TITLE:

Stand-alone/Grid-Connected Renewable Power System for Residential Use

1. MODELLING

Address: 14 Briarley Court Hampton park (3976), Melbourne, Australia Latitude: -38.04527598 Longitude: 145.28015653.

Figure 1: View of the house through Google maps

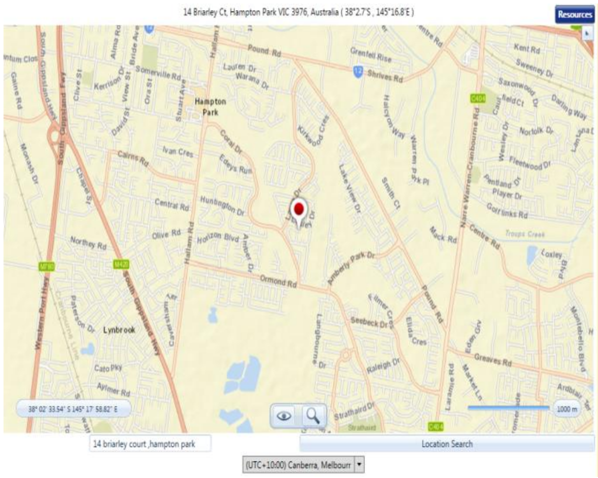


Figure 2: The address imputed to HOMER PRO

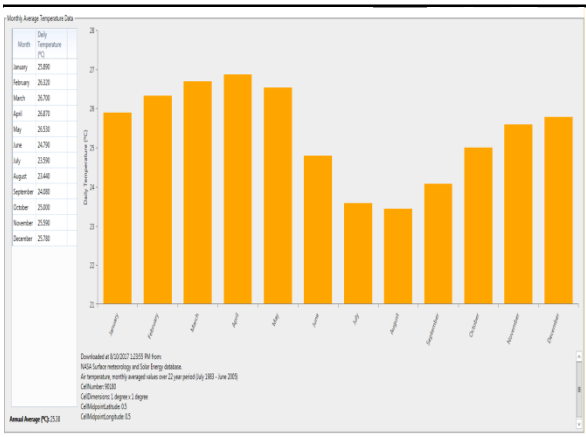


Figure 3:The annual temperatures for the house

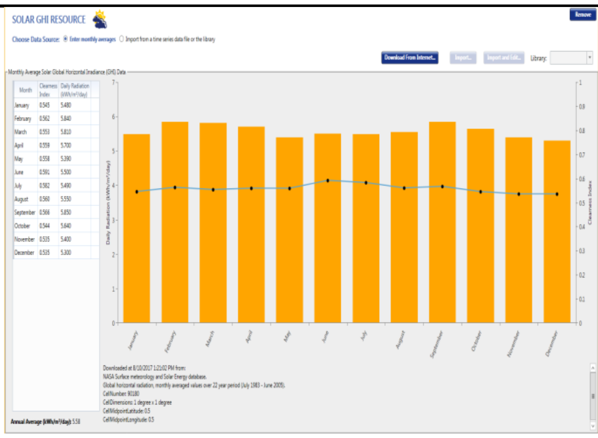


Figure 4:Annual Solar GHI resource for the house

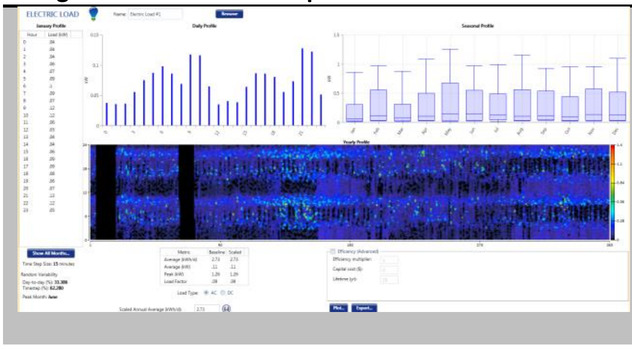


Figure 7:Load profile data

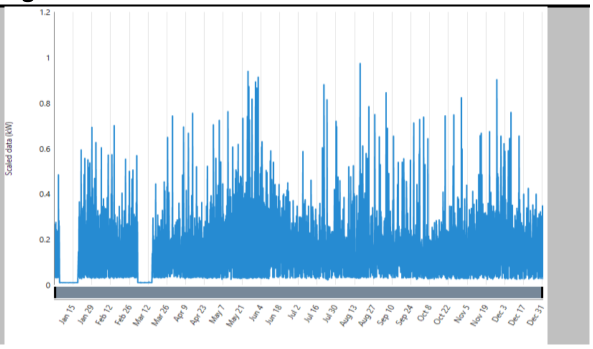


Figure 8:Load consumption graph for the household for one year

Grid Modelling

After loading our data the next step is to add the grid. We set the buying price according to energy Australia market prices available for the customers. We selected 41.5c plus 6 cents per kWh to incorporate the daily supply charges. Using the current rates of solar feed in tariffs we established a sell back price of 11.3c per kWh according to solarcalculator.com.au.

Prices

Price: Buy @ 47.5c per kWh with supply charges averaged at 6c/kw/hr.

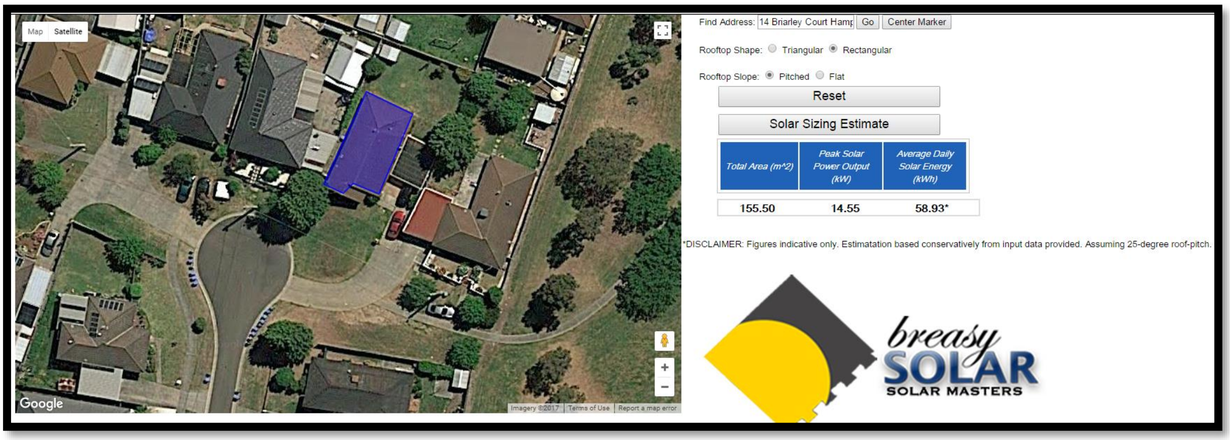
Sell @ 11.3c per kWh

Electricity Charges: Residential Time of Use

Applicable Charges	Price (excl. GST)	Price (incl. GST)
Usage • Peak usage per day • Between 7am & 11pm, Monday to Friday AEST	37.78 cents per kWh	41.558 cents per kWh
Usage • Off-Peak usage per day (if applicable) • All other times	20.30 cents per kWh	22.33 cents per kWh
Daily Supply Charge	128.00 cents per day	140.80 cents per day

PV panel Modelling

Looking at the simulation we can see that the average daily power usage is around 2.62kWh per day. We decided to set our total PV generation at 1.5kWh this option gives us a reasonable capital cost and optimisation. Other factors considered were the insolation which averaged 4 kWh /m^2/day and peak of 6.12 kWh /m^2/day in January.



Using the roof size area we can calculate the number of PV panels required for a 1.5kW capacity. To come up with a good design we need to research on the panels available, prices and reliability. Using a comparison among best available panels we decided to choose Suntech STP250-20/Wd solar panels for our design. Other factors considered in this design were a 5 year transferable power output warranty: 5 year/95%, 12 year/90%, 18 year/85%, 25 year/80% and 10 year material and workmanship warranty.

To verify that this meets the rooftop size requirements we calculate the total area occupied by the panels as follows:

$$P_{dc,STC} = 1\ \mathrm{kW/m^2}\ \text{insolation} \cdot A\ (\mathrm{m^2}) \cdot \eta$$

$$A(m^2) = \frac{P_{DC,STC}}{1kW/m^2 \times \eta}$$

Suntech STP250-20/Wd solar panel has a 15.7% efficiency therefore the required area is calculated as:

$$A(m^2) = \frac{1.5kW}{1kW/m^2 \times \eta} = \frac{1.5kW}{1kW/m^2 \times 0.157} = \mathbf{9.55m^2}$$

Or we can say each Suntech panel dimensions - ***1640 × 992 × 35mm*** giving an area of $1.63m^2$ per panel
Total area required: $1.63 \times 6 = \mathbf{9.78m^2}$
Both calculations confirm that the arrangement can fit on our roof which has a capacity of ***155.5m²***
*Total cost of PV panels: **$203*** $\times \mathbf{6} = \$\mathbf{1218}$
Assume installation total cost of $800
Total capital is $2018
With 6 modules in total, we can have a combination of:
1x6, 6x1, 2x3, 3x2,

Sunny Boy 1.5 MPPT range is 160-500V
With 2 modules per string the STC rated voltage would be 2 × 30.8 = 61.6V, - out of MPPT range
With 3 modules per string the STC rated voltage would be 3 × 30.8 =92.4V, - out of MPPT range
With 6 modules per string the STC rated voltage would be 6 × 30.8 = 184.8V, - within MPPT range
Considering the roof layout it would be reasonable to use a 6×1 arrangement.
It is imperative to estimate the maximum open-circuit voltage of the PV array and confirm it does not violate the highest DC voltages that the inverter can handle. In our case the inverter accepts 600V. Our design has 6 modules in series and 1 in parallel.
With 6 modules in series, and a VOC at STC of 37.4 V, the string voltage would be 6 ×37.4 =224.4 V. This is below the 600V that our inverter can handle. Also assuming the coldest day of -2°, VOC would be:

$$V_{OC,max} = V_{OC,string} \times [1 + 0.0038(T_{STC} - T_{amb})$$

$$\boldsymbol{Voc = 224.4 \times [1 + 0.0038(25 + 2)] = 247V}$$

Still below the 600V

Final PV specifications:

Name	Panel Type	Capacity	Array	Price per PV
Suntech STP250	Flat plate	250W	6×1	$203

Converter Modelling

The system inverter converts DC into AC power. Using our daily peak power generated from the PV we can propose a suitable inverter for the system. Generally the inverter has to be bigger than the PV rated capacity however due to losses and efficiency of the PV panels' one can choose an underrated inverter. In our design we decided to go with 4.5kW inverter to match the rated PV power.

Name	Capacity	MPP	Output current	Price per PV
Sunny Boy 1.5	1500W	600V	7A	$1975

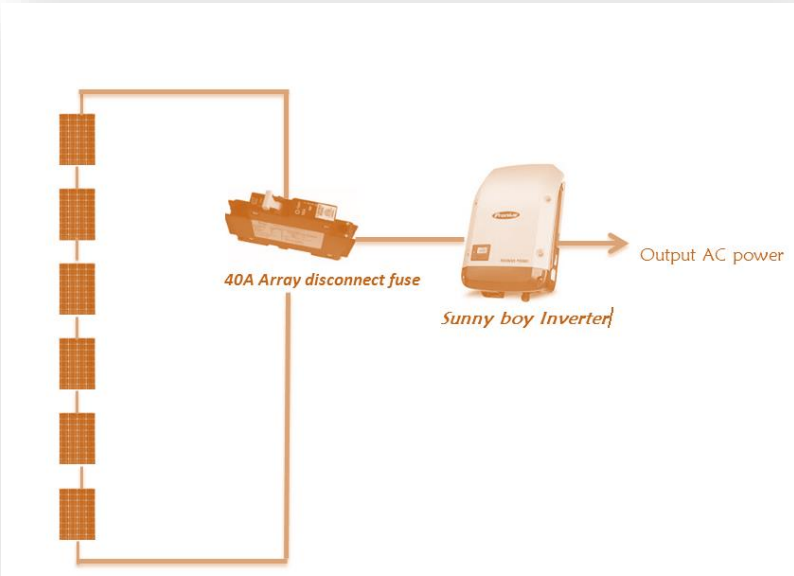
Fuse Modelling

The STC short-circuit current for each string of module is 8.63A. We apply the 125% factor for effects of high insolation and low temperature and a 25% to carter for oversizing.

Combiner fuse is therefore: $8.63 \times 1.25 \times 1.25 = 13.48$A hence we use a **15A combiner fuse**.

The array disconnect fuse should accommodate 1 strings hence it must handle Array disconnect fuse greater than $13.48 \times 1 = 13.48$A choose a **15A array disconnect fuse**.

Considering a 1.25 current multiplier to the 1500W, 360V inverter, the inverter fuse must be rated $1.25 \times \frac{1500}{360}$=5.2A therefore use **6A inverter fuse.**



Battery Modelling

A battery bank will help our design store any excess energy before we sell the rest to the grid. By allowing the system to use more power generated by PV rather than buying from the grid, we can optimise our system. A battery would be helpful to store enough power during cloudy days or at night. With 1260 peak watts as simulated by the software, a suitable system voltage would be 24 V (to avoid currents more than 100 A).

$$Ah\ from\ batteries = \frac{Power\ to\ load}{System\ Voltage\ x\ Inverter\ Eff} \qquad = \frac{2620W}{24 \times 0.97} = 112.5\text{AH}$$

$$Amp\ hrs\ to\ batteries = \frac{Ah\ out}{Coulomb\ efficiency} = \frac{112.5}{0.8} = 140.6\text{Ah}$$

Based on these calculations we chose a Surrette s260 battery with the following specs.

Battery cost $289

Installation $150

Total cost $439

Nominal Voltage	Nominal Capacity	Maximum Capacity	Efficiency	Max Charge Current	Price per unit
12V	1.36kWh	113 Ah	85%	250A	$289

Other factors considered were reliability and costs and that the battery is designed for on/off-grid systems. This battery also has a 7 year warranty.

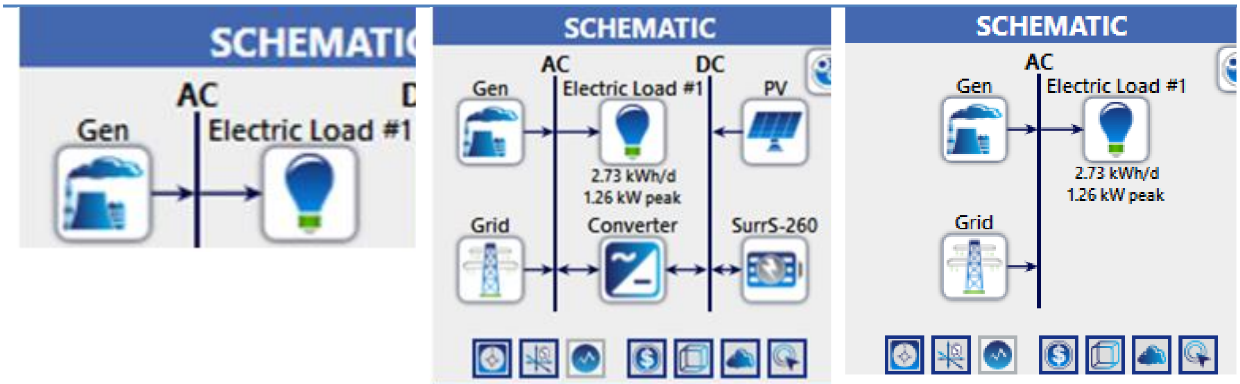
We require 1260W therefore the number of batteries required is:

Voltage $= 2 \times 12 = 24V$

Current $= \frac{1260}{24} = 52.4A$

Total number of batteries ***required 2 in series.***

System Modelling



Generator Only | Complete System | Generator and Grid Only

2. SIMULATION AND OPTIMISATION RESULTS

Simulation 1 – Grid Connected (Buy: 47.5c/Kwh, Sell: 11.3 /Kwh)

Architecture		Cost				System		Grid	
Grid (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Excess Elec (kWh/yr)	Energy Purchased (kWh)	Energy Sold (kWh)
999,999	CC	$0.475	$6,110	$472.61	$0.00	0	0	995	0

Optimization

Left Double Click on a particular system tc

Architecture		Cost				System		Grid	
Grid (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Excess Elec (kWh/yr)	Energy Purchased (kWh)	Energy Sold (kWh)
999,999	CC	$0.475	$6,110	$472.61	$0.00	0	0	995	0

Figure 1-Grid simulation results

Simulation 2- Diesel price $128c/litre, Grid Price Unchanged

Architecture		Cost				System	Gen
Gen (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Production (kWh)
1.40	CC	$3.41	$110,913	$3,341	$1,750	0	3,078

Figure 2-Diesel and load only

Simulation 3: Sensitivity analysis, Diesel Price increased by 50%

Architecture		Cost				System	Gen
Gen (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Production (kWh)
1.40	CC	$4.43	$144,114	$4,358	$1,750	0	3,078

Figure 3-Diesel and load only

Simulation 4-Diesel generator with grid only

Architecture			Cost				System	Gen	Grid		
Gen (kW)	Grid (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Production (kWh)	Capacity	Energy Purchased (kWh)	Energy Sold (kWh)
	999,999	CC	$0.475	$15,441	$472.61	$0.00	0		999,999	995	0
1.40	999,999	CC	$0.520	$18,338	$507.72	$1,750	0	128	999,999	952	84.7

Figure 4-Diesel and Grid connected

Simulation 5 - Diesel price 128c/litre, Grid Price (Buy: 47.5 c/Kwh, Sell: 11.3c/Kwh) (Current pricing) No Renewable rebates.

Architecture						Cost				System	Gen	PV		31-AGM		Grid		
PV (kW)	Gen (kW)	31-AGM	Grid (kW)	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Production (kWh)	Capital Cost ($)	Production (kWh)	Autonomy (hr)	Annual Throughput (kWh)	Capacity	Energy Purchased (kWh)	Energy Sold (kWh)
1.50			999,999	1.50	CC	$0.0911	$7,644	$137.56	$3,150	77.2		2,018	2,089			999,999	585	1,575
1.50		4	999,999	1.50	LF	$0.122	$7,799	$115.44	$4,028	96.7		2,018	2,089	38.2	594	999,999	64.4	963
1.50	1.40		999,999	1.50	CC	$0.125	$10,931	$184.59	$4,900	73.9	127	2,018	2,089			999,999	575	1,692
1.50	1.40	4	999,999	1.50	LF	$0.166	$11,121	$163.53	$5,778	91.9	127	2,018	2,089	38.2	611	999,999	39.4	1,058
		4	999,999	1.50	LF	$0.520	$16,914	$456.18	$2,010	0.382				38.2	4.34	999,999	991	0
	1.40	4	999,999	1.50	CC	$0.562	$19,821	$491.59	$3,760	0	128			38.2	1.18	999,999	951	83.8

Figure 5-Whole System

<u>SIMULATION 6 - DIESEL COST @ CURRENT RATE AND A 40% GOVERNMENT REBATE ON PV PANEL, CONVERTER AND BATTERIES WITH NO CHANGE IN GRID PRICE.</u>

Architecture						Cost				System	Gen	PV		31-AGM		Grid		
PV (kW)	Gen (kW)	31-AGM	Grid (kW)	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Production (kWh)	Capital Cost ($)	Production (kWh)	Autonomy (hr)	Annual Throughput (kWh)	Capacity	Energy Purchased (kWh)	Energy Sold (kWh)
		2	999,999	1.50	LF	$1.07	$2,846	$475.25	$1,571	0.191				19.1	2.17	999,999	993	0
1.50			999,999	1.50	CC	$0.501	$3,454	$113.47	$3,150	77.2		2,018	2,089			999,999	585	1,575
1.50		2	999,999	1.50	LF	$0.694	$3,818	$85.30	$3,589	93.0		2,018	2,089	19.1	504	999,999	143	1,056
	1.40	2	999,999	1.50	LF	$1.77	$4,731	$525.64	$3,321	0	128			19.1	72.4	999,999	889	0
1.50	1.40		999,999	1.50	CC	$0.752	$5,423	$194.97	$4,900	73.9	127	2,018	2,089			999,999	575	1,692
1.50	1.40	2	999,999	1.50	LF	$1.01	$5,791	$168.48	$5,339	88.7	127	2,018	2,089	19.1	525	999,999	115	1,149

Figure 6-Whole System

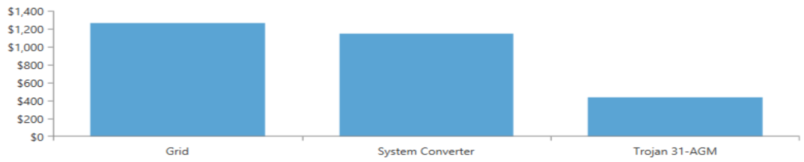
System Architecture: Trojan 31-AGM (1.00 strings) HOMER Load Following
System Converter (1.50 kW)
Grid (999,999 kW)

Total NPC: $2,846.21
Levelized COE: $1.07
Operating Cost: $475.25

Cost Summary | Cash Flow | Compare Economics | Electrical | Trojan 31-AGM | Grid | System Converter | Emissions

Cost Type: Net Present / Annualized

Categorize: By Component / By Cost Type



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Grid	$0.00	$0.00	$1,265.71	$0.00	$0.00	$1,265.71
System Converter	$1,132.00	$9.79	$0.00	$0.00	-$0.138	$1,141.66
Trojan 31-AGM	$439.00	$0.00	$0.00	$0.00	-$0.154	$438.85
System	$1,571.00	$9.79	$1,265.71	$0.00	-$0.291	$2,846.21

Figure 7-Expense Plot of the optimised system

3. PRACTICALITY OF THE OPTIMISATION RESULTS

Our initial design consisted of a 4.5kW PV system however this was not practical and we had to redesign our system with a 1.5kW PV system. From the optimisation results simulation 6 is not that practical as there is storage battery with no PV system.

4. DISCUSSION

Simulation 1 – Optimised (**Grid only**) - from the simulation we determined a base average of ***995kWh*** usage in one year. The next stage of the design was to add a diesel generator. The generator will be used as backup in the event that other power sources are no longer available.

Simulation 2 – Optimised **(Diesel only) -** the operating cost when the generator is the only source of power is $3341 with an initial capital cost of $1750

Simulation 3- Optimised **(Diesel only) - 50%** increase in diesel price= 128/100×50+128=192c/L. This is the price used for the simulation. When comparing simulation 2 and 3 it can be noted that when the diesel price is hiked the operating cost which was initially $3341 increases by $1017 because of the higher cost involved in operation however the initial capital costs remain the same.

Simulation 4- Optimised **(Diesel and Grid only) - b**y examining the results is can be seen that the output is identical to the grid only connection system. We are assuming load shedding and the simulation takes into consideration the pre-set load shedding times. The optimised result from the simulation gives us an initial capital coast of $1750 and operation cost of $472 per month.

Simulation 5 – The optimised (**Grid and PV only**) operating cost for the whole system is $137 per month with a capital cost of $3150. Other optimisation results which include the whole components result in an operating cost of $167 which is a bit higher. The initial capital cost for this setup would be $5778. With a sell back price of 11c/kW we can realise 0.113×1575×12 = $2135.7 per year income.

Simulation 6 – Optimised (**Grid and battery only**) - Introducing the rebate results in increased operating costs from $137 to $475; however the initial capital cost is reduced by $1579.

5. CONCLUSION

6. REFERENCE

http://www.solarroofcalculator.appspot.com/

https://www.choice.com.au/home-improvement/energy-saving/solar/review-and-compare/solar-panels