TE WHARE WĀNANGA O TE ŪPOKO O TE IKA A MĀUI
VICTORIA
UNIVERSITY OF WELLINGTON
https://www.victoria.ac.nz/sustainable-energy-systems

KAITIAKITANGA WHAKAPAPA MAURI

Solar180

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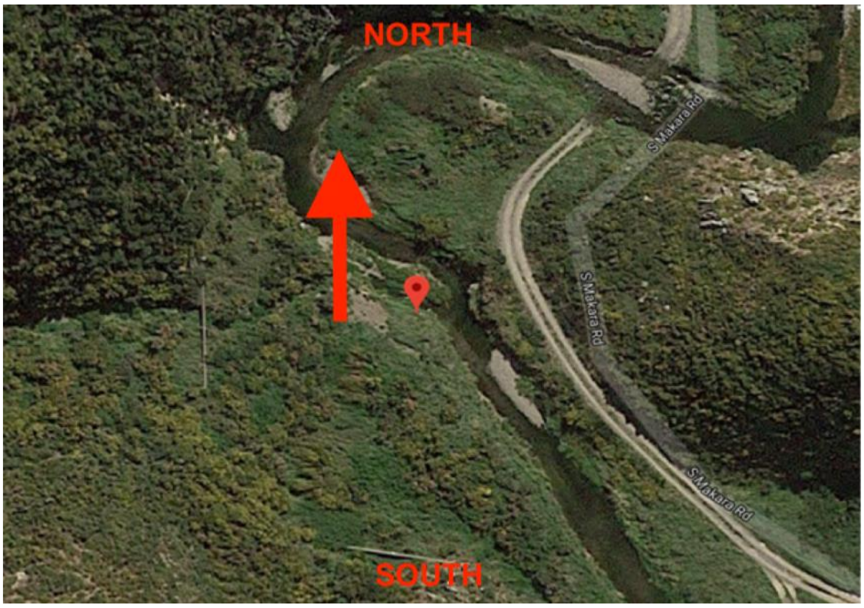
Design specifications

The Sustainable Cabin Project specifies to build an off-grid solar energy system 40 sqm cabin, housing a family of three. Solar180 needs to design a cabin that needs to be able to hold three residents and function off-grid. The family will need to generate their own electricity sufficient to power all the appliances and continue to manage an extra day worth of electricity in batteries. The power needs to be generated by solar panels and should be able to store up to two days' worth of energy in batteries. The cabin will also need to have a supply of water, needs to be able to support an "on-grid" lifestyle and to be as efficient and cost-effective as possible.

Cabin location and design

Solar180 has chosen the cabin location of Makara, Wellington 6972. The GPS coordinates of the exact location are 41°19'22.9"S 174°40'50.0"E (longitude: -41.323028, latitude: 174.680556). Makara is located west of Wellington, location chosen due to the availability of water (situated right next to a river), hills and wind turbines as well as access to a road as shown in the picture below. The river could also be used as another source of energy by using hydropower if necessary. While searching and deciding cabin locations, there were other locations considered within the group, such as: Mount Kaukau and Makara Peak. However, after analysing the SolarView data, the best power gain was from Makara. This means this location will be a direct source of water and good cumulative power gained per day in Winter and Summer.



The context behind the cabin design is that we are designing a cabin for a customer with a very high budget whom desires an off-grid cabin for a family of three. After the discussion with Solar180 of the design of the cabin, the final layout of the cabin would be a rectangular shaped cabin with dimensions of 5metres by 8 metres (Fig 2). The cabin will be facing North facing due to maximum sunlight (Fig 1), this will provide great natural lighting for the daytime as well as the solar panel placement which proves beneficial. As seen in Fig 2, the cabin will consist of 4 rooms: two bedrooms, one en suite bathroom and a living/dining area for the family. There will be minimal lighting due to the use of natural lighting by placing large windows facing East and West to follow the sun's rising and falling.

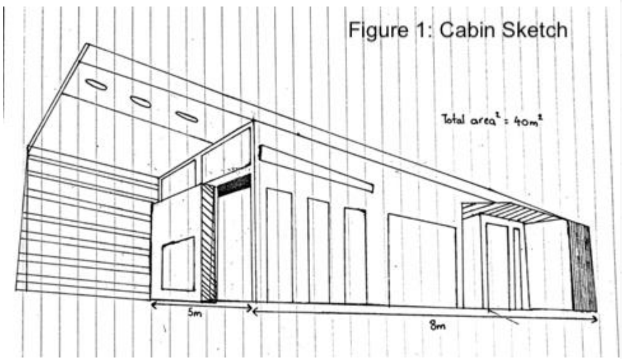


Figure 1: Cabin Sketch

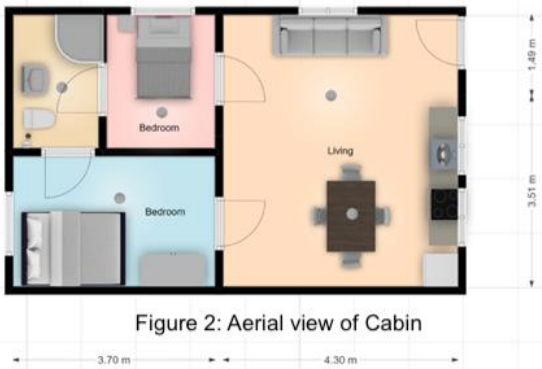
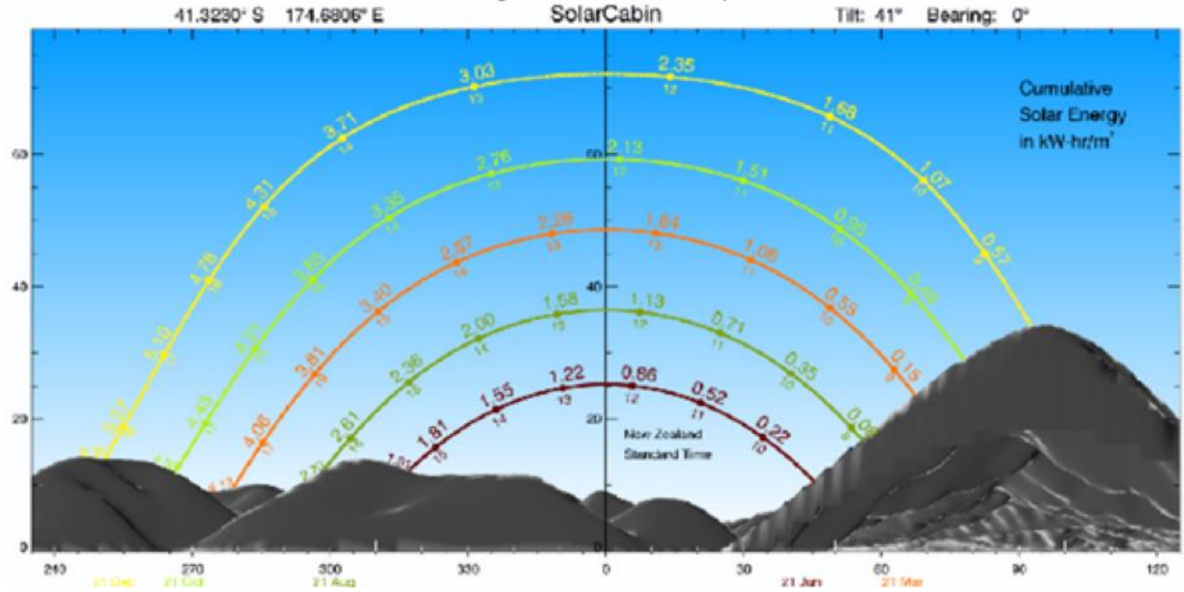


Figure 2: Aerial view of Cabin

Solar Resource Analysis

Figure 3: SolarView Graph



As shown in the image above (Fig 3), Solar180 used the site SolarView by NIWA to calculate the cumulative power gained over the Summer and Winter solstice. The graph shows much energy is delivered in a day at various times in a year. Below is data for Summer and Winter solstice:

- The shortest day of the year is 21st of Jun after cumulative power gained via sunlight is 1.93 kW-hr/m^2
- The longest day of the year is 21st of Dec after cumulative power gained via sunlight is 5.33 kW-hr/m^2

Cabin Power and Load Characterisation

Part of the research stage of this project involved finding the best possible energy and cost efficient appliances for the cabin. Below is a table which shows all the appliances and the total cost estimation of how much energy the items will likely consume in a day during the Summer and Winter solstice. Though the time calculated is a rough estimation, as using each appliance can change accordingly to current stored energy and solar energy collected in the future. The values below, as well as assumptions made below, are intended to support an on-grid lifestyle while still being conservative about energy use.

Assumptions:

- Shower calculations are made assuming that every member of the family showers for 3 minutes every second day.

- Induction cooker calculations are made assuming that stovetop can be used for a maximum of 35 minutes a day. This is due to the use of the wood burning fireplace as a cooker during the winter.
- Assumptions of all appliances in the table will not be used for more than the time stated in one day.

Quantity:	**Appliances:**	**Time (hours)**	**Energy used per day (**kW/hr)	**Power Rating (W)**
1	Refrigerator		0.88	
4	Lights (LED)	6	0.24	10
1	Laptop	1	0.006	60
1	TV	3	0.3	100
2	Phones	2	0.02	5
1	Washing Machine	0.2	0.1	500
1	Induction Cooker	0.5	2.05	4100
1	UV water filter	0.05	0.0006	12
1	Water pump	0.55	0.66	1200
1	Solar water tank with electric boost	1	3.6	3600
	Miscellaneous loads		0.5	
Total			7.702	
Total with 10 % safety margin			8.522	

For maximum efficiency the use of an induction cooker will help minimize the cost and lessen the energy consumption when only used in winter. There will also be the use of evacuated tubes to heat water integrated with a tank with electric boost, used for days with poor weather. Solar180 have come to the final decision to use a wood burner for heating and cooking, rather than using a stovetop and separate heating. The family will only be able to cook using the induction cooker in the summer and use a wood fire stove in winter where the fireplace will provide heat for the cabin as well. This is because it will save energy in winter when there is little of it.

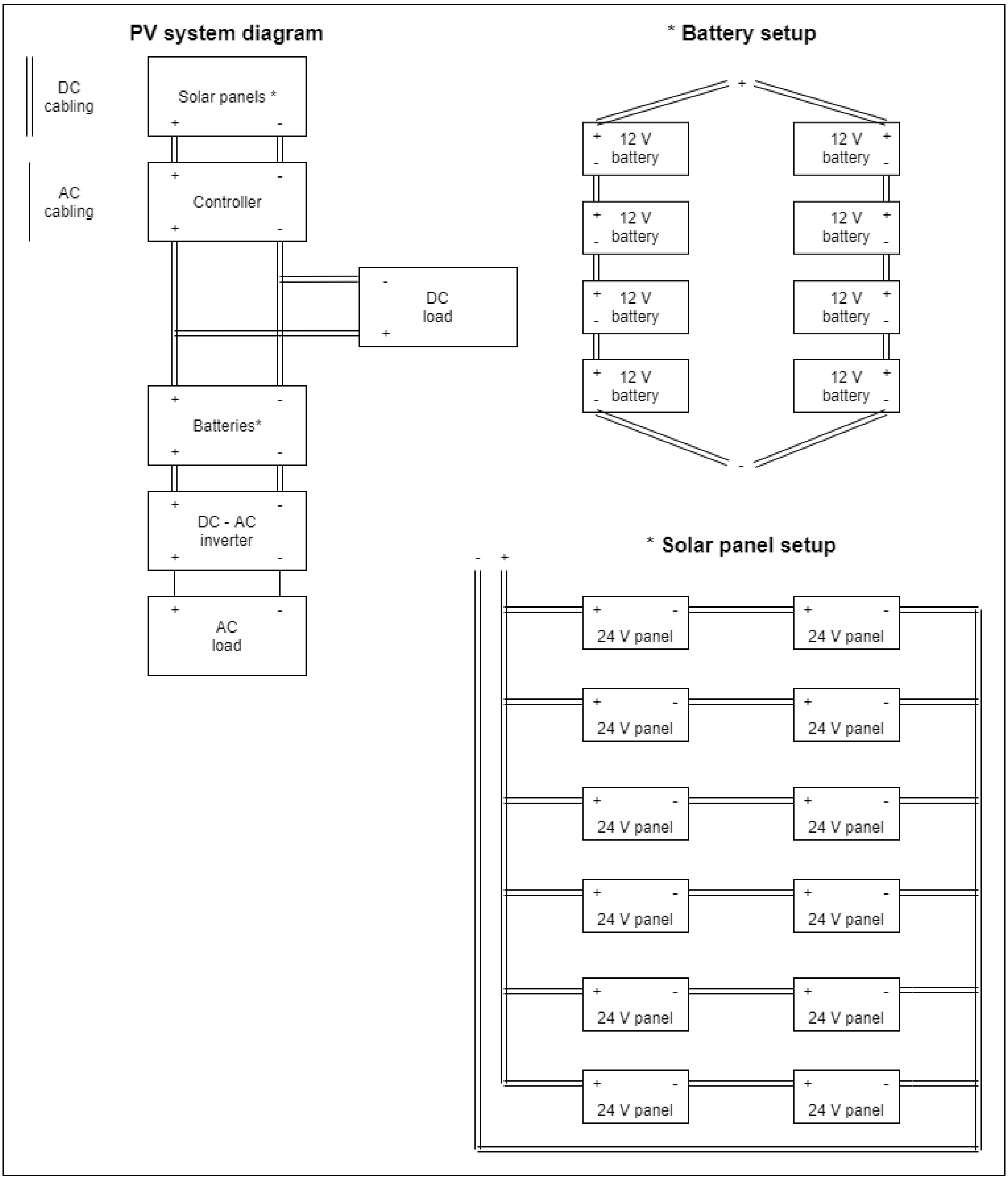
There are also no costs included for an electric heating system due to the costs of powering a heater in an off-grid cabin would mean increasing battery capacity and the number of solar panels which is a lot more expensive than using a woodfire fireplace, duct heat and good insulation. The cabin will also use a UV filter as this uses very little energy to filter water but still very effective.

PV System Design and Calculations

To get at least 8.522 KWh a day on the day with the least sunlight the area of the solar panels will need to be area = 8.522/(1.93*0.19) = 23.2397 m^2. Because the solar panels are 1.936 m^2 each, this means the cabin will need 12 units. With 12 units of solar panels, the family will always be able to collect enough solar energy to power the house for the day even during bad weather conditions. In summer when the accumulative w/m^2 is high at 5.33 w/m^2, the panels will collect around 12 = E/(1.93*0.19) E = 23.53 kWh of energy over a day.

The family will need to store an extra day worth of solar energy in batteries for extremely serious weather conditions. This means the cabin will need to have a substantial amount of energy so Solar180 decided it would be suitable to have a large battery capacity to hold at least two times the daily energy usage with the 10% safety margin, which is 17.44 kWh. To increase the efficiency of the PV system, the use of impedance matching will help maximize the power output of the solar panels with the use of a controller in the PV system.

Solar180 decided a 48V system is a suitable size for the cabin as most on-grid houses use this along with a 230V AC inverter. The Solar Panels and evacuated tubes will be on the roof of the cabin with a module azimuth of 0 degrees and a module tilt of 41 degrees to maximize sunlight collected. Below is a diagram of the entire system followed by specifications of parts used.



Component List and Specifications					
Inverter	48V Input	230AC V Output	2KWh continuous output		
Batteries	12V	200 A/H:		8 units	

		(200*12)/1000 2.4KWh for each battery Total: 19.2KWh			
Controller	48V Input				
Panels	24V			12 units 1.936m^2 each	Efficiency 19%

Item	**Cost**	**Link**
Solar Panels	$380 per unit	Fazcorp
STD 30 Solar Thermal Collector	$1,665	IceSolar
LED lights	$5	TheWarehouse
Refrigerator	$2,399	Samsung
Washing Machine	$945	NoelLeeming
Computer	$845	HarveyNorman
Full HD Smart LED Television	$999	NoelLeeming
Pure Sine Wave Inverter	$2,599	RVWorldStore
Controller	$535	WaveInverter
Battery	$899 per unit 8 units = $7,192	RVWorldStore
Labour	$10,000	
Minor Supplies	$2,000	
Total Cost	$33,762	

All appliances and PV system components listed above in the table are available locally to decrease shipping costs.

Uncertainties and contingencies

Variations in accumulative W/m^2 during summer won't cause too much of a problem as the cabin will most likely collect an excess amount of energy in a day. However, during the winter if the cumulative W/m^2 goes below 1.93 per day, then there will not be enough energy to use the appliances with originally calculated time, unless there is leftover energy stored in the batteries from previous days. Due to this, it's possible though quite unlikely that the cabin will have a day where it cannot supply enough energy for an on-grid lifestyle. If this prediction is wrong, because of the location of the cabin is situated right next to a river then there are two options that can go ahead. Hydropower could be implemented to collect sufficient energy, or more solar panels could be installed on the roof as there would still be at least another 15 m^2 of area available. However, it would be a better option to have different methods of collecting energy if there is an extended period with poor sunlight.

Conclusion and recommendations

To sum up the Sustainable Cabin Project, Solar180 feel that the group has satisfied the cabin requirements and with a low cost of $33,762. The cabin can support an on-grid lifestyle off-grid as well as fulfills the physical requirements and energy requirements. Solar180 were able to do this is due to the efficient components and PV design, and the practical design which suits the circumstances of the cabin. The family who be living in the cabin should try to be as energy conservative as possible during winter, and if need be to purchase more appliances to also consider purchasing more solar panels or installing hydropower. To improve the design, if Solar180 had more time or another chance to design an off-grid cabin then there would be more emphasis spent for selecting the most efficient appliances. This is because it would significantly decrease the cost of the cabin as less power would be needed and would make the cabin more cost-effective.