

HOMER Training for Renewable Energy System Modeling

Community Energy Malawi
Wind Empowerment

Training Session
21st January, 2016

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HOMER – simulation tool for hybrid electricity systems

HOMER is an electrical system design and simulation package which simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone, and distributed generation (DG) applications.

HOMER's optimization and sensitivity analysis algorithms allow the user to evaluate the economic and technical feasibility of a large number of technology options and to account for uncertainty in technology costs, energy resource availability, and other variables.

It was initially produced by NREL, but is now a commercial organization HOMER ENERGY..

Download the program

The (free) HOMER Legacy version is available here:

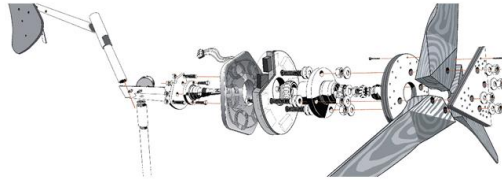
http://www.homerenergy.com/HOMER_legacy.html

You will need to register and apply to download this file. HOMER Legacy is no longer supported by HOMER ENERGY, and is slowly being phased out to be replaced by HOMER PRO.

HOMER Pro is a more commercial product which is will be replacing within soon HOMER Legacy:

<http://www.homerenergy.com/>

This has a free 30-day trial version.

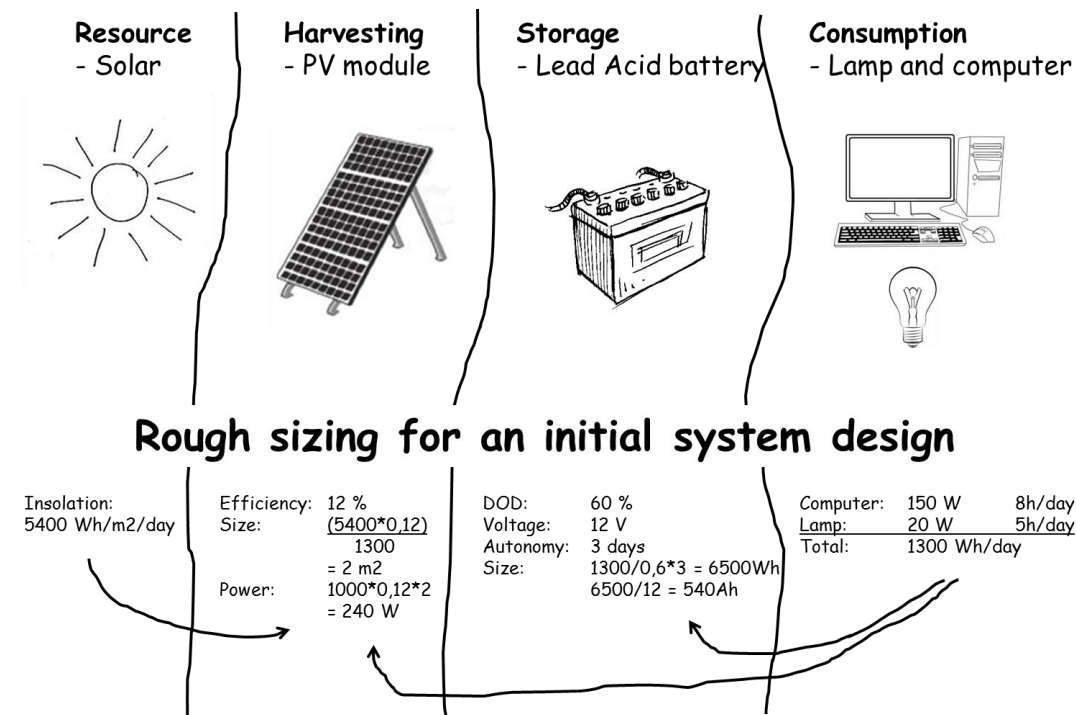


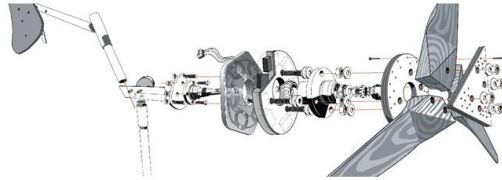
Test System

In order to run this exercise, we will start by creating a small solar electricity system intended to supply a load of a PC and a lamp.

- Let us locate the system in Lilongwe, which gives us an average of about 5,4 kWh/m²/day of solar input.
- We want to power a computer 8 hours per day and a lamp 5 hours per day. That requires 1300 Wh per day. Let us further pretend that the computer use DC power.
- The battery should be large enough to store energy for 3 days of no sunshine. We try and some locally available 12V mono block, and to spare it a bit we don't discharge more than 60% of the nominal capacity. Hence, we will need 540Ah.
- The solar cells have to provide at least 1300Wh per day on average to the loads. Assuming an efficiency of 12% and given the insolation in Lilongwe, we will need about 2 m², which corresponds to about 240W peak-power.

There is nothing accurate about this rough sizing, but gives us starting point.





HOMER Legacy Instructions

Starting a project

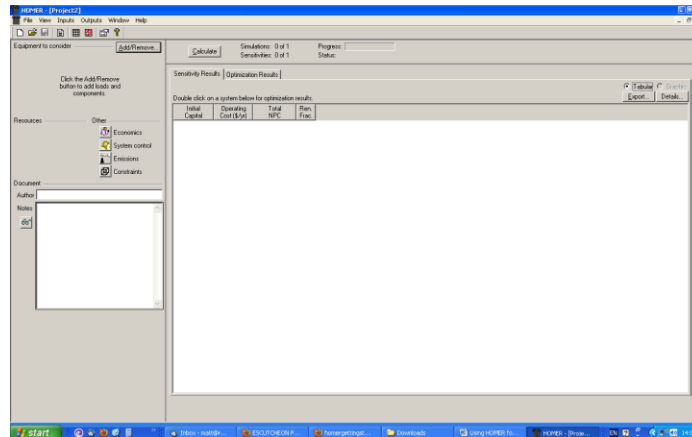
HOMER is a complex package which allows design of relatively complex systems. This is simple run through of the basics to get you going. You will be using HOMER for the group design project. Also, please refer to the 'getting started' guide (<http://www.homerenergy.com/downloads/homergettingstarted210.pdf>).

Create a HOMER file

HOMER files end in .hmr.

Go to File -> New

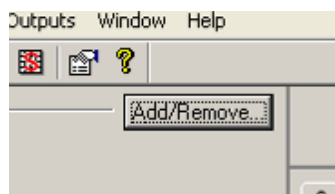
You should get a page looking like this:



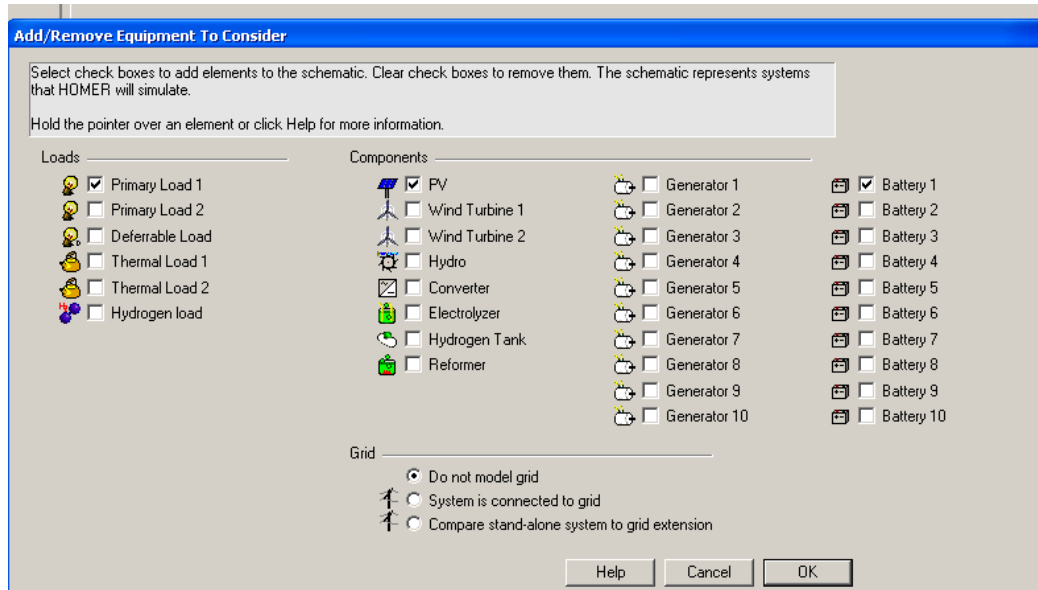
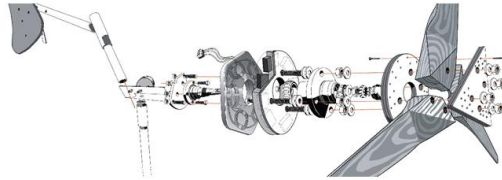
We are going to create a small stand-alone system with one solar panel, one battery and one load and then run some simulations.

Create our Solar/Battery System

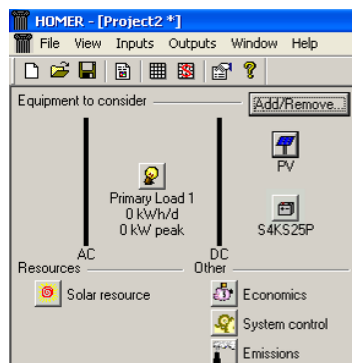
Click on the Add/Remove button:



This will give you a pop-up box. We want one primary load, one solar PV panel and one battery, so click on each of those, then click 'OK':



You will see that these components are placed in the top left hand corner:



HOMER is relatively intuitive – if you would like to change anything then click on the component.

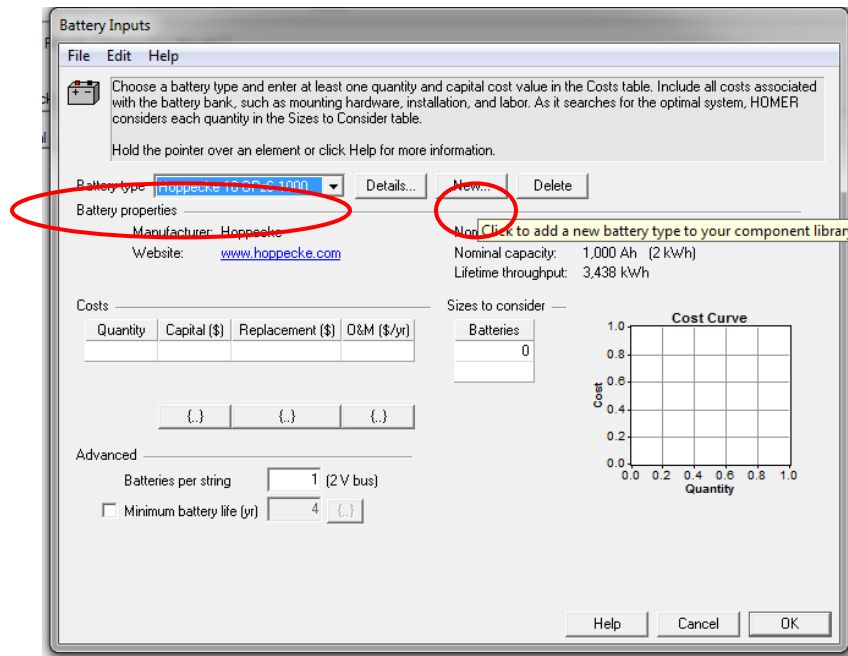
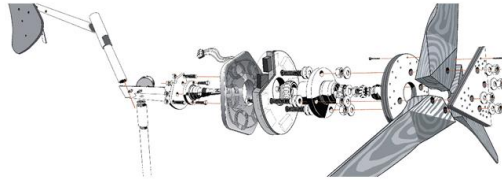
Battery

Let us change the battery type to define one that fit our system.

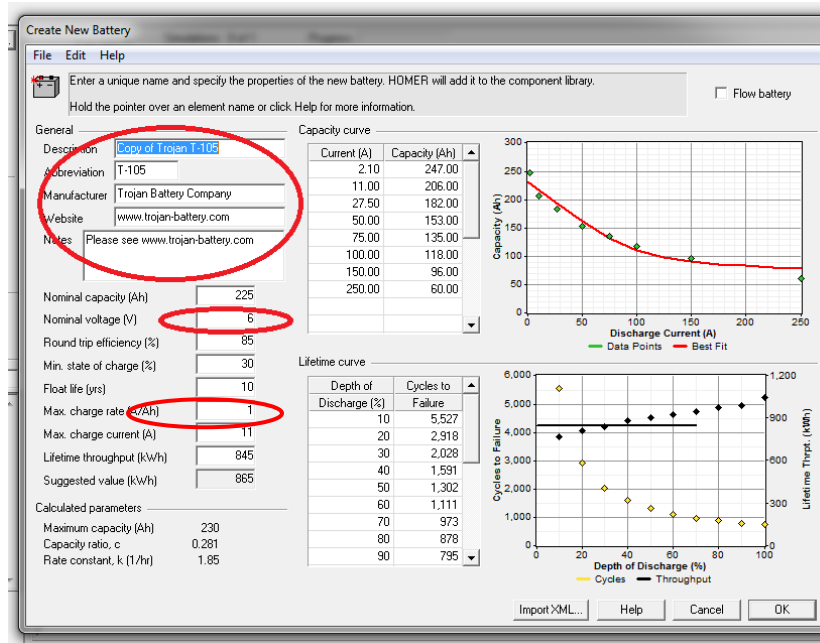
Click on the battery image:



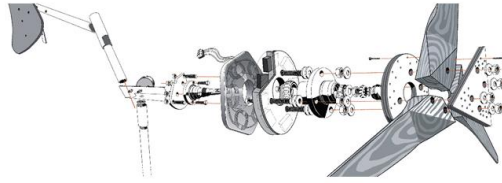
This will bring up a pop up box with details on the battery, as shown in the screen shot below.. We will create a new battery type. Use the scroll list to choose the battery named “Trojan T-105”, and click “New” to create a copy of this battery to the component library.



Once you have got a copy of the battery, you can change the properties. In our case we want to work with a 12V battery rather than the original 6V. Change that. We also said that we don't want to discharge more than 60%. Hence, Min. state of charge should be put to 40%.



Once you are done, it should look like in the screenshot below. Click "OK" to save your new battery.



Create New Battery

File Edit Help

Enter a unique name and specify the properties of the new battery. HOMER will add it to the component library. Flow battery

Hold the pointer over an element name or click Help for more information.

General

Description: New Battery

Abbreviation: NB

Manufacturer: New Battery Company

Website:

Notes:

Nominal capacity (Ah): 225

Nominal voltage (V): 12

Round trip efficiency (%): 85

Min. state of charge (%): 40

Float life (yrs): 10

Max. charge rate (A/Ah): 1

Max. charge current (A): 11

Lifetime throughput (kWh): 1721

Suggested value (kWh): 1721

Calculated parameters

Maximum capacity (Ah): 233

Capacity ratio, c: 0.252

Rate constant, k (1/hr): 2.13

Capacity curve

Current (A)	Capacity (Ah)
2.10	247.00
11.00	206.00
27.50	182.00
50.00	153.00
75.00	135.00
100.00	118.00
150.00	96.00
250.00	60.00

Lifetime curve

Depth of Discharge (%)	Cycles to Failure
10	5,527
20	2,918
30	2,028
40	1,591
50	1,302
60	1,111
70	973
80	878
90	795

Capacity (Ah) vs Discharge Current (A)

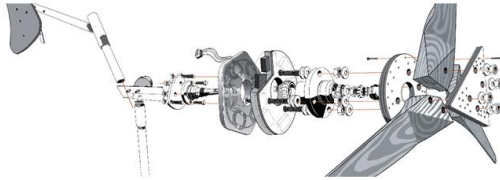
Legend: Data Points (green diamonds), Best Fit (red line)

Cycles to Failure and Lifetime Throughput (kWh) vs Depth of Discharge (%)

Legend: Cycles (yellow diamonds), Throughput (black diamonds)

Import XML... Help Cancel OK

HOMER simulates the system also based on costs, and to make that possible, we will need to add some economic parameters to our new battery. Further, we will need to tell HOMER how batteries it ought to consider when trying out various system configurations. Looking back at our rough system design we need 540Ah battery capacity, should be about 2 of our New Batteries, each having 265Ah. Let us set the search space “Sizes to Consider” to 1, 2, 3 batteries.



Battery Inputs

File Edit Help

Choose a battery type and enter at least one quantity and capital cost value in the Costs table. Include all costs associated with the battery bank, such as mounting hardware, installation, and labor. As it searches for the optimal system, HOMER considers each quantity in the Sizes to Consider table.

Hold the pointer over an element or click Help for more information.

Battery type: Details... New... Delete

Battery properties

Manufacturer: New Battery Company
Website: _____

Nominal voltage: 12 V
Nominal capacity: 225 Ah (2.7 kWh)
Lifetime throughput: 1,688 kWh

Quantity	Capital (\$)	Replacement (\$)	O&M (\$/yr)
1	200	200	10.00
(.)	(.)	(.)	(.)

Sizes to consider

Batteries

- 1
- 2
- 3

Advanced

Batteries per string: (12V bus)

Minimum battery life (yr): (.)

Cost Curve

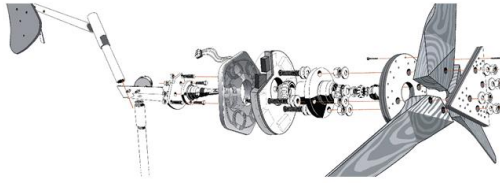
Quantity	Capital Cost (\$)	Replacement Cost (\$)
0.0	0	0
1.0	200	100
2.0	400	200
3.0	600	300

Help Cancel OK

Then click OK.

Save your work

Now is a good time to save the project. As usual click File-> Save As and then enter a sensible filename and save to a sensible place.



Solar Panel

Let us change the solar PV panel properties.
Click on the PV symbol:



Let us assume that we can find 120W panels at a price of \$400 a piece. Further, like for the batteries, we need to set the search space to limit the various system variations that we allow HOEMR to try. Set “Sizes to consider” to **0, 0.12, 0.24, 0.36, 0.48, 0.6, 0.72 and 0.84**. Further, since we are south of the equator, the Azimuth should be set to 180 as a start configuration. Fill in the pop up box as shown:

PV Inputs

File Edit Help

Enter at least one size and capital cost value in the Costs table. Include all costs associated with the PV (photovoltaic) system, including modules, mounting hardware, and installation. As it searches for the optimal system, HOMER considers each PV array capacity in the Sizes to Consider table.

Note that by default, HOMER sets the slope value equal to the latitude from the Solar Resource Inputs window.

Hold the pointer over an element or click Help for more information.

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/yr)
0.120	400	350	10
(.)	(.)	(.)	(.)

Sizes to consider

Size (kW)
0.000
0.120
0.240
0.360
0.480

Cost Curve

Properties

Output current AC DC

Lifetime (years) (.)

Deraing factor (%) (.)

Slope (degrees) (.)

Azimuth (degrees W of S) (.)

Ground reflectance (%) (.)

Advanced

Tracking system

Consider effect of temperature

Temperature coeff. of power (%/°C) (.)

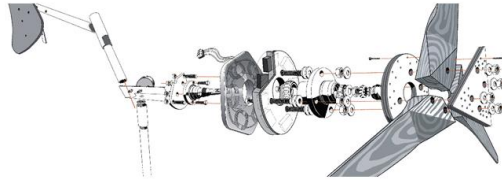
Nominal operating cell temp. (°C) (.)

Efficiency at std. test conditions (%) (.)

Help Cancel OK

Load Profile

For the system design we need to add our computer and lamp as electric loads. This gets a bit more complex as loads will vary through the day. Click on the “Load” icon which will bring up the following screen:



Primary Load Inputs

File Edit Help

Choose a load type (AC or DC), enter 24 hourly values in the load table, and enter a scaled annual average. Each of the 24 values in the load table is the average electric demand for a single hour of the day. HOMER replicates this profile throughout the year unless you define different load profiles for different months or day types. For calculations, HOMER uses scaled data: baseline data scaled up or down to the scaled annual average value.

Hold the pointer over an element or click Help for more information.

Label: Primary Load 1 Load type: AC DC Data source: Enter daily profile(s) Import time series data file Import File...

Baseline data

Month: January Day type: Weekday

Hour	Load (kW)
12:00 - 13:00	0.000
13:00 - 14:00	0.000
14:00 - 15:00	0.000
15:00 - 16:00	0.000
16:00 - 17:00	0.000
17:00 - 18:00	0.000
18:00 - 19:00	0.000
19:00 - 20:00	0.000
20:00 - 21:00	0.000
21:00 - 22:00	0.000
22:00 - 23:00	0.000
23:00 - 00:00	0.000

Random variability: Day-to-day 15%, Time-step-to-time-step 20%

Scaled annual average (kWh/d): 0

	Baseline	Scaled
Average (kWh/d)	0.00	0.00
Average (kW)	0.00	0.00
Peak (kW)	0.00	0.00
Load factor	1.00	1.00

Efficiency Inputs... Plot... Export... Help Cancel OK

Let us say that the 20W lamp is used for 4 hours every evening from 18.00 to 22.00, and 1 hour in the morning from 06.00 to 07.00. Further, the 150W computer is used from 08.00 to 16.00. Enter in the information in the table on the left as shown in the screen shot below. Also remember to assume that both loads are DC loads. Click “OK” when you are done.

Primary Load Inputs

File Edit Help

Choose a load type (AC or DC), enter 24 hourly values in the load table, and enter a scaled annual average. Each of the 24 values in the load table is the average electric demand for a single hour of the day. HOMER replicates this profile throughout the year unless you define different load profiles for different months or day types. For calculations, HOMER uses scaled data: baseline data scaled up or down to the scaled annual average value.

Hold the pointer over an element or click Help for more information.

Label: Primary Load 1 Load type: AC DC Data source: Enter daily profile(s) Import time series data file Import File...

Baseline data

Month: January Day type: Weekday

Hour	Load (kW)
11:00 - 12:00	0.150
12:00 - 13:00	0.150
13:00 - 14:00	0.150
14:00 - 15:00	0.150
15:00 - 16:00	0.150
16:00 - 17:00	0.000
17:00 - 18:00	0.000
18:00 - 19:00	0.020
19:00 - 20:00	0.020
20:00 - 21:00	0.020
21:00 - 22:00	0.020
22:00 - 23:00	0.000

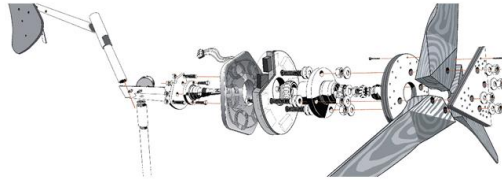
Random variability: Day-to-day 15%, Time-step-to-time-step 0%

Scaled annual average (kWh/d): 1.29

	Baseline	Scaled
Average (kWh/d)	1.29	1.29
Average (kW)	0.0537	0.0537
Peak (kW)	0.220	0.220
Load factor	0.245	0.245

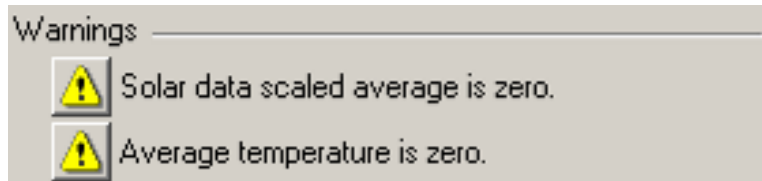
Efficiency Inputs... Plot... Export... Help Cancel OK

Now we have finished with the system design, but we still need to enter the solar resource for Lilongwe.



Add the resource data

You can see that there are still warnings about the system shown on the left of the page:



We need to sort out these warnings, so let us start by adding the solar data:

Click on 'Solar resource'. This will bring up the pop up box below:

Solar Resource Inputs

HOMER uses the solar resource inputs to calculate the PV array power for each hour of the year. Enter the latitude, and either an average daily radiation value or an average clearness index for each month. HOMER uses the latitude value to calculate the average daily radiation from the clearness index and vice-versa.

Hold the pointer over an element or click: Help for more information.

Location

Latitude: 0° 0' North South Time zone: (GMT) Iceland, UK, Ireland, West Africa

Longitude: 0° 0' East West

Data source: Enter monthly averages Import time series data file

Baseline data

Month	Clearness Index	Daily Radiation (kWh/m ² /d)
January	0.000	0.000
February	0.000	0.000
March	0.000	0.000
April	0.000	0.000
May	0.000	0.000
June	0.000	0.000
July	0.000	0.000
August	0.000	0.000
September	0.000	0.000
October	0.000	0.000
November	0.000	0.000
December	0.000	0.000
Average:	0.000	0.000

Global Horizontal Radiation

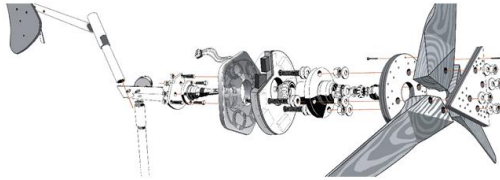
Daily Radiation (kWh/m²/d) vs Clearness Index

Scaled annual average (kWh/m²/d): 0

Buttons: Plot..., Export..., Help, Cancel, OK

The coordinates for Malawi – Longitude is 33° 42' E and Latitude: 13° 57' S.

Enter in this data then click on 'Get Data Via Internet' (this assumes you have an internet connection). You will have to enter an email address. This brings in the data we need:



Solar Resource Inputs

File Edit Help

HOMER uses the solar resource inputs to calculate the PV array power for each hour of the year. Enter the latitude, and either an average daily radiation value or an average clearness index for each month. HOMER uses the latitude value to calculate the average daily radiation from the clearness index and vice-versa.

Hold the pointer over an element or click Help for more information.

Location

Latitude 13 ° 57 ' North South Time zone
Longitude 33 ° 42 ' East West (GMT) Iceland, UK, Ireland, West Africa

Data source: Enter monthly averages Import time series data file

Baseline data

Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.439	4.948
February	0.457	5.037
March	0.495	5.134
April	0.562	5.209
May	0.606	4.945
June	0.632	4.793
July	0.635	4.964
August	0.622	5.444
September	0.634	6.267
October	0.599	6.435
November	0.561	6.258
December	0.489	5.513
Average:	0.554	5.413

Global Horizontal Radiation

Scaled annual average (kWh/m2/d) 5.41

Plot... Export... Help Cancel OK

Click 'OK'.

Note that there should not be any warnings now. It's probably a good time to save your work.

Performing the simulation

Now you have designed the system and included the resource parameters you can run the simulation.

Click on the 'Calculate' button.

HOMER - [Lecture1.hmr *]

File View Inputs Outputs Window Help

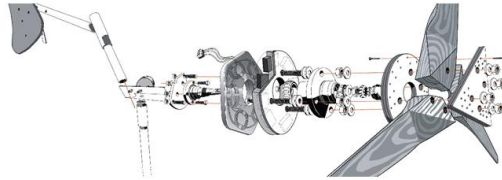
Equipment to consider: Add/Remove... Calculate Simulations: 15 of 15 Progress: Completed in 0 seconds. Sensitivities: 1 of 1 Status: Completed in 0 seconds.

Sensitivity Results Optimization Results

Double click on a system below for simulation results.

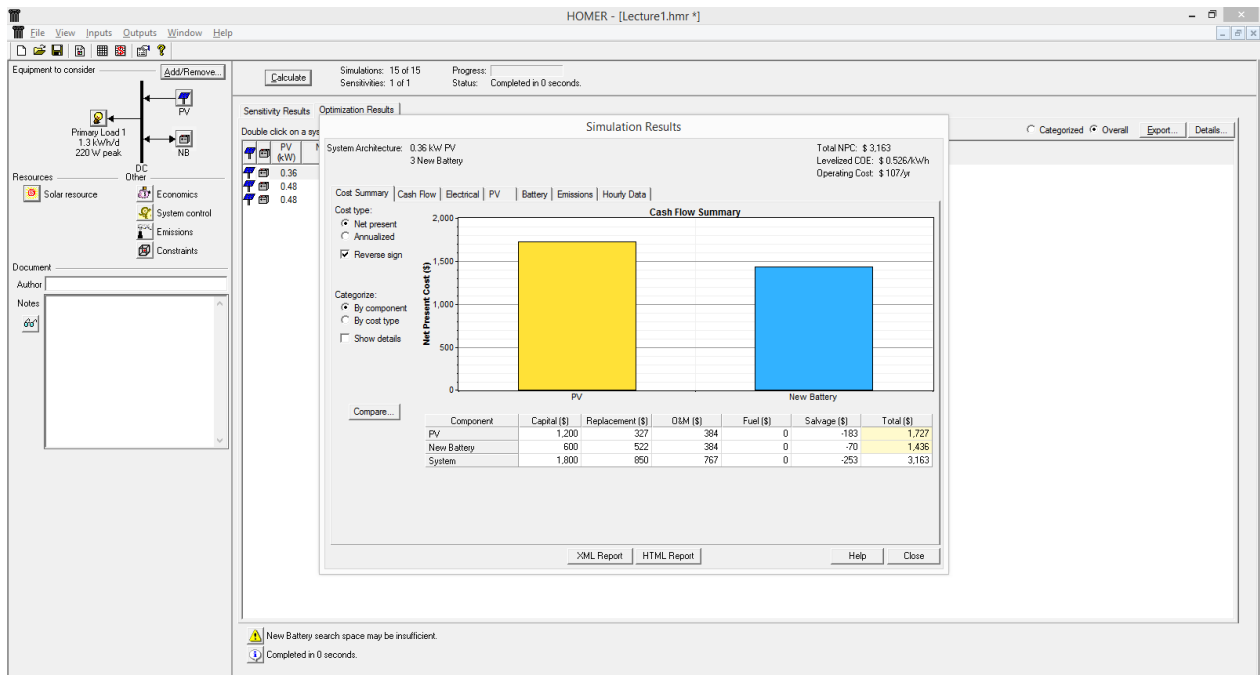
	PV (kW)	NB	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kWh)	Ren. Frac.
	0.36	3	\$ 1,800	107	\$ 3,163	0.526	1.00
	0.48	2	\$ 2,000	99	\$ 3,260	0.542	1.00
	0.48	3	\$ 2,200	120	\$ 3,739	0.621	1.00

This will run a simulation and you will get a list within the optimization of the system based on the search spaces that we added for the number of batteries and the size of PV modules. Double click on any of the system configurations to get more detailed information from the results.



Results

When on 'Optimization Results' click on the system and you will get the pop up box below:



As you can see – you can look at the costs and cash flow and the various electrical parameters for the system performance. Have a click on all the different tabs and try and make sense of the results.

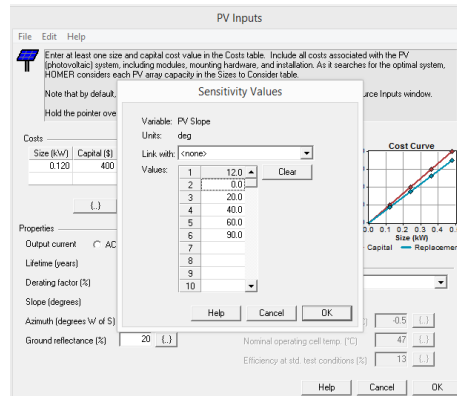
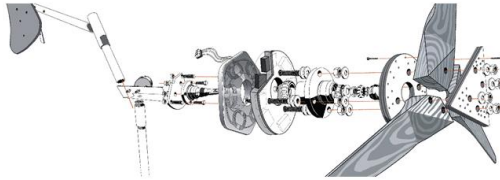
You can export any of this data or any of the graphs by clicking on the report buttons.

Sensitivity Analysis

HOMER allows us to produce many reports from different scenarios so that we can see what effects variations in resources, system configurations or loads cause the entire performance.

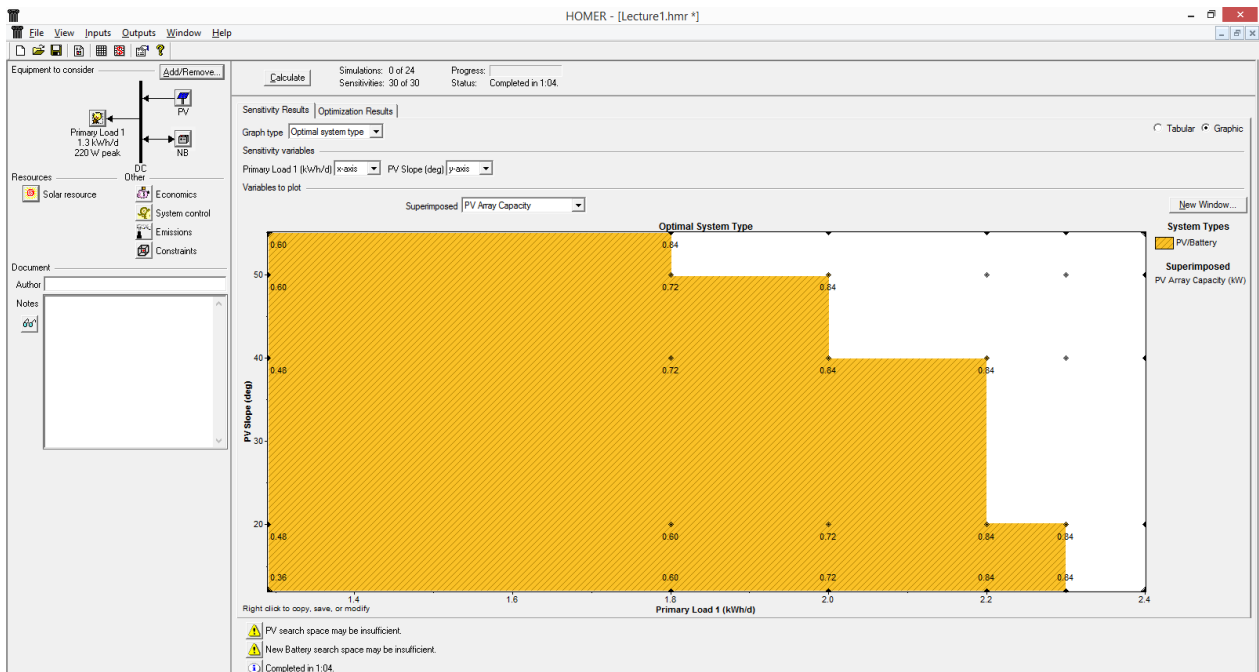
Let us try as an example so see what happens if we change the slope of the PV panels.

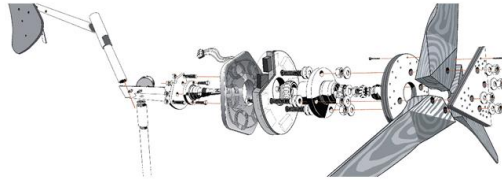
Click on the PV equipment and {...} symbol next to the "Slope" input. Here you can add different slopes to test. Add **0, 20, 40, 50 and 55** to the list.



In a similar manner, go to the “Primary Load 1” and you will find at the bottom a box called “Scaled annual average (kWh/day)”. Click the “{...}” next to it and enter **1.8, 2.0, 2.2, 2.3 and 2.4** the list in order to see what happens when the load increases.

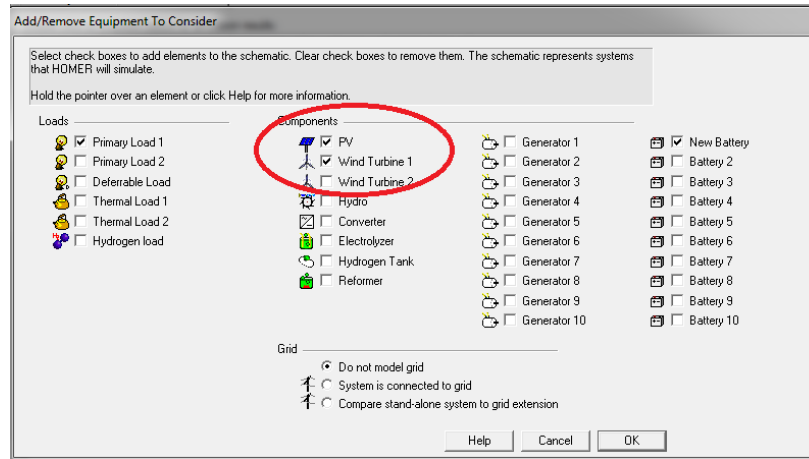
Run “Calculate” again (it will take longer this time) and explore the output result presented under the tab “Sensitivity Results”. Click “Graphic” to see how the load that can be covered varies with the slope of the PV modules. If you “Superimpose” the “PV array capacity” to the graph you will also see that the higher the slope, the large the PV array is needed to cover the same load.



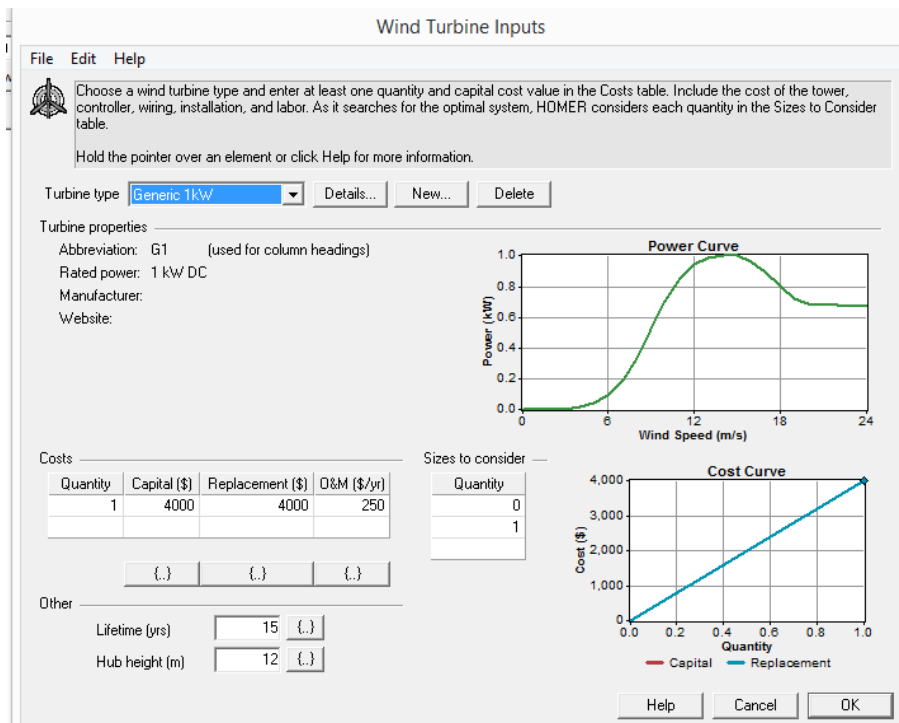


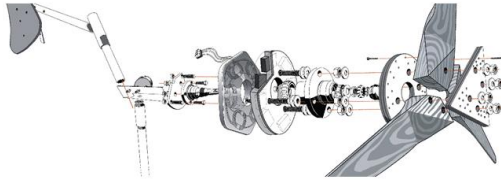
Add Wind Turbine

So far, so good. Now, let us add a small wind turbine to the system. Go back and click the “Add/Remove” button again. Mark “Wind Turbine 1” to the system.



Click on the wind turbine symbol to set the details of the turbine. Chose from the scroll list “Generic 1kW”, and enter the economic parameters for one turbine; Capital cost \$4000, replacement \$4000 and O&M \$250. Further, set the hub height to 12m.





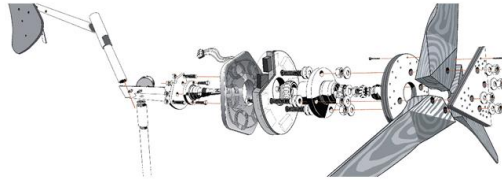
In order to simulate the output of the wind turbine, we also need to add information about the wind conditions. Go back to “Resources” and click “Wind Resource”. You cannot download wind data the same way you did with the solar data. Instead you will have to find this data yourself. One source possible, is the NASA data base:

<https://eosweb.larc.nasa.gov/cgi-bin/sse/grid.cgi?email=skip@larc.nasa.gov>

For Lilongwe we will use the following monthly average wind speed data.

January	4,13
Feburary	4
March	4,24
April	4,2
May	4,3
June	4,66
July	5,04
August	5,39
September	5,95
October	6,07
November	5,75
December	4,67

The annemometer hub height for this data is **50 m**. The altitute of Lilongwe is about **1050 m** above sea level.



Wind Resource Inputs

File Edit Help

HOMER uses wind resource inputs to calculate the wind turbine power each hour of the year. Enter the average wind speed for each month. For calculations, HOMER uses scaled data: baseline data scaled up or down to the scaled annual average value. The advanced parameters allow you to control how HOMER generates the 8760 hourly values from the 12 monthly values in the table.

Hold the pointer over an element or click Help for more information.

Data source: Enter monthly averages Import time series data file

Baseline data

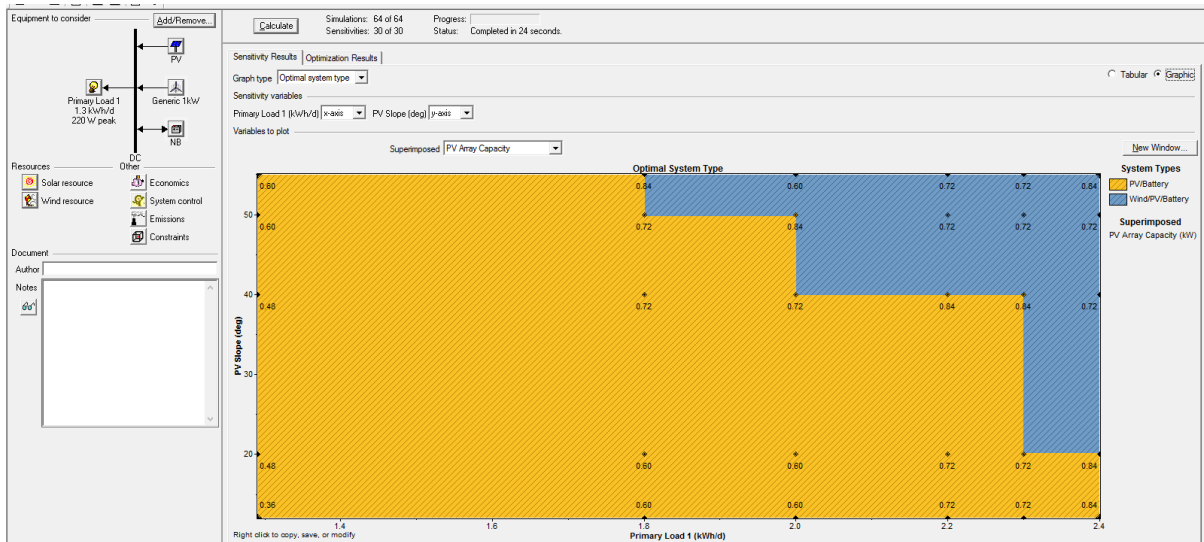
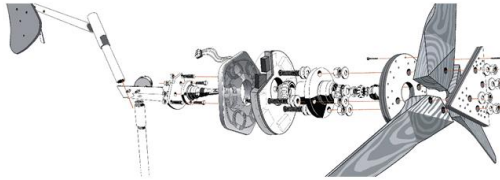
Month	Wind Speed (m/s)
January	4.130
February	4.000
March	4.240
April	4.200
May	4.300
June	4.660
July	5.040
August	5.390
September	5.950
October	6.070
November	5.750
December	4.670
Annual average:	4.871

Other parameters: Altitude (m above sea level) Anemometer height (m)

Advanced parameters: Weibull k Autocorrelation factor Diurnal pattern strength Hour of peak windspeed

Scaled annual average (m/s)

Continue to try the new system design by running the simulation again “Calculate”. You can explore the economic- and performance related effects of adding a turbine to the system. One consequence is that we now can cover the load size and PV-slope combination that previously was impossible by help from the wind turbine.



Most of the input variable can be given sensitivity parameters in a similar way in order to explore the dependency of the system performance and economy on variations of external factors.

Thank you very much for your participation!