American International University- Bangladesh

Department of Electrical and Electronic Engineering

EEE: Renewable Energy Technology Laboratory

Title: Introduction to HOMER software for Renewable Energy Based System Design

Abstract:

The purpose of this experiment is to be familiarized with HOMER Software for Renewable Energy Sources (RES) Based System Design. The students will design and investigate a RES based system (In this case Wind-Diesel Hybrid). They will also perform optimization and sensitivity analysis for the system.

Introduction:

HOMER is the global standard in microgrid software, based on decades of listening to the needs of users around the world with experience in designing and deploying microgrids and distributed power systems that can include a combination of renewable power sources, storage, and fossil-based generation (either through a local generator or a power grid). The HOMER (Hybrid Optimization of Multiple Energy Resources) model greatly simplifies the task of designing hybrid renewable microgrids, whether remote or attached to a larger grid. HOMER's optimization and sensitivity analysis algorithms allow you to evaluate the economic and technical feasibility of a large number of technology options and to account for variations in technology costs, electric load, and energy resource availability.

The primary objectives of the lab experiment are-

1. To be familiarized with Homer Software
2. To design a RES based system using Homer and to investigate the system
3. To perform optimization and sensitivity analysis

Theory and Methodology:

HOMER simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER compares the electric and thermal demand in the hour to the energy that the system can supply in that hour, and calculates the flows of energy to and from each component of the system. For systems that include batteries or fuel-powered generators, HOMER also decides for each hour how to operate the generators and whether to charge or discharge the batteries.

HOMER performs these energy balance calculations for each system configuration that you want to consider. It then determines whether a configuration is feasible, i.e., whether it can meet the electric demand under the conditions that you specify, and estimates the cost of installing and operating the system over the lifetime of the project. The system cost calculations account for costs such as capital, replacement, operation and maintenance, fuel, and interest.

Optimization: After simulating all of the possible system configurations, HOMER displays a list of configurations, sorted by net present cost (sometimes called lifecycle cost), that you can use to compare system design options.

Sensitivity Analysis: When you define sensitivity variables as inputs, HOMER repeats the optimization process for each sensitivity variable that you specify. For example, if you define wind speed as a sensitivity variable, HOMER will simulate system configurations for the range of wind speeds that you specify.

Pre-Lab Homework:

Study about optimization and sensitivity analysis using HOMER software. Check you tube videos or other tutorials to get an idea about HOMER Software.

Apparatus:

Computer installed with HOMER Software and necessary system requirements.

Experimental Procedure:

Step 1: Formulate a question that HOMER can help answer

HOMER can answer a wide range of questions about the design of small power systems. It is useful to have a clear idea of a question that you want HOMER to help answer before you begin working with HOMER. Examples of the kinds of questions that HOMER can answer are:

- Is it cost-effective to add a wind turbine to the diesel generator in my system?
- How much will the cost of diesel fuel need to increase to make photovoltaics cost effective?
- Will my design meet a growing electric demand?
- Is it cost-effective to install a microturbine to produce electricity and heat for my grid-connected facility?

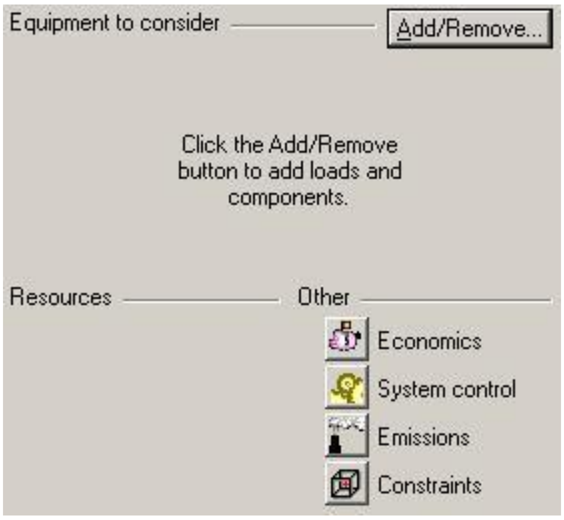
For this exercise, let us assume that diesel generators typically serve small loads in a remote area, and that we want to use HOMER to find out whether it makes sense to add wind turbines to such systems. The question we will use HOMER to help answer is: How do changes in average wind speed and fuel price affect the feasibility of adding wind turbines to a diesel-only system design?

Step 2: Create a new HOMER file

A HOMER file contains all of the information about the technology options, component costs and resource availability required to analyze power system designs. The HOMER file also contains the results of any calculations HOMER makes as part of the optimization and sensitivity analysis processes. HOMER file names end in .hmr, for example: WindVsDiesel.hmr. When you start HOMER, it looks for the most recently saved file and opens it. If HOMER can not find the file, it displays a blank window.

For this exercise, create a new HOMER file:

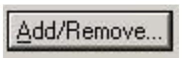
1. Click New File , or choose File, New from the menu to create a new HOMER file. HOMER displays a blank schematic on the Main Window.

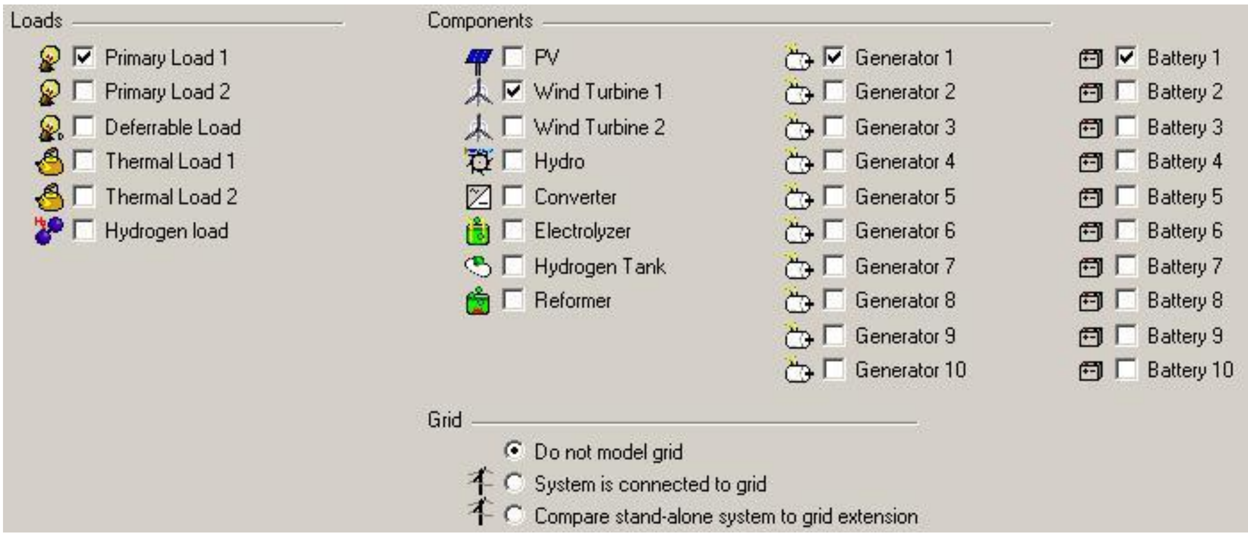


Step 3: Build the schematic

HOMER compares multiple technology options for a power system design. The schematic represents all of the technology options that you want HOMER to consider: it is not a schematic of a particular system's configuration. You build the schematic to give HOMER information about the components to consider to answer your question. The schematic may include components that are not in the optimal design.

In this exercise, HOMER will simulate systems that include wind turbine and diesel combinations to answer the question “*How do changes in average wind speed and fuel price affect the feasibility of adding wind turbines to a diesel-only system design?”*

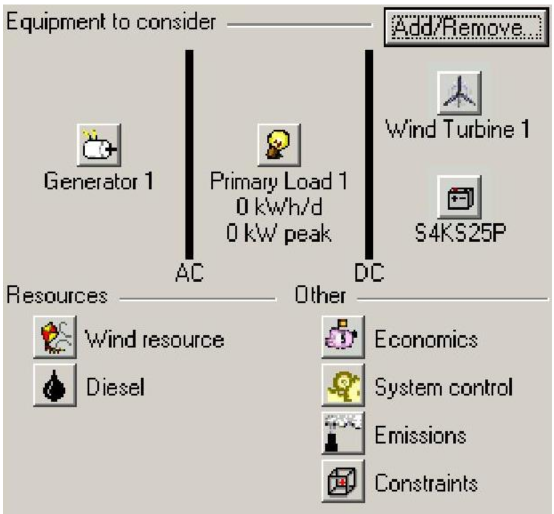
1. Click Add/Remove  to choose the components that you want HOMER to consider. HOMER displays all of the possible components in the Add/Remove window.
2. Select the Primary Load 1 check box.
3. Select the Wind Turbine 1, Generator 1, and Battery check boxes.



4. Click OK to return to the Main window.

HOMER displays buttons on the schematic that represent the load and components (wind turbine, diesel generator, and battery).

In the Resources section (directly below the schematic) HOMER displays buttons for the resources that each component will use. In this case, buttons for the wind and diesel resources appear in the resources section of the schematic.



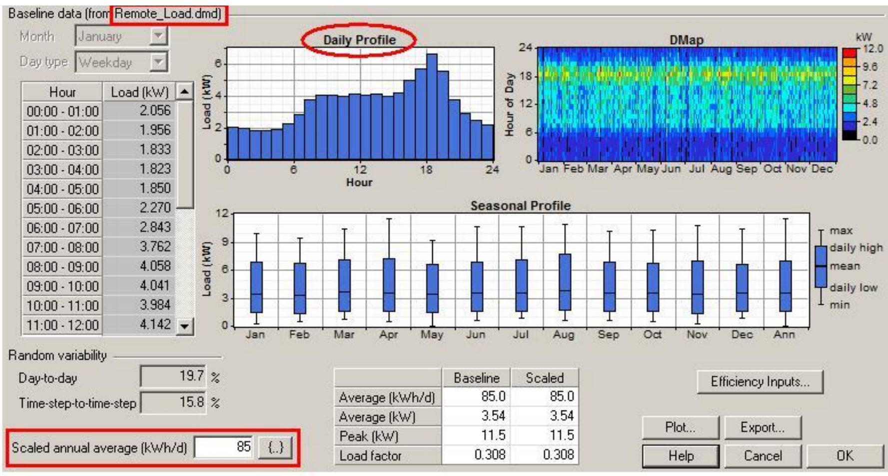
Step 4: Enter load details

The load details are inputs to the HOMER simulations. The load inputs describe the electric demand that the system must serve. This section describes how to import a sample load file.

1. Click Primary Load 1  on the schematic to open Load Inputs.
2. Type Remote Load as a label for the load.

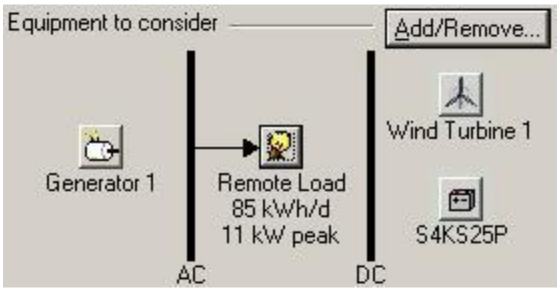
3. Choose AC as the load type.
4. Choose Import hourly data file and then click the Import File button to open the sample load file Remote_Load.dmd.

HOMER displays the daily load profile in the table and graph.



5. Click OK to return to the Main window.

On the schematic, notice the arrow that now connects the load button to the AC bus and shows the direction of energy flow. Also note that the label you typed, "Remote Load," appears on the schematic, along with the values of the average and peak demand.



Step 5: Enter component details

The component inputs describe technology options, component costs, and the sizes and numbers of each component that HOMER will use for the simulations. This section describes how to enter cost data for diesel generators, wind turbines, and batteries. The costs in this exercise may not reflect real market conditions.

1. Click Generator 1  on the schematic to open Generator Inputs.
2. In the Costs table, enter the following values: Size 1, Capital 1500, Replacement 1200, O&M 0.05. Note that O&M stands for operation and maintenance. Generator O&M costs should not include fuel costs, since HOMER calculates fuel costs separately.

Costs

Size (kW)	Capital ($)	Replacement ($)	O&M ($/hr)
1.000	1500	1200	0.050

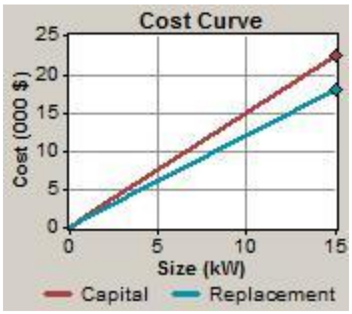
This tells HOMER that installing a diesel generator in the system initially costs $1500 per kilowatt, that replacing the generator would cost $1200 per kilowatt, and that it will cost $0.05 per hour per kilowatt to operate and maintain. Notice that HOMER plots the cost curve based on the values you enter in the Costs table.

3. In the Sizes to consider table, remove 0.000 and 1.000, and add 15. To remove a value, you may right-click on it and select Cut from the pop-up menu. The values in the Sizes to consider table are called optimization variables. The table should look like the one shown below:

Sizes to consider

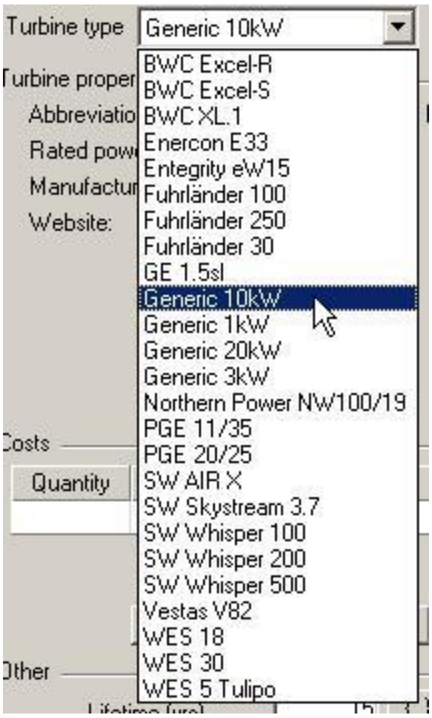
Size (kW)
15.000

HOMER will simulate systems with a 15 kilowatt generator. On the Cost curve, notice that HOMER displays the optimization variables as diamonds:



HOMER uses the values in the Costs table for the system costs calculations that are part of the simulation process to determine how much installing, operating, and maintaining the diesel generator will add to the power system's cost. The optimization variables tell HOMER how much diesel generator capacity to include in the various system configurations it will simulate.

4. Click OK to return to the Main window.
5. Click Wind Turbine 1  on the schematic to open Wind Turbine Inputs.
6. In the Turbine Type list, click Generic 10kW to select the generic 10 kilowatt wind turbine. HOMER displays the Generic turbine's power curve. Notice the rated power of this turbine is 10 kW DC.



In the Costs table, enter the following values: Quantity 1, Capital 30000, Replacement 25000, O&M 500. This corresponds to $3000/kW capital cost for small wind turbines. HOMER automatically displays 0 and 1 in the Sizes to consider table.

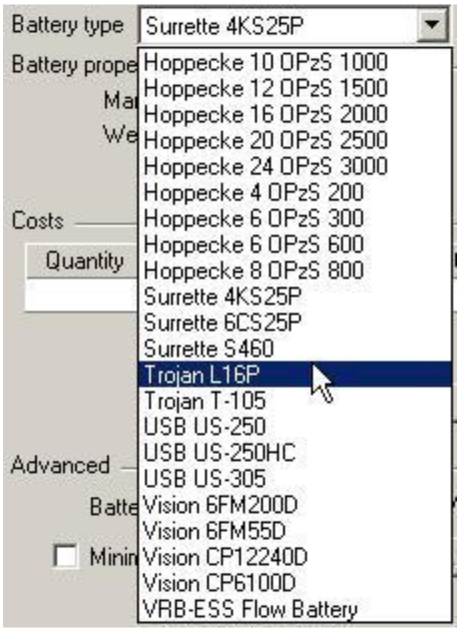
Costs

Quantity	Capital ($)	Replacement ($)	O&M ($/yr)
1	30000	25000	500

8. Click OK to return to the Main window.

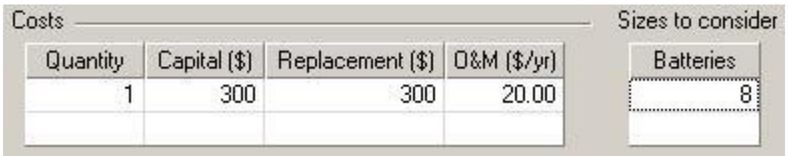
9. Click Battery  on the schematic to open Battery Inputs.

10. In the Battery Type list, click Trojan L16P to select the Trojan model L16P battery. HOMER displays the battery's properties.

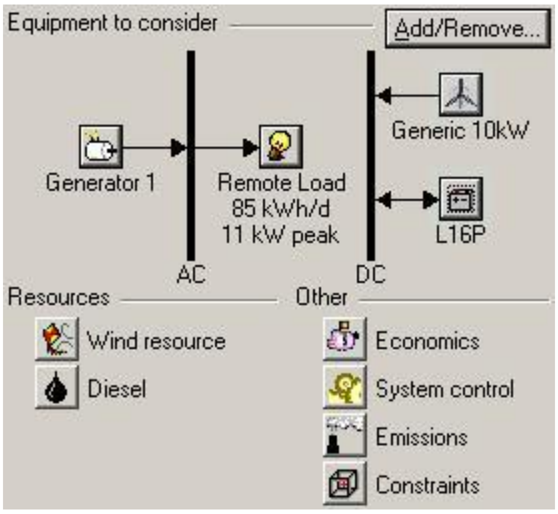


11. In the Costs table, enter the following values: Quantity 1, Capital 300, Replacement 30, O&M 20.

12. In the Sizes to consider table, delete 0 and 1, and add 8.



13. Click OK to return to the Main window. You are now finished entering component information. The schematic should look like this:



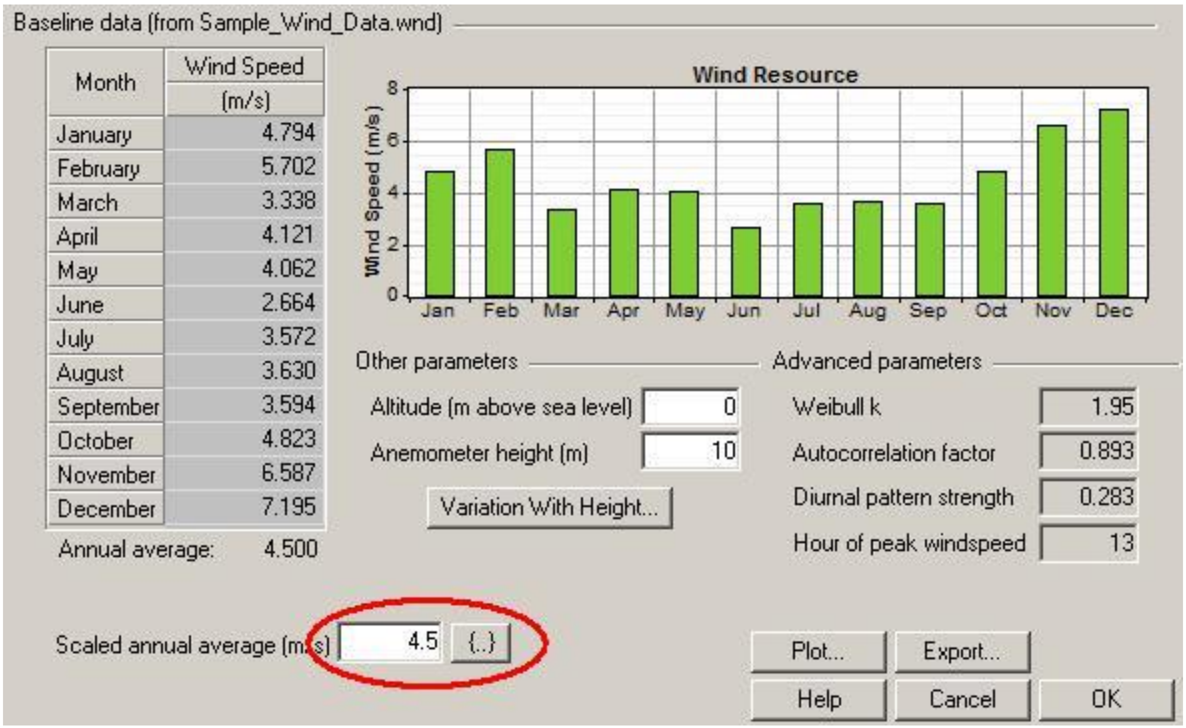
__Step 6: Enter resource details:__

The resource inputs describe the availability of solar radiation, wind, hydro, and fuel for each hour of the year. For solar, wind, and hydro resources, you can either import data from a properly formatted file, or use HOMER to synthesize hourly data from average monthly values.

This section describes how to define resource inputs for wind and fuel, which are the resources required by the two components HOMER will simulate: wind turbines and diesel generators.

1. Click Wind resource to open the Wind resource inputs window.
2. Choose Import hourly data file, then click Import File and open Sample_Wind_Data.wnd.

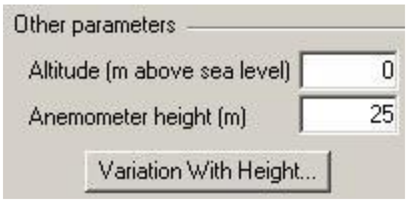
The baseline data is a set of 8,760 wind speed values that describe the wind resource for a single year. Pay special attention to the baseline annual average value (at the bottom of the wind speed table), and the scaled annual average.



HOMER uses scaled data for simulations to allow you to perform a sensitivity analysis on resource availability. To create scaled data, HOMER determines a scaling factor by dividing the scaled annual average by the baseline annual average and multiplies each baseline value by this factor. By default, HOMER sets the scaled average equal to the baseline average, which results in a scaling factor of one. You can change the scaled annual average to examine the effect of higher or lower wind speeds on the feasibility of system designs.

For this exercise, the scaled annual average is the same as the annual average, so HOMER will use the baseline data for simulations. In *Step ten: Add sensitivity variables*, we will see how to use the scaled annual average to examine how wind speed variations affect the optimal system design.

3. Set the anemometer height to 25 m, indicating that the wind speed data were measured at a height of 25 meters above ground.



4. Click OK to return to the Main window.
5. Click Diesel (in the Resources section) to open the Diesel Inputs window.
6. Set the diesel price to $0.4 per liter.

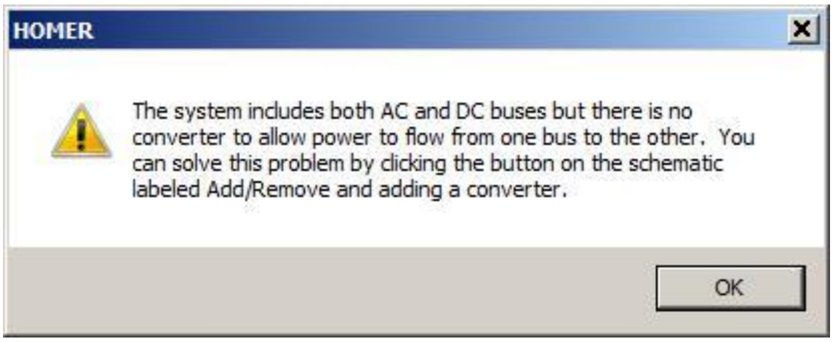
7. Click OK to return to the Main window.

Step 7: Check inputs and correct errors

HOMER checks many of the values that you enter in the input windows to see if they make technical sense. If HOMER notices values that do not make sense, it displays warning and error messages on the Main window.

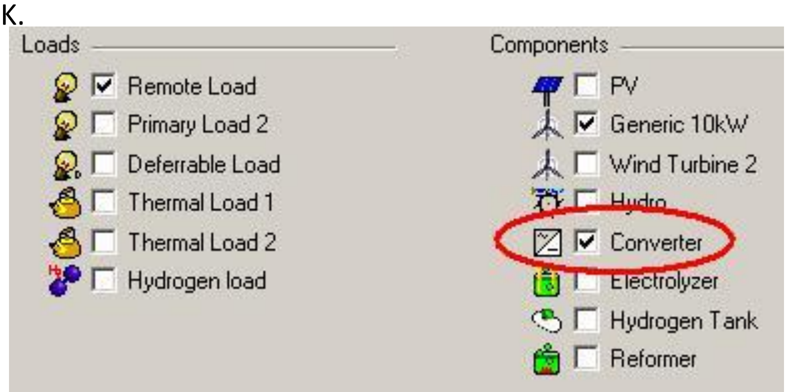
For this example, HOMER displays a message suggesting that a converter should be included in the system design. A converter is a component that converts alternating current, AC, to direct current, DC, (rectifier); DC to AC (inverter); or both.

1. Click the Warning button to view a more detailed message.



Warnings tell you that there may be a problem with one or more inputs. These problems may not prevent HOMER from running, but could indicate that there is a problem with the design of the system. You can see on the schematic that there is no arrow between the DC bus and the load. This means that power from the DC wind turbine will not be supplied to the AC load. The warning message suggests that adding a converter to the system design would correct this problem.

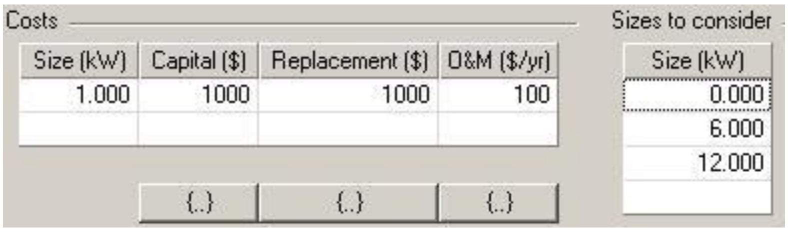
2. To add a converter to the schematic, Click Add/Remove, select the Converter check box, and click OK.



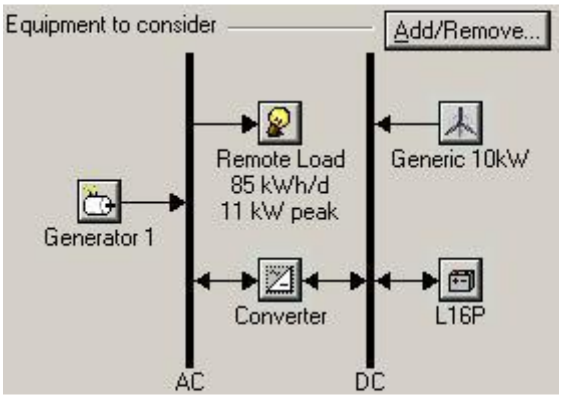
3. Click Converter on the schematic to open Converter Inputs.
4. In the Costs table, enter the following values: Size 1, Capital 1000, Replacement 1000, and O&M 100.

   This tells HOMER that the cost of either installing or replacing a converter in the system is $1,000 per kilowatt, and that it costs $100 per year per kilowatt to operate and maintain the converter.

5. In the Sizes to consider table, remove 1.000, and add the values 6 and 12.



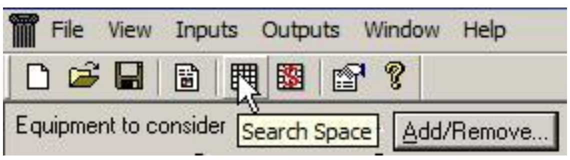
This tells HOMER to simulate system designs that include either no converter (0 kilowatts), a 6 kilowatt converter, or a 12 kilowatt converter. Since the peak load displayed on the schematic is 11.5 kilowatts, we can guess that a 12 kilowatt converter would meet the load for any hour that the wind turbine serves most of the load. Specifying the 6 kilowatt converter allows us to find out whether a using a smaller, less expensive converter is a more cost-effective design option.
Click OK to return to the Main window.



HOMER can now consider systems that deliver power from the DC wind turbine to the AC load.

7. In the Main window toolbar, click Search Space to review the optimization variables.
8.

   The Search Space summary table displays all of the optimization variables (sizes to consider) that you entered in the input windows for each component. You can add and remove sizes to consider for a component in this table, or by opening the input window for that component and editing the Sizes to consider table there.



	G10 (Quantity)	Label (kW)	L16P (Quantity)	Converter (kW)
1	0	15.00	8	0.00
2	1			6.00
3				12.00

In the table for this example, the heading G10 represents the Generic 10 kilowatt wind turbine, and Label represents Generator 1.

8. Click OK to return to the Main window.
9. In the Main window toolbar click Save and save your work to Wind_Diesel.hmr.

Step 8: Examine optimization results

HOMER simulates system configurations with all of the combinations of components that you specified in the component inputs. HOMER discards from the results all infeasible system configurations, which are those that do not adequately meet the load given either the available resource or constraints that you have specified.

1. Click Calculate to start the simulation. While HOMER is running, the progress indicator shows approximately how much time remains before HOMER finishes the simulation (for this example, approximately one second, which may be too fast to see the progress bar move).
2. When HOMER is finished running the simulations, click the Optimization Results tab, and click Overall to view a table of all feasible system configurations.

Sensitivity Results | Optimization Results

Double click on a system below for simulation results. ○ Categorized ⦿ Overall

G10	Label (kW)	L16P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
	15	8	6	$ 30,900	22,704	$ 321,138	0.810	0.00	17,812	7,062
	15	8	12	$ 36,900	23,459	$ 336,785	0.849	0.00	17,808	7,060
1	15	8	6	$ 60,900	21,614	$ 337,194	0.850	0.20	15,772	6,398
1	15	8	12	$ 66,900	22,342	$ 352,502	0.889	0.21	15,738	6,383

In the Overall Optimization Results table, HOMER displays a list of the four system configurations that it found to be feasible. They are listed in order (from top to bottom) of most cost-effective to least cost-effective. The cost-effectiveness of a system configuration is based on its net present cost, displayed under the heading "Total NPC" in the results tables. For this example, one diesel/battery configuration ( ) wins over the other configurations, including two wind systems ( ).

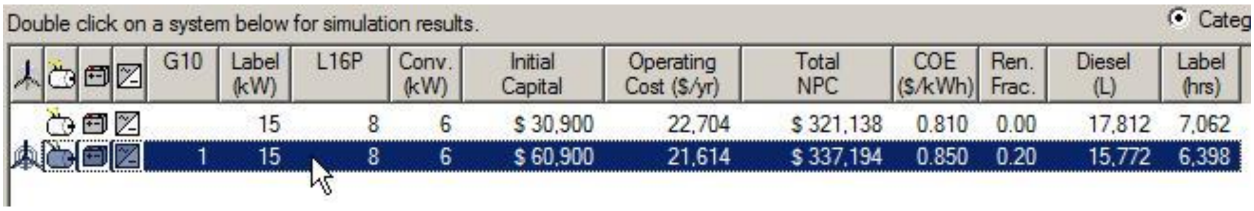
3. To view a table of sorted system designs, click the Optimization Results tab, and click Categorized. In the Categorized Optimization Results table, HOMER displays only the most cost effective configuration of each system design.

Sensitivity Results | Optimization Results

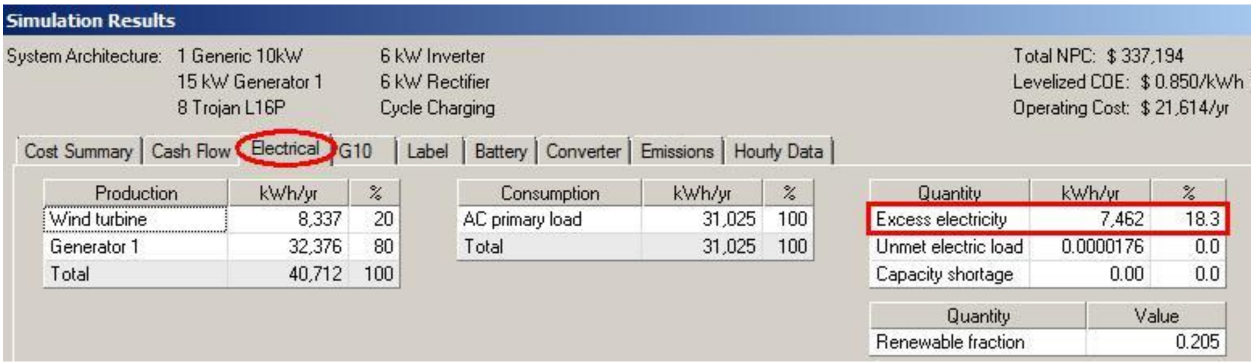
Double click on a system below for simulation results. ⦿ Categorized

G10	Label (kW)	L16P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
	15	8	6	$ 30,900	22,704	$ 321,138	0.810	0.00	17,812	7,062
1	15	8	6	$ 60,900	21,614	$ 337,194	0.850	0.20	15,772	6,398

4. To view the details for the most cost-effective wind/diesel/converter design, double-click the second row in the Optimization Results table.



In the Simulation Results window, you can view many technical and economic details about each system configuration that HOMER simulates. For this example, click the Electrical tab, and note that 18% of the total electric energy produced by the system is excess electricity, or energy that is not used by the system and goes to waste. Would including more batteries in the system design result in this excess electricity being used by the system?

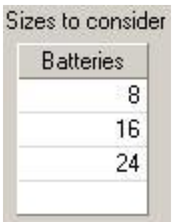


5. Click Close to return to the Main window.
6. In the File menu, choose Save As, and save the file as Excess_Energy.hmr.

Step 9: Refine the system design

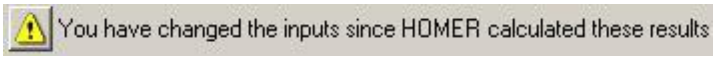
This section describes how to use the optimization results to improve the system design. For this example, we will see if adding batteries to the system design will reduce the amount of excess energy produced by the system.

1. Click the L16P Battery on the schematic to open Battery inputs.
2. In Sizes to consider, add 16 and 24. HOMER will simulate systems with 8, 16, and 24 batteries.



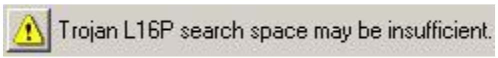
3. Click OK to return to the Main window. HOMER displays a warning message at the bottom of the Main window to let you know that the information in the results table

does not reflect the changes you just made.



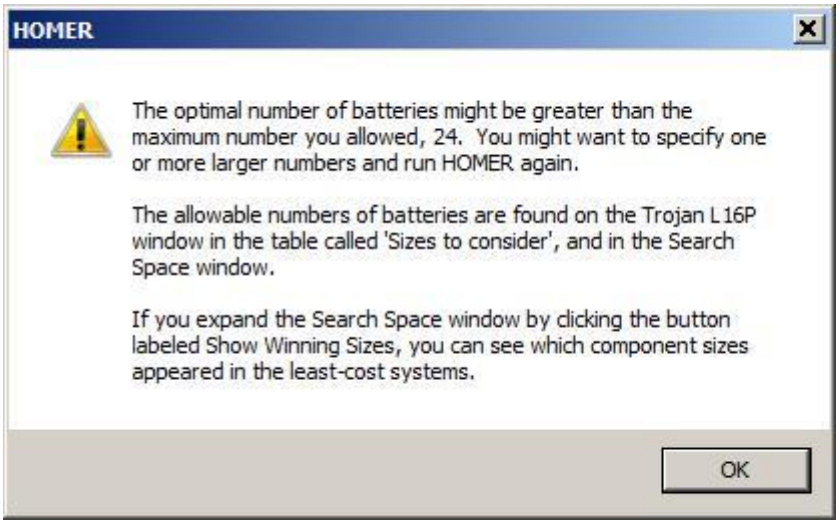
4. Click Calculate 

to start the optimization process. When the simulations are finished, HOMER displays the new results in the results tables, and also displays a warning message at the bottom of the Main window.



5. Click the Battery Search Space May be Insufficient Warning button .

HOMER displays a message suggesting that you add more battery quantities to the Sizes to consider table. Since we are not sure exactly how many batteries to add, we will add a range of new battery quantities.



6. Click OK to return to the Main window.
7. In the Main window toolbar, click Search Space  to open the Search Space Summary table.
8. Add 32, 40, 48, and 56 to the number of batteries.

	G10 (Quantity)	Label (kW)	L16P (Quantity)	Converter (kW)
1	0	15.00	8	0.00
2	1		16	6.00
3			24	12.00
4			32	
5			40	
6			48	
7			56	
8				

9. Click OK to return to the Main window.

10. Click Calculate [Calculate] to start the simulation.

    When the simulation process is finished, HOMER displays the new results for systems that include the battery quantities that we just added to the optimization table. This time, HOMER does not display warning messages.

    As you can see in the battery column of the Categorized Optimization Results table (L16P), the most cost-effective system configurations include 32 batteries.

11. In the Categorized Optimization Results table, double-click the wind/diesel/battery system (in the second row) to open the Simulation Results window.

Double click on a system below for simulation results.

G10	Label (kW)	L16P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
	15	32	6	$ 38,100	18,405	$ 273,372	0.689	0.00	14,464	4,318
1	15	56	6	$ 75,300	16,630	$ 287,890	0.726	0.21	11,278	3,017

    The excess electric energy produced by the most cost-effective configuration of the wind/diesel/battery system is dramatically reduced from 18% to 1.6%.

Cost Summary | Cash Flow | Electrical | G10 | Label | Battery | Converter | Emissions | Hourly Data

Production	kWh/yr	%
Wind turbine	8,337	21
Generator 1	30,630	79
Total	38,967	100

Consumption	kWh/yr	%
AC primary load	31,025	100
Total	31,025	100

Quantity	kWh/yr	%
Excess electricity	638	1.64
Unmet electric load	0.0000684	0.00
Capacity shortage	0.00	0.00

Quantity	Value
Renewable fraction	0.214

12. In the File menu, choose Save As, and save the file as Reduced_Excess.hmr.

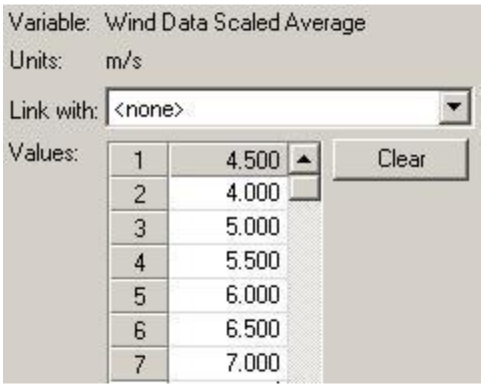
    HOMER has helped us refine the system design by adding batteries to store excess energy. However, systems with no wind are still more cost-effective than systems that use wind. Under what conditions does it make sense to include wind turbines in the system design? To understand this question, we will use HOMER to do a sensitivity analysis.

Step 10: Add sensitivity variables

In Step Five, you learned that HOMER uses scaled resource data for simulations. This section describes how to enter sensitivity values for both the wind speed scaled annual average and diesel price to perform a sensitivity analysis on these variables. The sensitivity analysis will allow you to explore how variations in average annual wind speed and diesel fuel prices affect the optimal design of the system. Another way to say this is that the analysis will show you the range of average annual wind speeds and diesel prices for which it makes sense to include wind turbines in the system design.

1. Click Wind resource to open the Wind Resource Inputs window.
2. Click the Scaled annual average Sensitivities button {..} to open the Sensitivity Inputs window.

3. Add the values 4, 5, 5.5, 6, 6.5, and 7 to the Average Wind Speed sensitivities table. Notice that the base value of 4.5 is already hard-coded into row 1.

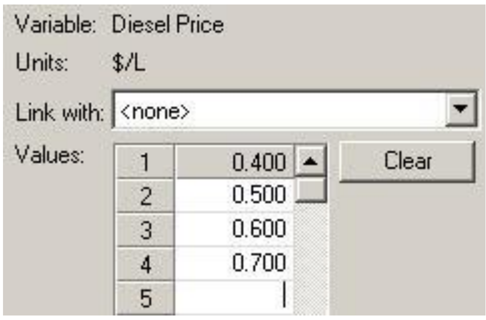


These sensitivity values tell HOMER to simulate each system configuration using seven sets wind speed data (scaled to each average annual wind speed value in the table).

4. Click OK to return to the Wind Resource Inputs window. Notice that the number of sensitivity variables, 7, appears in between the brackets on the Sensitivities button.

5. Click OK to return to the Main window.
6. Click Diesel  (in the Resources section) to open the Diesel inputs window.
7. Click Price Sensitivities button  to open the Sensitivity Inputs window.

8. Add the values 0.5, 0.6, and 0.7 to the Diesel Price Sensitivities table.



HOMER will simulate each system configuration for each diesel price value in the sensitivities table.

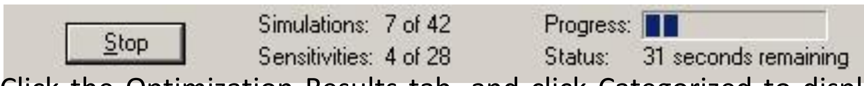
9. Click OK to return to the Diesel Inputs window, and then click OK to return to the Main window.

<u>Step 11: Examine sensitivity analysis results</u>

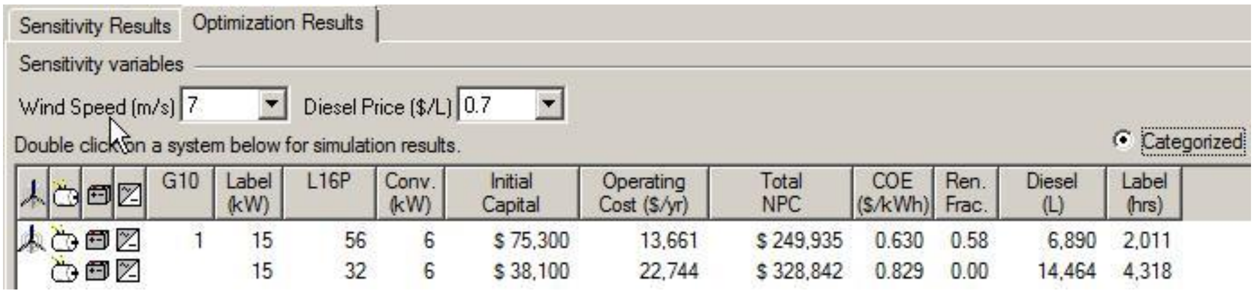
HOMER displays sensitivity results in graphs and tables. This section describes how to view and interpret the sensitivity results to determine under what conditions a wind/diesel system is more cost-effective than a diesel-only system.

1. Click Calculate 

to start the simulation. The progress bar indicates an estimate of the time remaining until the simulation and optimization process is complete.



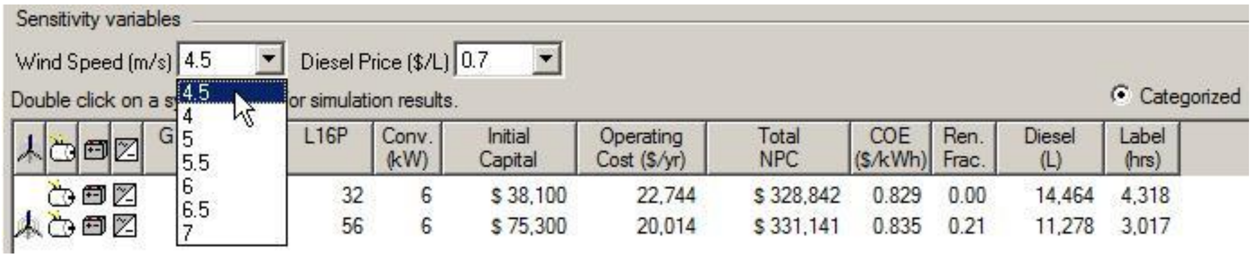
2. Click the Optimization Results tab, and click Categorized to display the table of sorted system designs.



	G10	Label (kW)	L16P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
	1	15	56	6	$ 75,300	13,661	$ 249,935	0.630	0.58	6,890	2,011
		15	32	6	$ 38,100	22,744	$ 328,842	0.829	0.00	14,464	4,318

HOMER now displays the Wind Speed and Diesel Price sensitivity variables in the boxes above the Categorized Optimization Results table. You can see that when the average annual wind speed is 7 meters per second and the price of Diesel fuel is $0.70 per liter, wind/diesel/battery is the optimal system type: it is more cost-effective than the system with no wind turbine.

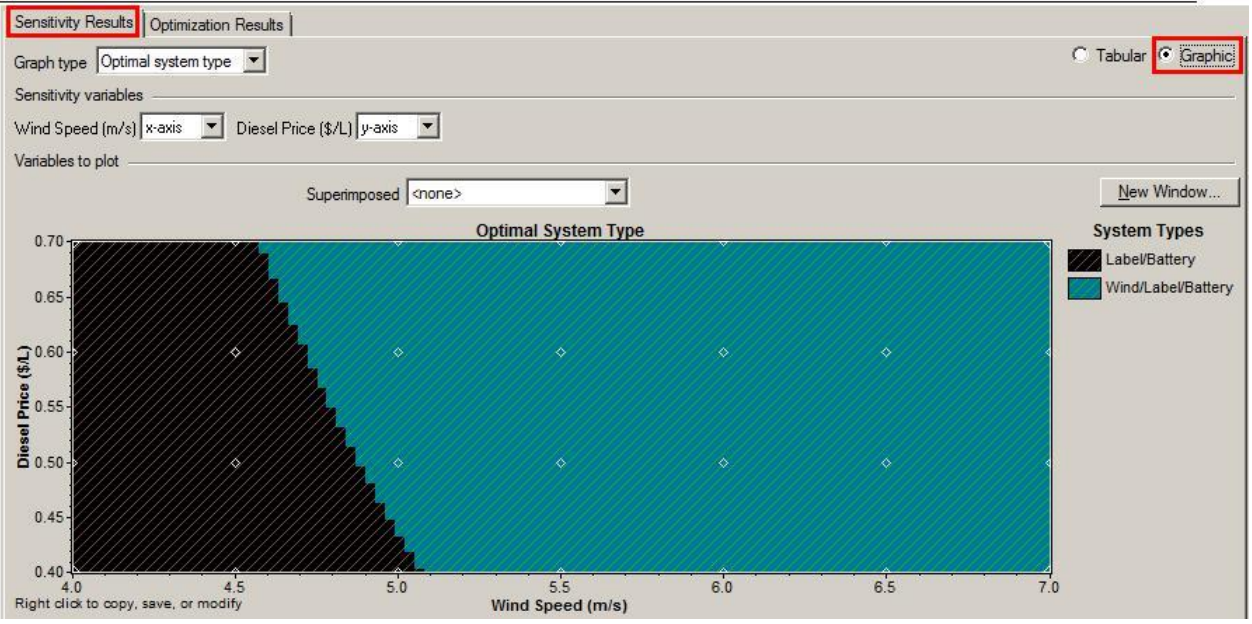
You can explore how changes in the average annual wind speed and diesel fuel price affect the optimal system type by selecting different wind speeds and fuel prices. For example, if the diesel fuel price is $0.70 per liter, and average annual wind speed is 4.5 meters per second or lower, system designs that include wind turbines are no longer optimal.



	G	L16P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)
		32	6	$ 38,100	22,744	$ 328,842	0.829	0.00	14,464	4,318
		56	6	$ 75,300	20,014	$ 331,141	0.835	0.21	11,278	3,017

HOMER also displays sensitivity results in graphs, which can be a more useful way to look at the results.

3. Click the Sensitivity Results tab, and click Graphic to display the table of sorted system designs. Make or verify the following selections:
   a. In the Wind Speed list, select x-axis. In the Diesel Price list, select y-axis.
   b. Under Variables to plot, select Optimal System Type in the Primary list. Select <none> in the Superimposed list.
   c.



On the Optimal System Type (OST) graph, you can simultaneously see the results for all the wind speeds and fuel prices you entered. The graph shows that the optimal system design depends both on the fuel price and on the annual average wind speed.

HOMER displays the results of the simulation and optimization in a wide variety of tables and graphs. Spend some time looking at the different graphs to familiarize yourself with these tables and graphs.

4. In the File menu, choose Save As, and save the file as Wind_Diesel_Sens.hmr.

Conclusion:

- To use HOMER, you enter inputs (information about loads, components, and resources), HOMER calculates and displays results, and you examine the results in tables and graphs.
- Using HOMER is an iterative process. You can start with rough estimates of values for inputs, check results, refine your estimates and repeat the process to find reasonable values for the inputs.
- You can use HOMER to simulate a power system, optimize design options for cost effectiveness, or to perform a sensitivity analysis on factors such as resource availability and system costs.
- HOMER is an hourly simulation model. HOMER models system components, available energy resources, and loads on an hourly basis for one year. Energy flows and costs are constant over a given hour. HOMER can synthesize hourly resource data from monthly averages that you enter in tables, or you can import measured data from properly formatted files.
- HOMER is primarily an economic model. You can use HOMER to compare different combinations of component sizes and quantities, and to explore how variations in resource availability and system costs affect the cost of installing and operating different system designs. Some important technical constraints, including bus voltage levels,

intra-hour performance of components, and complex diesel generator dispatch strategies are beyond the scope of an economic model such as HOMER. NREL's design tool for hybrid power systems, Hybrid2, can simulate these and other technical constraints and is useful for further exploring design options that HOMER identifies as cost-effective.

Report writing:

Design PV-Wind-Diesel Hybrid system and perform different analysis using HOMER. Show the simulation and results to your course instructor. Explain which is the best combination in your design and why.

Discussion and Conclusion:

Discuss your designed system for different scenarios. Also discuss the limitations of HOMER software.

References:

[1] http://www.homerenergy.com/

[2] Lilienthal, Peter, T. W. Lambert, and Paul Gilman. "Getting started guide for HOMER legacy (Version 2.68)." *HOMER Energy, Boulder* (2011)

