



Green Power
for Mobile

HOMER Software Training Guide for Renewable Energy Base Station Design

Areef Kassam – Field Implementation Manager





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Introduction

HOMER is a free software application developed by the National Renewable Energy Laboratory in the United States. This software application is used to design and evaluate technically and financially the options for off-grid and on-grid power systems for remote, stand-alone and distributed generation applications. It allows you to consider a large number of technology options to account for energy resource availability and other variables.

HOMER was first developed in 1993 for internal DOE (Department of Energy) use to understand the trade-offs between different energy production configurations. A few years after the original design

NREL made a version publically available for free to serve the growing community of system designers interested in Renewable Energy. Since then HOMER has remained a free software application which has evolved in to a very robust tool for modelling both conventional and renewable energy technologies.





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Objective

HOMER is one of the tools used by the GSMA for designing renewable energy base stations. This manual goes through HOMER and the different elements within the system in detail to demonstrate the depth of the software application and instruct telecom operators on how to design renewable energy sites with HOMER and interpret the results.



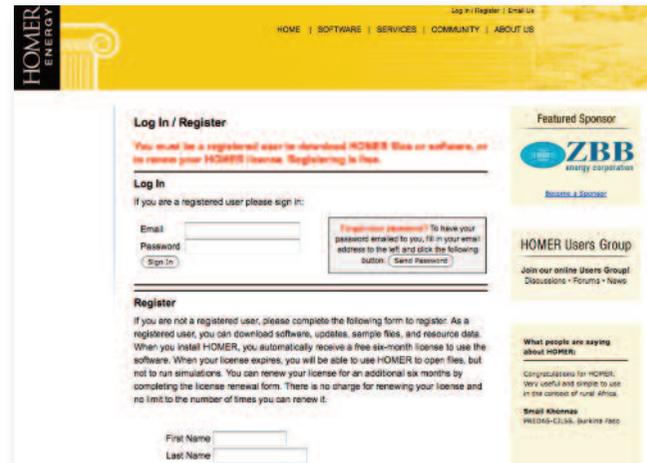


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Step 1 Downloading the Software

To download the HOMER software application go to:
<http://www.homerenergy.com/login.asp?redirect=/download.asp>

Once the application is downloaded proceed to install the application by running the .exe file. It is recommended that prior to going through the example below read the 'Getting Started Guide' available at:
<http://www.homerenergy.com/pdf/HOMERGettingStarted210.pdf>



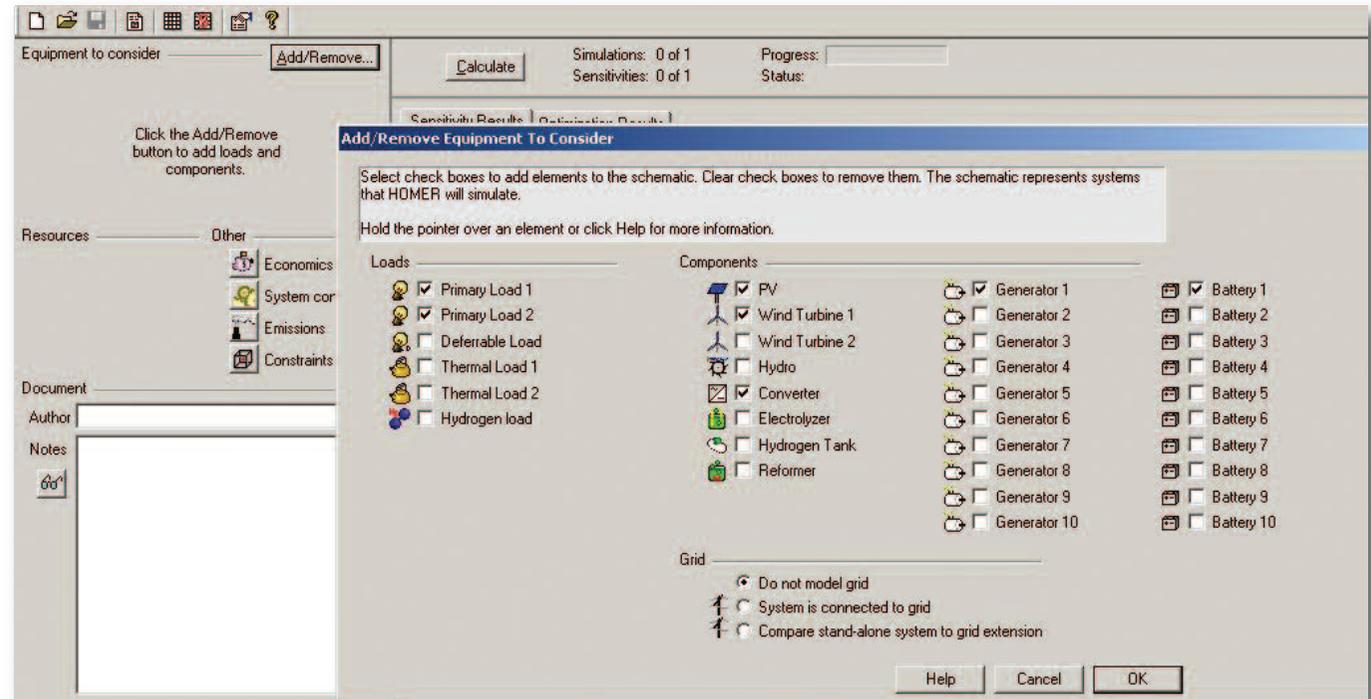


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Step 2 Defining the Power System

Define the power system design by clicking the Add/Remove button. Through the Add/Remove window you are able to select a number of different components including multiple loads, generators, battery banks, PV arrays and wind turbines and other power system components

For this example place check marks besides Primary Load 1, Primary Load 2, PV, Wind Turbine 1, Converter, Generator 1 and Battery 1. At the bottom of the window select 'do Not Model Grid'





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Step 3 Defining the Site Load

HOMER enables you to model two separate load profiles for a single site, these loads can be defined in different ways. A primary load could be used to model the BTS load and the other primary load could be used to outline the transmission & cooling). Alternatively the primary loads could define the power profile for the AC and DC equipment respectively. The hourly load profile of each load needs to be entered into primary load according to the setup defined in the schematic and model. It is possible to conduct the measurements remotely using an ammeter connected to a GPRS modem which will transfer the collected data to the NOC (Network Operation Centre). An average power load profile can be defined, in case it is not possible to conduct specific measurements at the site, using data provided by equipment vendors.

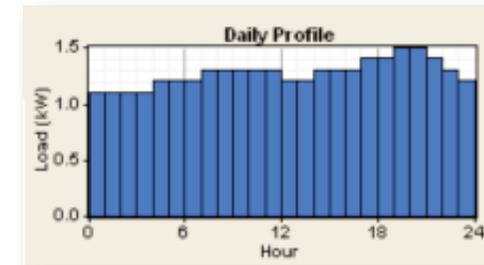
A BTS load profile depends on multiple parameters including configuration, temperature, transferred power, location, etc. therefore it is important to outline an accurate power profile in order to dimension correctly the renewable components for the system.

Typical BTS power and voice/data traffic show a similar trend, in our example power consumption peaks occur in the late afternoon/evening hours – typically from 17.00 to 21.00, when the mobile traffic is

more intense – while throughout the night there is a substantial decline in the site power requirement.

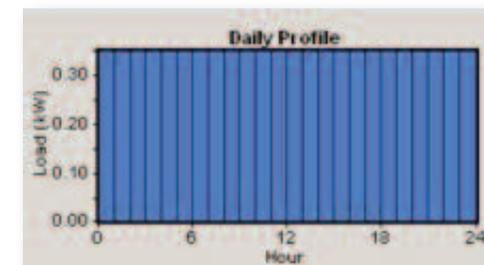
HOMER determines the average daily consumption of the system based on the outlined power profiles. By introducing different values for the power scaled annual average it is possible to conduct a sensitivity analysis showing the effects of the overall performances influenced by the change in the average daily power consumption. This analysis could be particularly helpful in case we intend to verify the renewable performance indicators resulting from a BTS configuration upgrade.

For this example we will opt to split the load by BTS and MW/Cooling equipment. By clicking on the icon for Primary load 1 set the load to DC and define the hourly profile as indicated in the diagram below. The scaled annual average of the combined primary loads should be 30.5 kWh/d. In our example add a sensitivity analysis of 27.5 kWh/d and 33.5 kWh/d. The random variability parameters should be set to 0% in case of accurate power load measurements.



Primary Not-critical Load (BTS)

The second primary load should also be defined as DC with a constant load of .350 kW throughout the day. The random variability parameter should be set to 0% as it was for the first load defined.



Primary Critical Load (MW)





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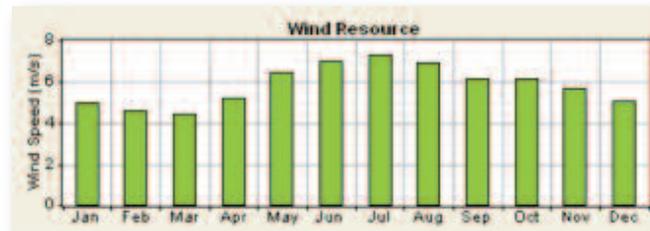
Step 4 Wind and Solar Resources

Wind Resources:

Wind resources are determined using the NASA Surface Meteorology and Solar Energy database (<http://eosweb.larc.nasa.gov/>) considering the wind direction at 50 metres above the surface of the earth. The database provides the monthly wind speed averaged for that month over a 10-year period (July 1983 - June 1993). Each monthly averaged value is evaluated as the numerical average of 3-hourly values for the given month.

Not all locations are suitable for the installation of effective wind turbines. The annual wind speed average could be a good indicator of the suitability of the installation of a wind turbine in a given location and generally values above 5m/s with few months below 4 m/s are considered adequate for satisfactory results.

For this example we will use a hypothetical site coordinates of latitude 11°36'S, longitude 40°25'. Log into the NASA Meteorology website from the URL above and enter the coordinates and select the annual wind speed average. Once the data is received click on the Wind Resource icon in HOMER and enter the monthly wind data as indicated below. The Altitude and Anemometer Height should be filled with the appropriate information from the NASA website.



Wind Speed



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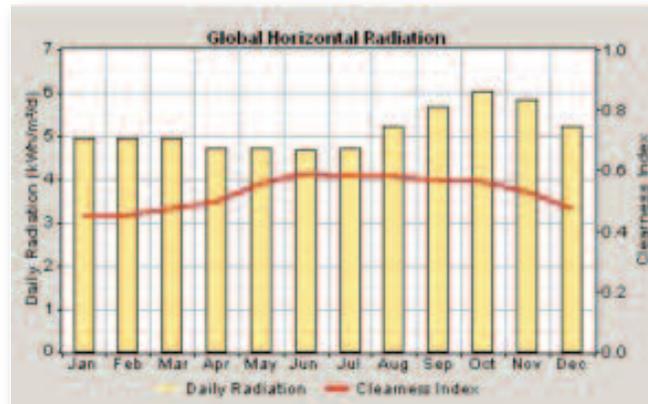
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Step 4 Wind and Solar Resources

Solar Resource:

Solar resources are imported directly by HOMER from the NASA Surface meteorology and Solar Energy database by entering the GPS coordinates.

Using the coordinates from the Wind Resource section, the annual solar radiation of this area is 5.14 kWh/m²/d. For this area the monthly solar radiation show a more constant trend than the wind speed. It is advisable that the average radiation should have a constant trend and the annual radiation be above 4 kWh/m²/d in order to have a reliable source of power coming from the photovoltaic panels.



Daily Radiation and Clearness Index





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Step 5 Diesel Price

Diesel price has a significant impact on the running costs of a system equipped with a diesel generator. The diesel price can be added by clicking the Diesel icon in HOMER.

In the example we considered 0.9 \$US/l as reference price for the diesel, in addition a sensitivity analysis has been added considering values ranging from 0.7 \$US/l to 1.1US/l with increments of \$0.1 US/l. In many developing countries currency exchange fluctuations have a strong impact on diesel prices.





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Step 6 Economics

The economic factors of the project such as: Annual Interest Rate, Project lifetime, System Fixed Capital Cost, System Fixed O&M Cost and Capacity Shortage Penalty can all be defined by clicking on the Economics icon in HOMER.

In this example set the project lifetime to 25 years – in line with the expected life span of the renewable equipment (wind turbine, photovoltaic system). Batteries and diesel generators have usually a much lower lifetime, which largely depends on the conditions where the equipment operates and the maintenance performed.

We have considered a real annual interest rate (nominal interest rate minus inflation) of 10%, which is a common value in many developing countries.





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Step 7 Equipment

Diesel Generator

By clicking on the Generator icon the Generator in the power system can be defined. The key parameters to consider when defining the generator are: Size, Cost, Replacement Cost, Operating Lifetime and O&M expenditure.

In our example a 16kVA Diesel Generator has been considered for the site under analysis. The minimum allowable load on the generator has been set as 30% of its rated capacity and it has 20,000 operating hours lifetime. We have used the default efficiency curve present in HOMER as often vendors do not provide comprehensive details to design a specific efficiency curve.

HOMER enables to include in the model operations and maintenance as cost per hour of operation. Many MNOs (Mobile Network Operators) have monthly lump-sum contract with companies which transport diesel at the site and also manage O&M services, therefore it is often difficult to determine the generator hourly maintenance cost. In our example we assumed an hourly O&M cost of 1 US\$.

Converter

In HOMER the converter in the power system represents both a rectifier, converting the alternating current (AC) provided by the diesel generator to direct current (DC) required to power the telecom equipment and an inverter if needed within the power system. The key parameters to consider when defining the Converter is the Size, Cost, O&M Cost and Energy Conversion efficiencies.

For this example, standard efficiency parameters have been considered for a 6kVA rectifier (Capacity relative to inverter 100%, Efficiency 85%). This configuration needs to be approved by the civil engineering team which will need to take into account the weight of the wind turbine, the axial force on turbine at max wind speed, the max torque generating around the turbine axis at the breaking time and other parameters which could compromise the stability of the mast.

Batteries

By clicking on the battery icon in HOMER you are able to define the battery bank used in the power system. HOMER has a built-in list of batteries each with its own unique specifications that can be used. If the particular battery of interest is not included in the list it can be created and saved in HOMER by clicking the 'New' button next to the existing battery list. When choosing an existing battery or defining a new battery the key parameters to consider or include are: Capacity, Voltage, Round Trip Efficiency, Min State of Charge, Capacity Curve and Lifetime Curve. Once the battery you would like to use has been selected or created it is important to enter the cost of the battery, the number of batteries per string and the number of strings of batteries to be modelled.

In this example we have considered three strings of Trojan L16P, 6V 360Ah sealed lead-acid batteries. These batteries require reduced maintenance and are suitable for renewable installations which require high demand levels. The details of these batteries, including lifetime and capacity curves, are already built-in in HOMER.

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Step 7 Equipment

Photovoltaic system

Solar panels are available in different shape and size. The size of the photovoltaic system depends on the power requirement of the site but it is important to take into account also the location and the available space on site.

for the site under analysis we considered 170W, 24V polycrystalline modules combined in 3 strings of 510W at a cost of US\$ 3096 per string (this value is valid both for capital and replacement costs and it does not include shipping, training and installation which will be added in the additional capital costs in order to determine the financial indicators for the renewable solution).

We assumed for the photovoltaic panels a derating factor of 80% and expected lifetime of twenty years. It has been conducted a sensitivity analysis having the size of the photovoltaic system ranging from 2.55 kW to 6.12 kW with increments of 510W. Solar panels do not require extensive maintenance; usually it is only required to remove dust from the panels twice a year so the O&M cost has been calculated as one-day of labour plus transport costs.

Wind Turbine

There are several small wind turbines manufactures exist but all the wind turbines available perform differently from one another. Two comparable 2.5kW wind turbines from different manufacturers may operate very differently from each other so it is important to be aware of the wind turbine power curve, cut-in speed, cut-out speed and mounting possibilities. HOMER has a list of wind turbines already defined to choose from, but if the wind turbine of interest is not included in the list it can be defined and saved in HOMER based on the manufacturer specifications.

Within telecom applications there are 2 possibilities for mounting a wind turbine; it can either be mounted on the existing telecom mast or a standalone monopole. It is not always possible to mount the wind turbine on top of the mast, this configuration needs to be approved by the civil team which will need to take into account the weight of the wind turbine, the axial force on turbine at max wind speed, the max torque generating around the turbine axis at the breaking time and other parameters which could compromise the stability of the mast.

For the site in the example consider a generic 2.5kW wind turbine mounted on top of the mast using one of the default models present in HOMER.

Wind turbines generally require a maintenance service every year, which in our example has been calculated as one-day of labour plus transport costs.





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Step 8 Calculate Results

By clicking the Calculate button, HOMER will calculate the different permutations of possible designs based on the inputs provided and simulate the power system.

According to the design we have dimensioned we are able to compare the standard diesel generator configuration with renewable hybrid (wind and solar), pure wind and pure solar models. A consistent business case for an off-grid site should compare the existing solution (or standard operator solution in case of a new site) to the preferred renewable option.

In addition by introducing the sensitivity analysis on the diesel price and primary load we are able to evaluate the financial and renewable indicators of the different models under numerous scenarios.

Optimisation Results

The optimisation result panel shows the list of configurations available basing on the input data we have introduced and ordered by the total NPC (Net Present Cost). It is possible to display the entire list of configurations or to show only the best solutions (from an economic perspective) per system design.

In our example the categorised list displays eight different configurations, ordered by most effective NPC we have:

- a. Hybrid (wind & solar) + DG + batteries
- b. Wind only + DG + batteries
- c. Solar only + DG + batteries
- d. DG + batteries
- e. Solar only + DG
- f. Hybrid (wind & solar) + DG
- g. DG only
- h. Wind only + DG

This order per system design is constant. We can change the diesel price and primary load in our sensitivity analysis and the window displays main configuration technical and financial details.

The overall view shows the entire list of system designs for a specific combination of sensitivity variables. The models are always listed by the most effective economic configuration, but it often happens that the best configuration does not meet the requirement of our system in terms of autonomy, renewable contribution, diesel consumption, etc. If this is the case we need to analyse multiple solutions and identify the model that best matches the need of our design.

	PV (kW)	GC	10kVA (kWh)	LTSP	Cost (kWh)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kWh)	Rem. Fac.	Diesel (L)	10kVA (kWh)
1	2.56	1	16	24	6	\$17,500	13,993	\$105,112	1.191	0.44	5,167	2,096
2	2.57	1	16	24	6	\$7,500	16,876	\$116,582	1.321	0.21	7,252	2,854
3			16	24	6	\$14,000	16,392	\$113,963	1.299	0.21	6,421	2,524
4			16	24	6	\$0	21,180	\$138,908	1.991	0.00	9,298	3,627
5	6.12		16		6	\$24,000	30,110	\$218,633	2.478	0.22	17,236	8,818
6	6.12	1	16		6	\$21,500	29,170	\$200,088	2.494	0.28	16,473	8,516
7			16		6	\$0	35,727	\$230,949	2.617	0.00	22,145	8,780
8		1	16		6	\$7,500	35,098	\$240,584	2.735	0.00	22,145	8,780

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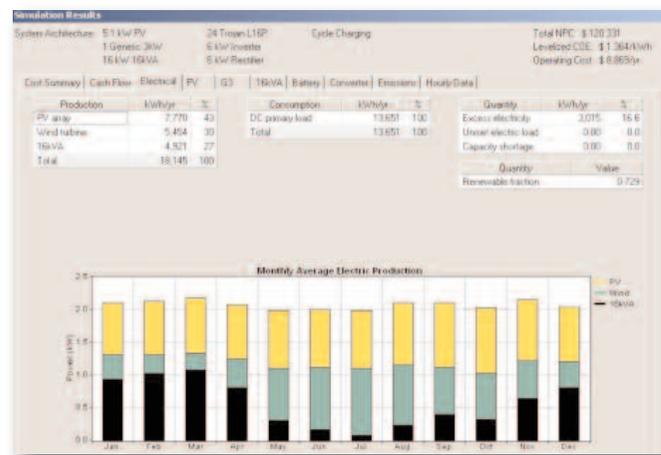
Step 8 Calculate Results

Simulation Results

By clicking on each of the displayed solution we can access a comprehensive set of data providing high level of detail on each system component. In addition it is possible to display many economical information essential to run a thorough business case.

The following analysis are related to the solution having the following system architecture: 5.1 kW Photovoltaic system, 3kW wind turbine, 16kVA Diesel Generator, 6kVA rectifier, three 48V strings of Trojan L16P setting the diesel price at US\$0.9 and not-critical primary load at 30.5 kWh/d.

Some examples of available data are given below:



The electrical tab in the Simulation Results window gives a useful overview of the overall and monthly electric production of the various sources of the system, excess electricity produced, etc. In our example it appears that during the months February-April and November-December the electric production of the wind turbine is limited, due to the lower speed of the wind, therefore the generator contributes in those months to nearly half of the required electrical supply. We could increase the size of the solar panels in order to counterbalance the shortage of electrical provision from the wind turbine.

In the selected example there is also a considerable waste of energy caused by the unutilised excess electricity (17%). Adding more battery strings would allow to optimise the usage of excess electricity and to increase the overall autonomy of the system.

By adding more battery strings and increasing the size of the photovoltaic system we improve the system performances but at the same time we are increasing the capital expenditures of the overall system and we may not have adequate space on site for the additional equipment (i.e. an average 5.1kW PV system has ~ 43 m2 footprint). Therefore the choice of the right configuration is a complex trade-off among financial, renewable, technical and design requirements.

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Step 8 Calculate Results

By clicking the Details button in the Cash Flow label the nominal and discounted total cost of ownership are displayed, providing for each configuration item capital, replacement, salvage and operating cost (including fuel) for the entire lifetime of the project.

The Cash Flow details represent a practical starting point for developing a customised business case, including financial indicators such as ROI, payback period and NPV, in comparison to the diesel generator only base case that will enable decision makers within operator organisations to make accurate investment decisions.

Component	Category	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Wind	Capital	20,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Replacement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Salvage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Operating	0	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
	Fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diesel	Capital	25,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Replacement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Salvage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Operating	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
PV	Capital	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Replacement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Salvage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Operating	0	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
	Fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diesel+PV	Capital	25,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Replacement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Salvage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Operating	0	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
	Fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diesel+PV+Wind	Capital	20,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Replacement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Salvage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Operating	0	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
	Fuel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

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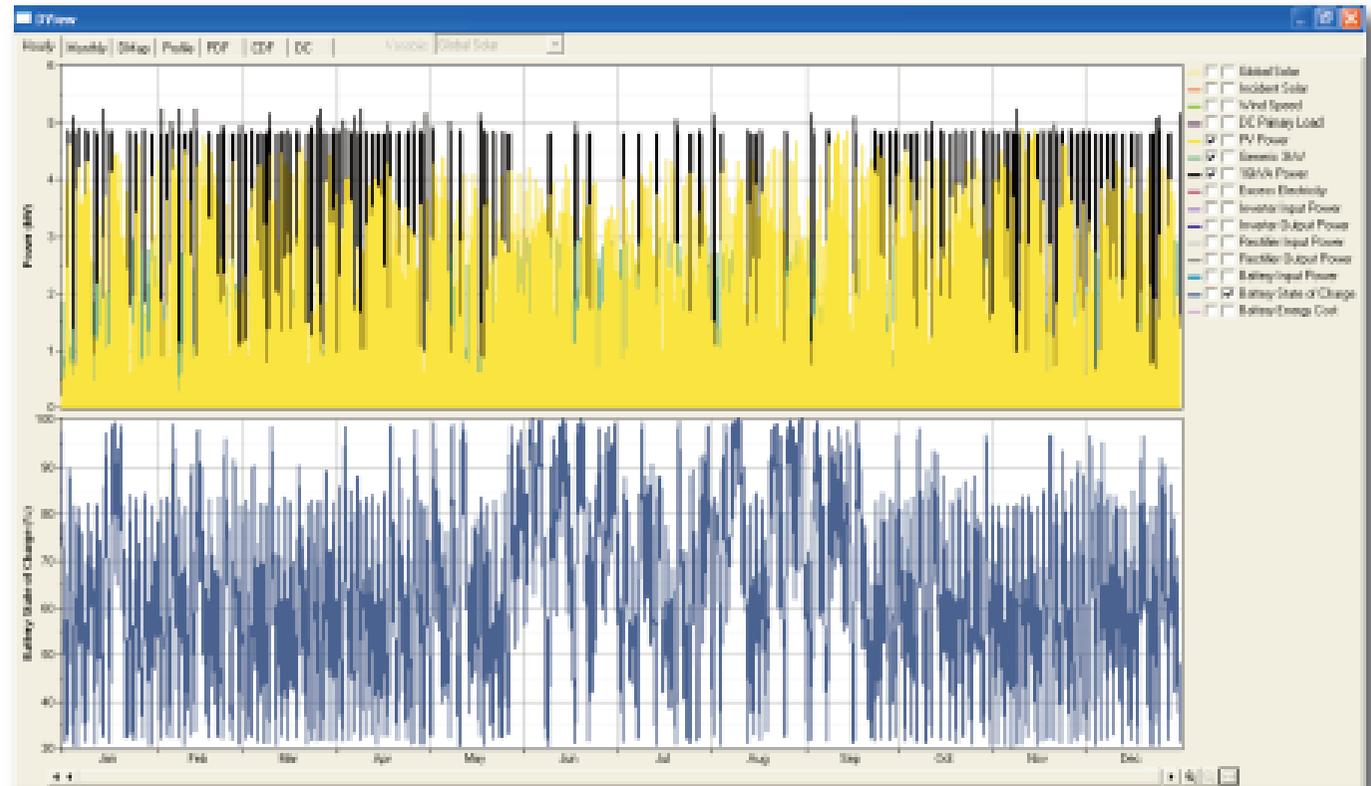


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Step 8 Calculate Results

The plot section in the hourly plot label enables to compare over two layer graph the most relevant variables of the selected configuration. In the figure to the right the graph on top shows the electrical production of photovoltaic system, wind turbine and diesel generator while the below graph displays the battery state of charge throughout the year.

The Simulation Results window include other relevant data concerning renewable equipment details (i.e. electrical production, hours or operation, etc.), diesel generator and batteries performances (i.e. diesel generator hours of operation, fuel consumption, battery state of charge histogram, etc.), emissions, etc.



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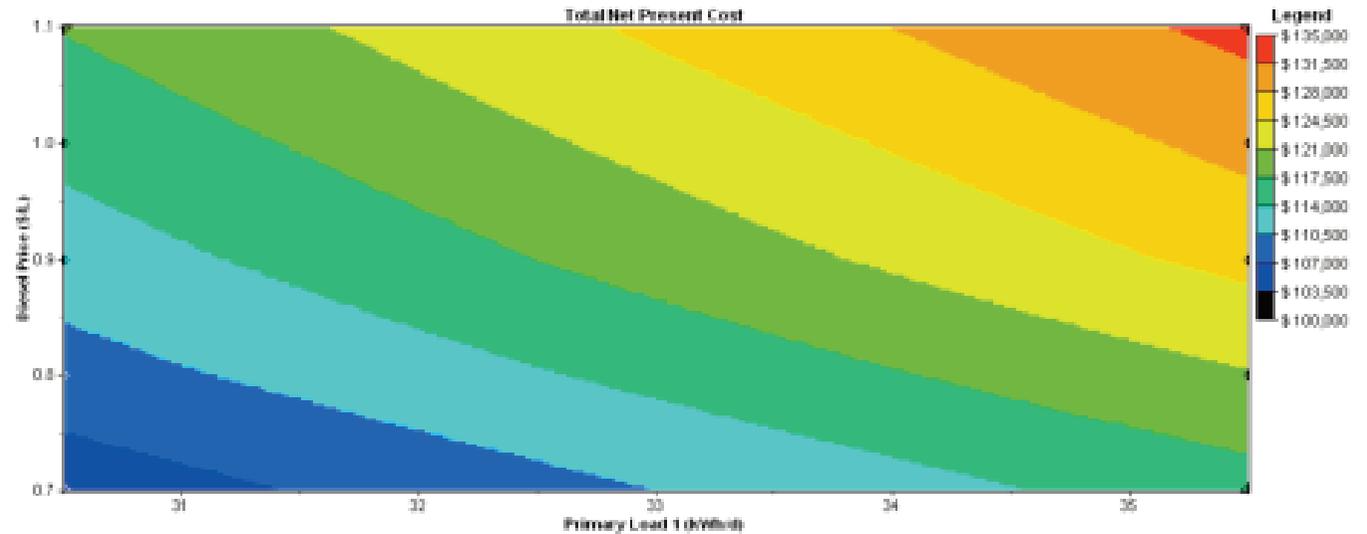
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Step 8 Calculate Results

Sensitivity Results

The Sensitivity Results label shows through different graph types the system dependency from from the sensitivity variables.

The effect of fuel price and the primary load have a huge impact on several variables including the Total Net Present Cost. By increasing the diesel price and the power load the installing and operating costs of the system rise accordingly.



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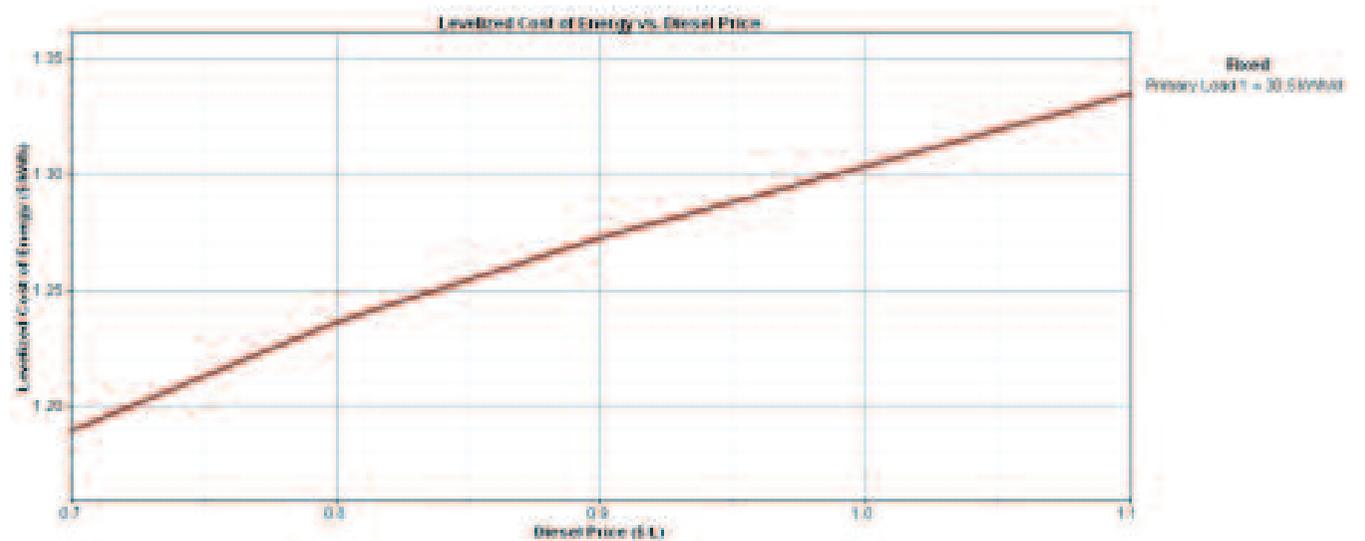




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Similarly using a line graph we can display the relation between the Levelised cost of energy (average cost of producing one kWh of electricity) versus the cost of diesel.



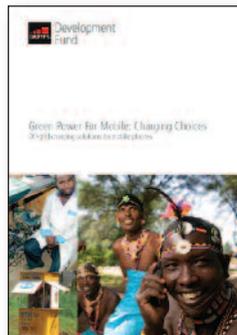


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Green Power for Mobile Resources

www.gsmworld.com/our-work/mobile_planet/green_power_for_mobile/resources.htm

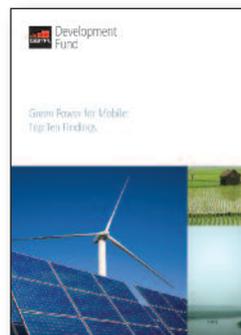
Reports



Green Power for Mobile: Charging Choices

gsmworld.com/documents/charging_choices.pdf

This study discusses charging solutions for handsets in off-grid areas and identifies a US\$2.3 billion market potential for those solutions.

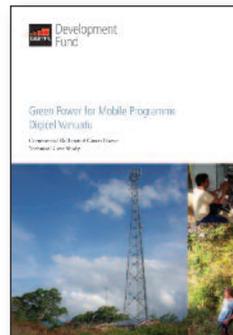


Green Power for Mobile: Top Ten Findings

www.gsmworld.com/documents/green_power_top10.pdf

An overview of the top ten research findings for green power solutions for mobile networks.

Case Studies



Commercial Roll-out of Green Power, Digicel Vanuatu (pdf)

www.gsmworld.com/documents/digicel_vanuatu.pdf

Technical case study of the commercial roll-out of green power for Digicel Vanuatu.



Wind and Solar, MTC Namibia (pdf)

www.gsmworld.com/documents/gsma_case_study_wind_solar.pdf

Trial case study; a wind and solar site trial in Namibia with MTC and Motorola.



Biofuels, IEDA Cellular, India (pdf)

www.gsmworld.com/documents/gsma_case_study_biofuels.pdf

Trial case study; two biofuel trials, one in India with IDEA Cellular and one in Nigeria with MTN.





For further information please contact
greenpower@gsm.org

GSMA London Office
T +44 (0) 20 7356 0600

www.gsmworld.com/greenpower

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