	2.9%	1.8%	1
Northland	Whangarei	Refurbishment	Tertiary	325	73.5%	12.4%	0.3%	11.2%	2.5%	1
Otago	Alexandra	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Otago	Alexandra	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Otago	Alexandra	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Otago	Alexandra	Refurbishment	Primary	225	90.2%	0.0%	0.0%	3.0%	6.8%	3
Otago	Alexandra	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	3.0%	6.8%	3
Otago	Alexandra	Refurbishment	Tertiary	325	41.8%	41.2%	0.9%	7.8%	8.3%	3
Otago	Dunedin	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Otago	Dunedin	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Otago	Dunedin	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Otago	Dunedin	Refurbishment	Primary	225	90.2%	0.0%	0.0%	3.0%	6.8%	3
Otago	Dunedin	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	3.0%	6.8%	3
Otago	Dunedin	Refurbishment	Tertiary	325	41.5%	41.5%	0.9%	7.8%	8.3%	3
Otago	Oamaru	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Otago	Oamaru	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Otago	Oamaru	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Otago	Oamaru	Refurbishment	Primary	225	90.2%	0.0%	0.0%	3.0%	6.8%	3
Otago	Oamaru	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	3.0%	6.8%	3
Otago	Oamaru	Refurbishment	Tertiary	325	41.8%	41.2%	0.9%	7.8%	8.3%	3
Otago	Queenstown	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Otago	Queenstown	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Otago	Queenstown	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Otago	Queenstown	Refurbishment	Primary	225	90.2%	0.0%	0.0%	3.0%	6.8%	3
Otago	Queenstown	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	3.0%	6.8%	3
Otago	Queenstown	Refurbishment	Tertiary	325	41.8%	41.2%	0.9%	7.8%	8.3%	3
Southland	Invercargill	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Southland	Invercargill	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Southland	Invercargill	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Southland	Invercargill	Refurbishment	Primary	225	90.2%	0.0%	0.0%	3.0%	6.8%	3
Southland	Invercargill	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	3.0%	6.8%	3
Southland	Invercargill	Refurbishment	Tertiary	325	38.8%	43.5%	1.0%	7.9%	8.8%	3
Taranaki	New Plymouth	New build	Primary	125	37.5%	3.1%	3.1%	6.3%	50.0%	2
Taranaki	New Plymouth	New build	Secondary	150	46.3%	11.0%	8.5%	3.7%	30.5%	2
Taranaki	New Plymouth	New build	Tertiary	180	23.1%	15.4%	7.7%	15.4%	38.5%	2
Taranaki	New Plymouth	Refurbishment	Primary	225	94.1%	0.0%	0.0%	2.9%	2.9%	2
Taranaki	New Plymouth	Refurbishment	Secondary	275	94.1%	0.0%	0.0%	2.9%	2.9%	2
Taranaki	New Plymouth	Refurbishment	Tertiary	325	64.6%	20.4%	0.4%	10.4%	4.1%	2
Tasman	Motueka	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Tasman	Motueka	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Tasman	Motueka	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Tasman	Motueka	Refurbishment	Primary	225	90.8%	0.0%	0.0%	2.9%	6.4%	3
Tasman	Motueka	Refurbishment	Secondary	275	90.8%	0.0%	0.0%	2.9%	6.4%	3
Tasman	Motueka	Refurbishment	Tertiary	325	40.9%	41.9%	1.0%	7.8%	8.4%	3
Waikato	Hamilton	New build	Primary	125	37.5%	3.1%	3.1%	6.3%	50.0%	2
Waikato	Hamilton	New build	Secondary	150	46.3%	11.0%	8.5%	3.7%	30.5%	2
Waikato	Hamilton	New build	Tertiary	180	23.1%	15.4%	7.7%	15.4%	38.5%	2
Waikato	Hamilton	Refurbishment	Primary	225	92.5%	0.0%	0.0%	3.5%	4.1%	2
Waikato	Hamilton	Refurbishment	Secondary	275	92.5%	0.0%	0.0%	3.5%	4.1%	2
Waikato	Hamilton	Refurbishment	Tertiary	325	57.0%	27.2%	0.6%	9.6%	5.5%	2
Waikato	Taupo	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
Waikato	Taupo	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
Waikato	Taupo	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
Waikato	Taupo	Refurbishment	Primary	225	92.5%	0.0%	0.0%	3.5%	4.1%	3
Waikato	Taupo	Refurbishment	Secondary	275	92.5%	0.0%	0.0%	3.5%	4.1%	3
Waikato	Taupo	Refurbishment	Tertiary	325	57.0%	27.2%	0.6%	9.6%	5.5%	3
Wellington	Wellington	New build	Primary	125	37.5%	3.1%	3.1%	6.3%	50.0%	2
Wellington	Wellington	New build	Secondary	150	46.3%	11.0%	8.5%	3.7%	30.5%	2
Wellington	Wellington	New build	Tertiary	180	23.1%	15.4%	7.7%	15.4%	38.5%	2
Wellington	Wellington	Refurbishment	Primary	225	94.0%	0.0%	0.0%	2.9%	3.0%	2
Wellington	Wellington	Refurbishment	Secondary	275	94.0%	0.0%	0.0%	2.9%	3.0%	2
Wellington	Wellington	Refurbishment	Tertiary	325	64.6%	20.5%	0.4%	10.3%	4.1%	2
West Coast	Greymouth	New build	Primary	125	45.7%	7.1%	4.3%	5.7%	37.1%	3
West Coast	Greymouth	New build	Secondary	150	47.7%	20.9%	7.0%	2.3%	22.1%	3
West Coast	Greymouth	New build	Tertiary	180	25.0%	25.0%	7.1%	14.3%	28.6%	3
West Coast	Greymouth	Refurbishment	Primary	225	90.2%	0.0%	0.0%	3.0%	6.8%	3
West Coast	Greymouth	Refurbishment	Secondary	275	90.2%	0.0%	0.0%	3.0%	6.8%	3
West Coast	Greymouth	Refurbishment	Tertiary	325	39.1%	43.4%	1.0%	7.9%	8.7%	3