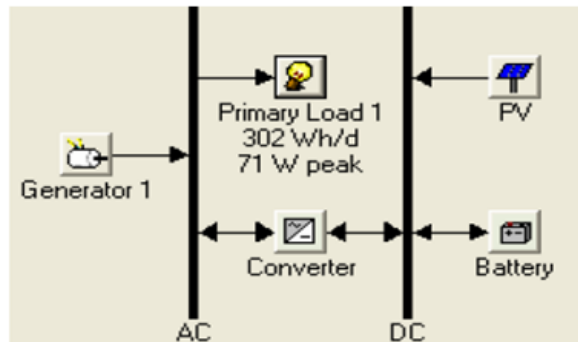


Micro-power System Modeling using HOMER - Tutorial 1



Charles Kim

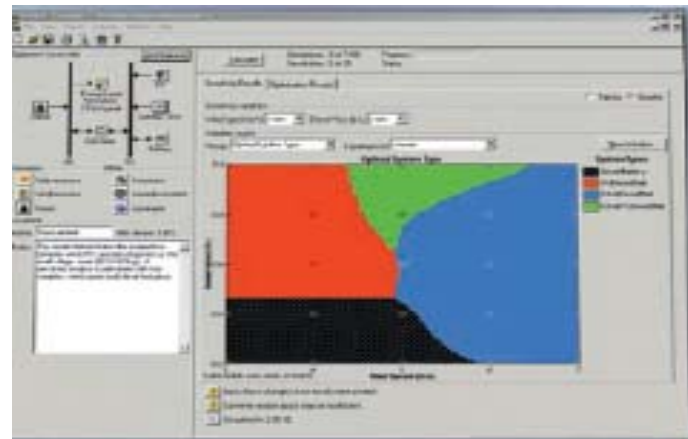


Howard University

www.mwftr.com

HOMER

⌘ Homer (Hybrid Optimization Model for Electric Renewables)



HOMER models micropower systems with single or multiple power sources:

- Photovoltaics
- Wind turbines
- Biomass power
- Run-of-river hydro
- Diesel and other reciprocating engines
- Cogeneration
- Microturbines
- Batteries
- Grid
- Fuel cells
- Electrolyzers

Homer – a tool

⌘ A tool for designing micropower systems

- ☒ Village power systems
- ☒ Stand-alone applications and Hybrid Systems

- Wind turbines



- PV



- Batteries

- Diesels

- Microturbines



- Fuel cells



- Small hydro



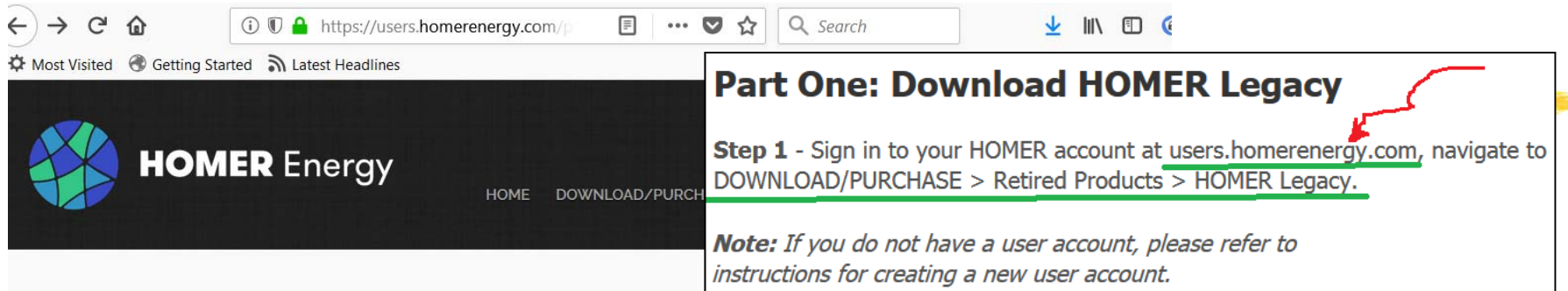
- Small modular biomass



- Grid connection



“HOMER Legacy” software



The screenshot shows a web browser at the URL <https://users.homerenergy.com/p>. The browser's address bar includes navigation icons, a search bar, and a search icon. Below the address bar, there are links for 'Most Visited', 'Getting Started', and 'Latest Headlines'. The main content area features the HOMER Energy logo and navigation links for 'HOME' and 'DOWNLOAD/PURCHASE'. A callout box with a black border and white background is overlaid on the right side of the page. It contains the following text:

Part One: Download HOMER Legacy

Step 1 - Sign in to your HOMER account at users.homerenergy.com, navigate to [DOWNLOAD/PURCHASE > Retired Products > HOMER Legacy](#).

Note: If you do not have a user account, please refer to instructions for creating a new user account.

HOMER Legacy

HOMER[®] Legacy was created at the [National Renewable Energy Laboratory](#) as a tool to find affordable energy solutions for village power. HOMER Legacy set the standard for early stage microgrid design and assessment, but [HOMER Pro](#) is our supported and developed product. Most people who have landed on this page should be using [HOMER Pro](#).

HOMER Energy continues to make HOMER Legacy available to the following people:

- Classroom and thesis use
- Small non-profit organizations that are working to improve access to energy in developing countries.

If you do not fit one of the above profiles, please use [HOMER Pro](#) instead. We may have to discontinue this charity if we continue to get too many inappropriate requests.

Support and training: No support or training is available for HOMER Legacy, and HOMER Legacy will never be updated. HOMER Legacy users can receive and provide mutual support via the [HOMER Users Group](#). There is no cost to join or participate.

[Download HOMER Legacy](#)

First-time user, or existing user with new computer. Previous HOMER installation requires renewal.

Homer - capabilities

⌘ Finds combination components that can service a load at the lowest cost with answering the following questions:

- ☑ Should I buy a wind turbine, PV array, or both?
- ☑ Will my design meet growing demand?
- ☑ How big should my battery bank be?
- ☑ What if the fuel price changes?
- ☑ How should I operate my system?
- ☑ And many others...

Homer - Features

- ⌘ Simulation—Estimate the cost and determine the feasibility of a system design over the 8760 hours in a year
- ⌘ Optimization—Simulate each system configuration and display list of systems sorted by net present cost (NPC)
 - ⊞ Life-Cycle Cost:
 - ⊞ Initial cost – purchases and installation
 - ⊞ Cost of owning and O&M and replacement
 - ⊞ NPC: Life-cycle cost expressed as a lump sum in “today’s dollars”
- ⌘ Sensitivity Analysis—Perform an optimization for each sensitivity variable

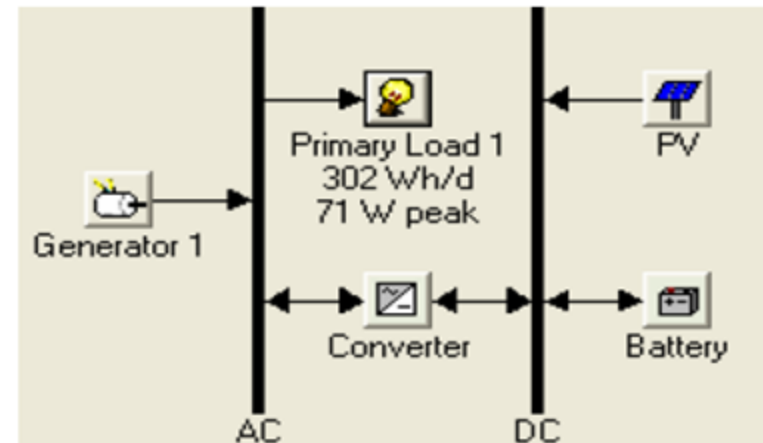
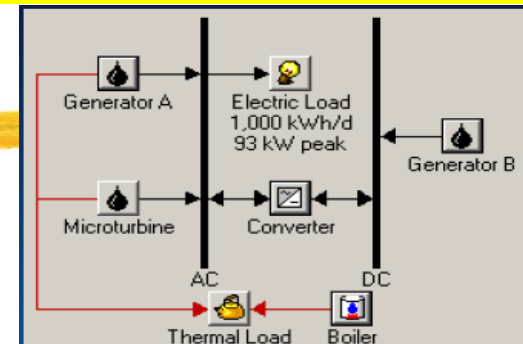
Features

⌘ Homer can accept max 3 generators

- ☑ Fossil Fuels
- ☑ Biofuels
- ☑ Cogeneration

⌘ Renewable Technologies

- ☑ Solar PV
- ☑ Wind
- ☑ Biomass and biofuels
- ☑ Hydro



Features

⌘ Emerging Technologies

- ⊞ Fuel Cells

- ⊞ Microturbines

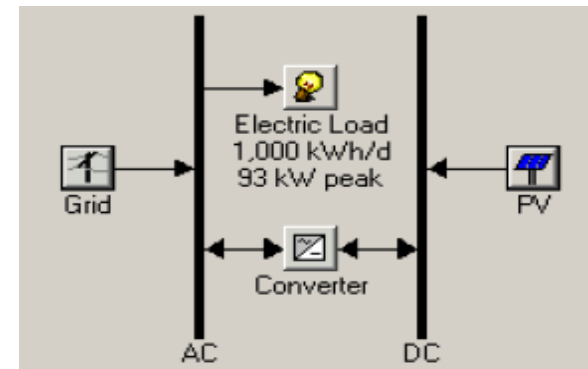
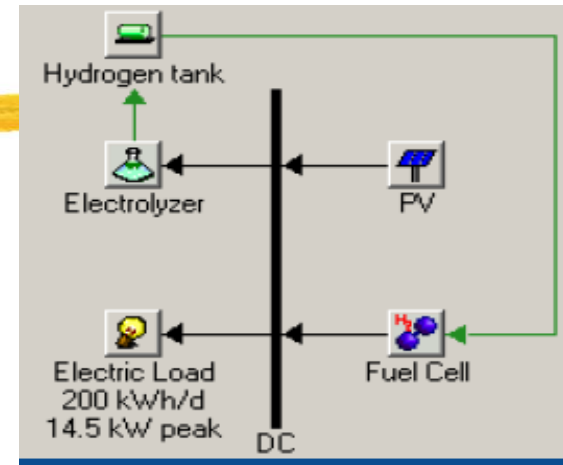
- ⊞ Small Modular biomass

⌘ Grid Connected System

- ⊞ Rate Schedule, Net metering, and Demand Charges

⌘ Grid Extension

- ⊞ Breakeven grid extension distance: minimum distance between system and grid that is economically feasible



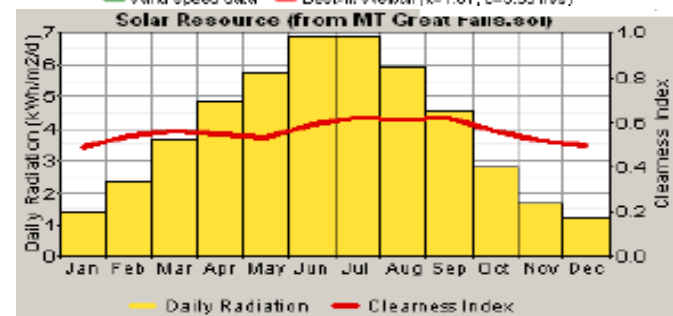
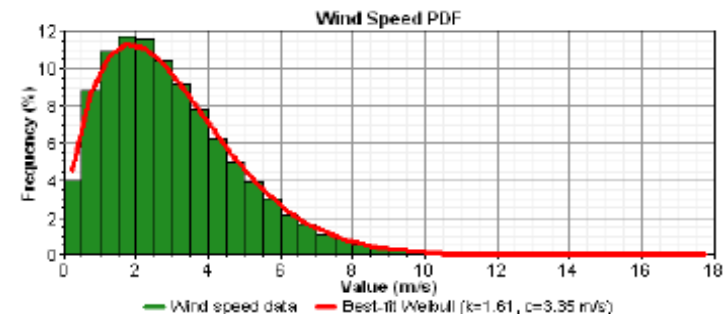
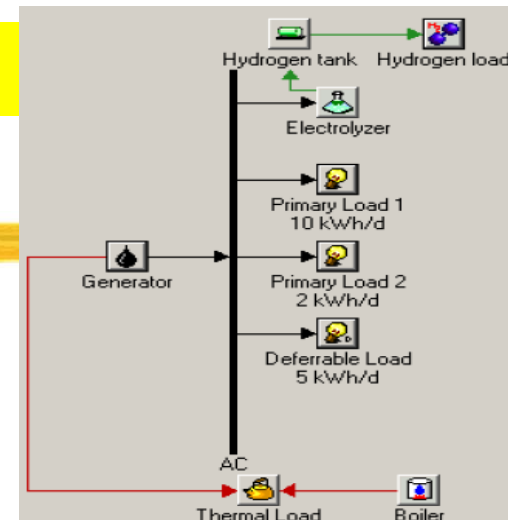
Features

⌘ Loads

- ⊞ Electrical
- ⊞ Thermal
- ⊞ Hydrogen

⌘ Resources

- ⊞ Wind speed (m/s)
- ⊞ Solar radiation (kWh/m²/day)
- ⊞ Stream Flow (L/s)
- ⊞ Fuel price (\$/L)

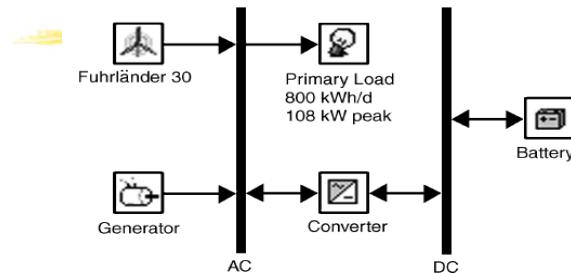


Optimization

- ⌘ Best possible system configuration that satisfies the user-specified constraints at the **lowest total NPC (net present cost)**.
- ⌘ Decide on the mix of components that the system should contain, the **size** or **quantity** of each component,
- ⌘ Ranks the feasible ones according to total net present cost

Optimization Example

⌘ Configuration and 140 (5x1x7x4=140) search spaces



	FL30 (Quantity)	Gen (kW)	Batteries (Quantity)	Converter (kW)
1	0	135.00	0	0.00
2	1		16	30.00
3	2		32	60.00
4	3		48	120.00
5	4		64	
6			96	
7			128	
8				

⌘ Overall Optimization results

				FL30	Gen (kW)	Batt.	Conv. (kW)	Initial Capital	Total NPC	COE (\$/kWh)	Diesel (L)	Gen (hrs)
				1	135	64	30	\$ 216,500	\$ 849,905	0.273	75,107	4,528
				2	135	64	30	\$ 346,500	\$ 854,660	0.274	54,434	3,350
				1	135	48	30	\$ 200,500	\$ 855,733	0.275	78,061	4,910
				2	135	48	30	\$ 330,500	\$ 856,335	0.275	57,654	3,685

⌘ Categorized optimization result

				FL30	Gen (kW)	Batt.	Conv. (kW)	Initial Capital	Total NPC	COE (\$/kWh)	Diesel (L)	Gen (hrs)
				1	135	64	30	\$ 216,500	\$ 849,905	0.273	75,107	4,528
					135	64	30	\$ 86,500	\$ 885,175	0.284	101,290	5,528
					135			\$ 0	\$ 996,273	0.320	132,357	8,760
				1	135			\$ 130,000	\$ 1,130,637	0.363	127,679	8,740

Sensitivity Analysis

- ⌘ Optimization: best configuration under a particular set of input assumptions
- ⌘ Sensitivity Analysis: Multiple optimizations each using a **different set of input assumptions**
- ⌘ “How sensitive the outputs are to changes in the inputs” – results in various tabular and graphic formats
- ⌘ User enters a range of values for a single input variable:
 - ☑ Grid power price
 - ☑ Fuel price,
 - ☑ Interest rate
 - ☑ Lifetime of PV array
 - ☑ Solar Radiation
 - ☑ Wind Speed

Sensitivity Values

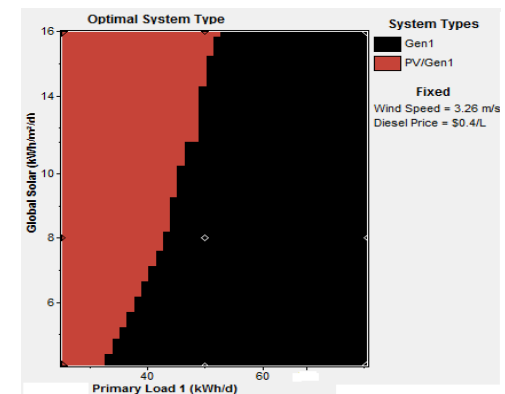
Variable: Solar Data Scaled Average
Units: kWh/m²/d

Link with: <none>

Values:

1	4,010	▲	Clear
2	8,000		
3	12,000		
4	16,000		
5			
6			
7			
8			
9			
10		▼	

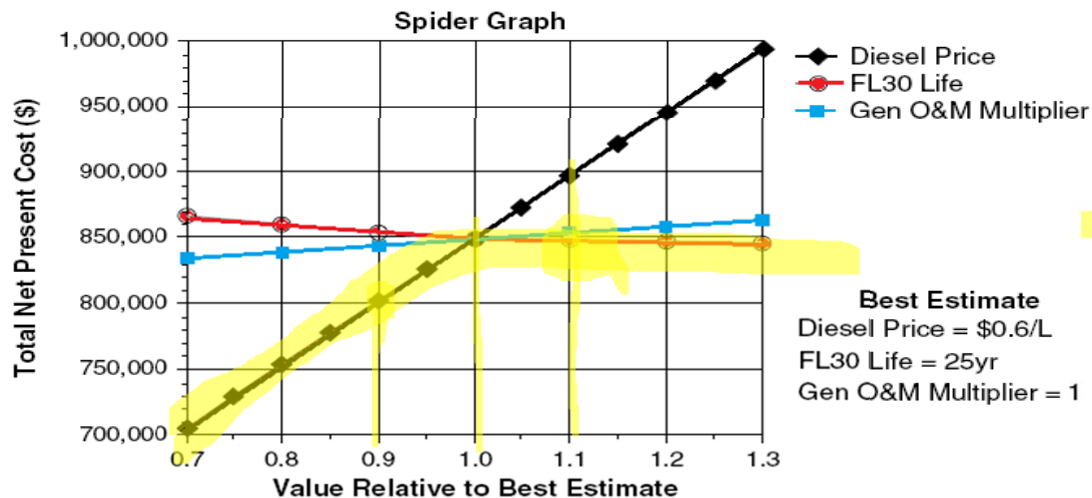
Help Cancel OK



Why Sensitivity Analysis? Uncertainty!

- ⌘ When unsure of a particular variable, enter several values covering the likely range and see how the results vary across the range.
- ⌘ Diesel Generator – Wind Configuration: Uncertainty in diesel fuel price with \$0.6 per liter in the planning stage and 30 year generator lifetime
- ⌘ Example: Spider Graph

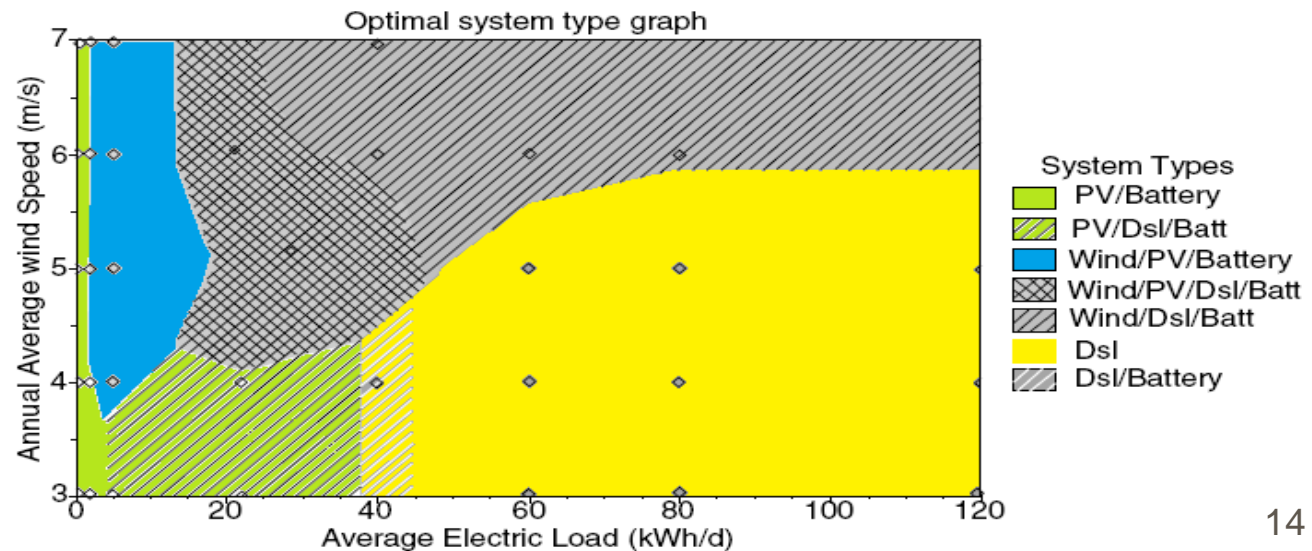
Tabular Format



Diesel (\$/L)	FL30	Gen (kW)	Batt.	Conv. (kW)	Total NPC
0.420		135	48	30	\$ 688,679
0.450		135	48	30	\$ 721,987
0.480	1	135	64	30	\$ 753,695
0.510	1	135	64	30	\$ 777,748
0.540	1	135	64	30	\$ 801,800
0.570	1	135	64	30	\$ 825,852
0.600	1	135	64	30	\$ 849,905
0.630	2	135	64	30	\$ 872,093
0.660	2	135	64	30	\$ 889,525
0.690	2	135	64	30	\$ 906,957
0.720	2	135	64	30	\$ 924,389

Sensitivity Analysis on Hourly Data Sets

- ⌘ Sensitivity analysis on hourly data sets such as primary electric load, solar/wind resource
- ⌘ 8760 values that have a certain average value with scaling variables
- ⌘ Example: Graphical Illustration
 - ⊞ Hourly primary load data with an annual average of 22 kWh/day with average wind speed of 4 m/s
 - ⊞ Primary load scaling variables of 20, 40, ---, 120kWh/day & 3, 4, ---, 7 m/s wind speeds.



Resources Modeling

- ⌘ **Solar Resources:** average global solar radiation on horizontal surface (kWh/m² or kWh/m²-day) **or** monthly average clearness index (atmosphere vs. earth surface). Inputs – solar radiation values and the latitude and the longitude. Output – 8760 hour data set
- ⌘ **Wind Resources:** Hourly or 12 monthly average wind speeds. Anemometer height. Wind turbine hub height. Elevation of the site.
- ⌘ **Hydro Resources:** Run-of-river hydro turbine. Hourly (or monthly average) stream flow data.
- ⌘ **Biomass Resources:** wood waste, agricultural residue, animal waste, energy crops. Liquid or gaseous fuel.
- ⌘ **Fuel:** density, lower heating value, carbon content, sulfur content. Price and consumption limits

Component Modeling– See **Appendix** for details

⌘ HOMER models 10 types of part that generates, delivers, converts, or stores energy

⌘ 3 intermittent renewable resources:

- ⌘ PV modules (dc)
- ⌘ wind turbines (dc or ac)
- ⌘ run-of-river hydro turbines (dc or ac)

⌘ 3 dispatchable energy sources: [control them as needed]

- ⌘ Generators
- ⌘ the grid
- ⌘ boilers

⌘ 2 energy converters:

- ⌘ Converters (dc \leftrightarrow ac)
- ⌘ Electrolyzers (ac,dc \rightarrow electrolysis \rightarrow Hydrogen)

⌘ 2 types of energy storage:

- ⌘ batteries (dc)
- ⌘ hydrogen storage tanks

How to build a HOMER project

⌘ 1. Collect Information

⊞ Electric demand (load)

⊞ Energy resources

⌘ 2. Define Options (Gen, Grid, etc)

⌘ 3. Enter Load Data

⌘ 4. Enter Resource Data

⌘ 5. Enter Component Sizes and Costs

⌘ 6. Enter Sensitivity Variable Values

⌘ 7. Calculate Results

⌘ 8. Examine Results

⌘ Caveat: HOMER is only a model. HOMER does not provide "the right answer" to questions. It does help you consider important factors, and evaluate and compare options.

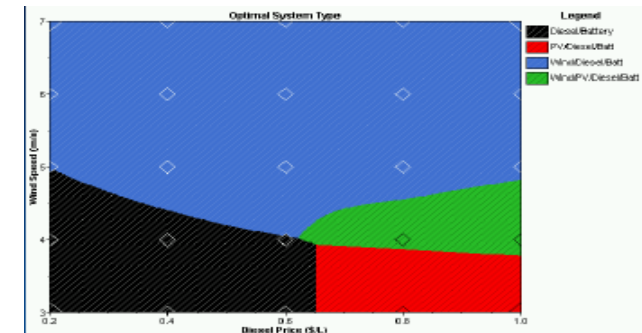
Calculate Simulations: 709 of 3790 Progress: Interrupted after
Sensitivities: 2 of 25 Status:

Sensitivity Results Optimization Results

Sensitivity variables:
Wind Speed (m/s) [0.4] Diesel Price (\$/L) [0.4]

Double click on a system below for simulation results.

	PV (kW)	G10	Dsl (kW)	Batt.	Conv. (kW)	Disp. Strgy	Total Capital
	6		8	4	4	CC	\$ 63,700
	6		8		2	CC	\$ 56,400
	6	1	8	4	4	CC	\$ 90,700
	6	1	8		4	CC	\$ 85,300



Example Case – Micro Grid in Sri Lanka

⌘ Load profile:

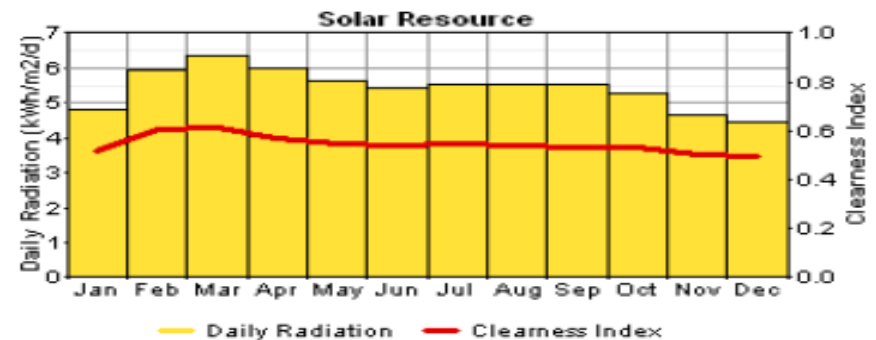
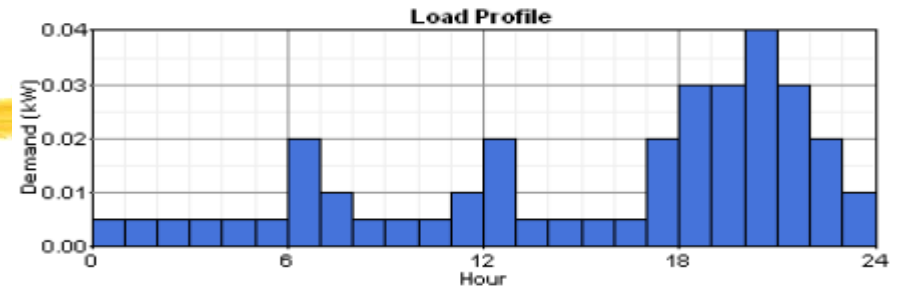
- ⊞ base load of 5W, small peaks of 20 W, peak load of 40W; total daily average load = 350 Wh
- ⊞ Sensitivity analysis range: [0.3kW/h, 16kWh/d]

⌘ Solar Resource

- ⊞ 7.30 Latitude & 81.30 longitude
- ⊞ NASA Surface Meteorology and Solar Energy Web: average solar radiation = 5.43 kWh/m²/d.

⌘ Diesel Fuel Price

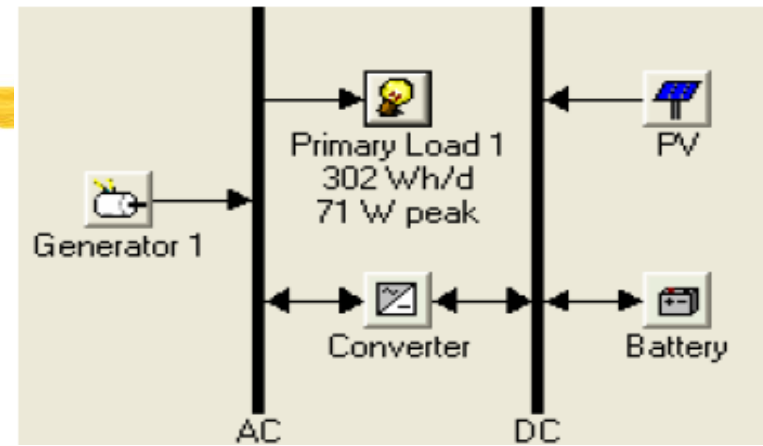
- ⊞ \$0.4/L – \$0.7/L
- ⊞ Sensitivity analysis range: [\$0.3, 0.8] with increment of \$0.1/L



- **Economics:**
 - Real annual interest rate at 6%
 - **Reliability Constraints**
 - 0% annual capacity shortage
- Sensitivity Analysis range: [0, 5 – 5]₁₈%

Example Case – Micro Grid in Sri Lanka

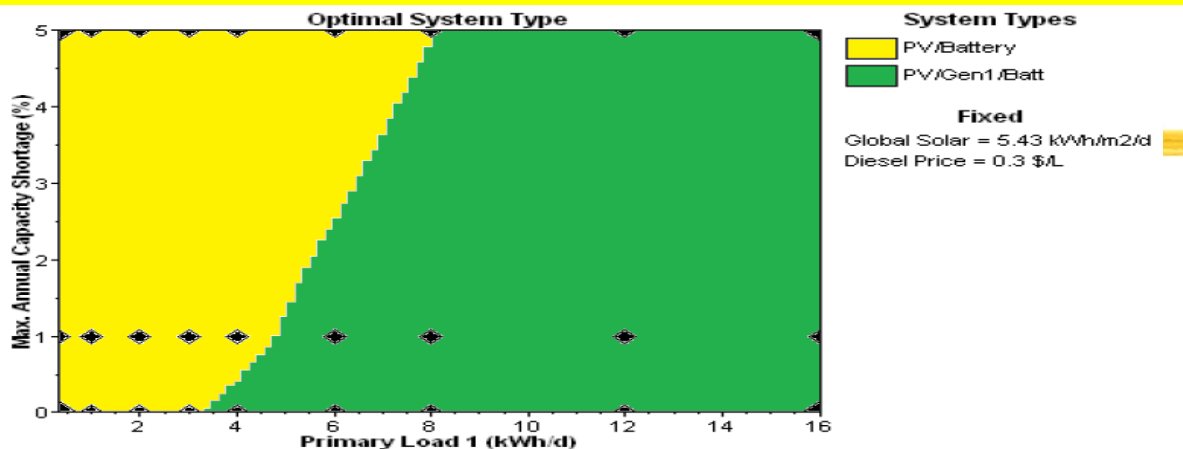
- ⌘ PV: de-rating factor at 90%
- ⌘ Battery: T-105 or L-16
- ⌘ Converters: efficiency at 90% for inversion and 85% for rectification
- ⌘ Generator: not allowed to operate at less than 30% capacity



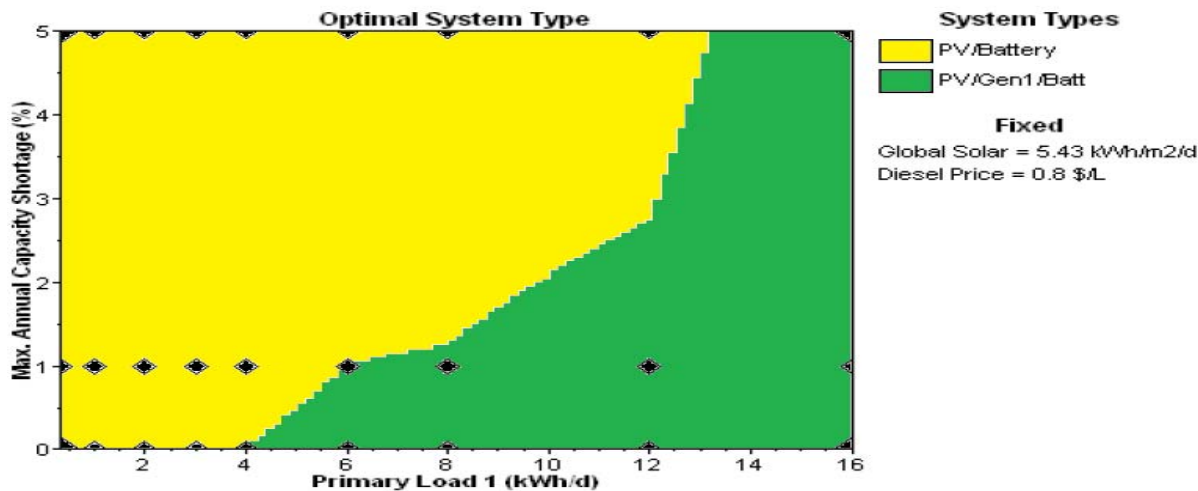
Component	Size	Capital Cost (\$)	Replacement Cost	O&M Cost (\$)	Lifetime
PV Panels	0.05 – 5.0 kW	\$7,500/kW	\$7,500/kW	0.00	20 years
Trojan T-105 Batteries	225 Ah / 6 volt (bank size: 1 – 54 batteries)	\$75/battery	\$75/battery	\$2.00/year	845 kWh of throughput per battery
Converter	0.1 – 4.0 kW	\$1,000/kW	\$1,000/kW	\$100/year	15 years
Generator	4.25 kW	\$2,550	\$2,550	\$0.15/hour	5000 hours

Analysis Result

⌘ Diesel
price
\$0.3/L

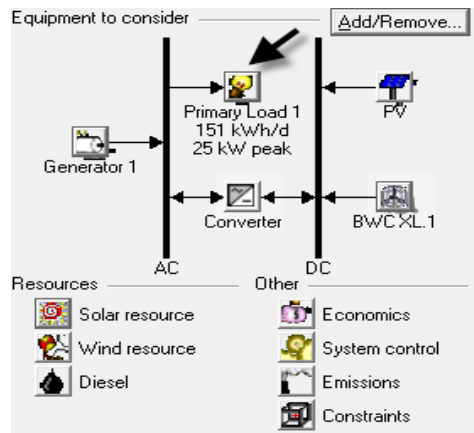


⌘ Diesel
Price
\$0.8/L

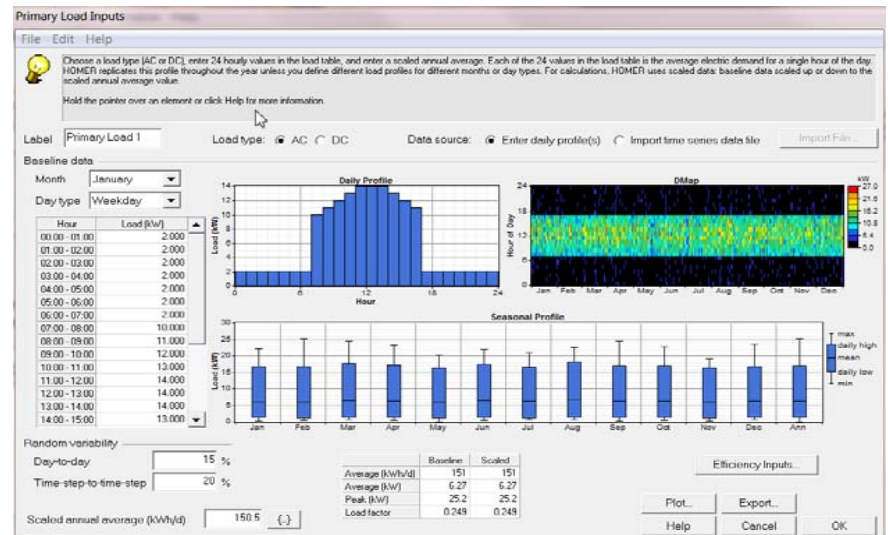
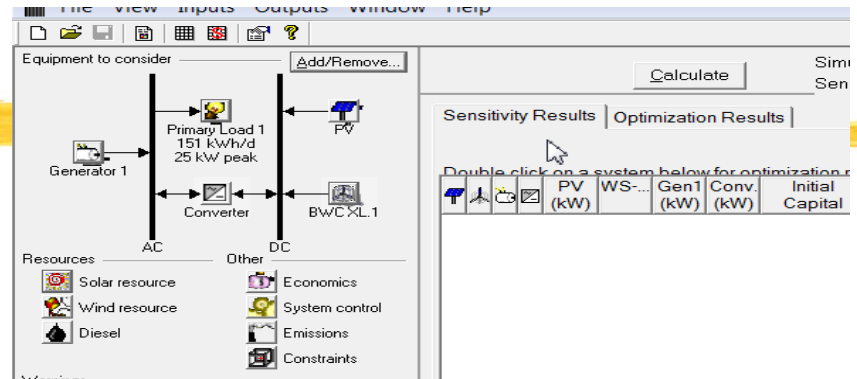


HOMER: Getting Started – with existing file

- ⌘ 1. “ExampleProject.hmr”
- ⌘ 2. Open the Example Project File: ExampleProject.hmr
- ⌘ 3. Click the Primary Load



- ⌘ 4. Exit out of HOMER – We have things to do



Find the Site [Location]

⌘ Latitude and Longitude

- ⌘ Your dorm room
- ⌘ Your home
- ⌘ Your favorite place

www.latlong.net 50% Search

ted Getting Started New Tab

Place Name
Washington, DC Find

Add the country code for better results. Ex: London, UK

Latitude Longitude
38.907192 -77.036871

Facebook Degrees in Decimal

Map Satellite Dupont Circle Church St NW Stead Park Church St NW Logan Circle Historic District Whole Foods Market
The Front Page Firefly McDonald's National Geographic Museum Washington Plaza The Westin Washington, DC City Center Loews Madison Iowa Condominiums
Nordstrom Rack

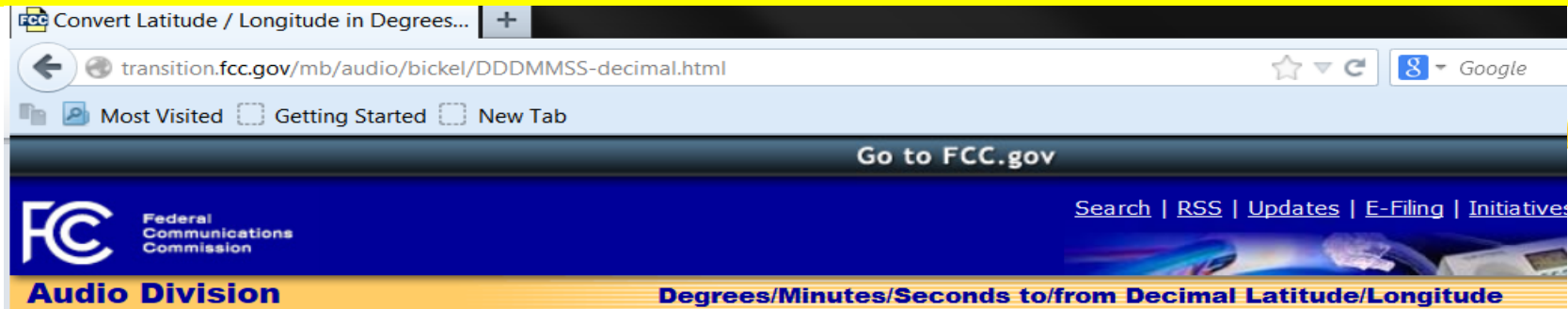
(38.907192, -77.036871) X

Google

Lat Long	GPS Coordinates	Map Mouse Over Location
(38.907192, -77.036871)	38° 54' 25.8912" N 77° 2' 12.7356" W	

Degrees in Decimal Degrees in Minutes Seconds

LAT and LONG --- Conversion



Degrees Minutes Seconds to Decimal Degrees

Enter Degrees Minutes Seconds latitude:	<input type="text" value="38"/>	<input type="text" value="54"/>	<input type="text" value="25.891"/>
Enter Degrees Minutes Seconds longitude:	<input type="text" value="-77"/>	<input type="text" value="2"/>	<input type="text" value="12.735"/>
<input type="button" value="Convert to Decimal"/>		<input type="button" value="Clear Values"/>	
Results: Latitude:	<input type="text" value="38.907192"/>	Longitude:	<input type="text" value="-77.036871"/>

Decimal Degrees to Degrees Minutes Seconds

Decimal Latitude:	<input type="text" value="38.901792"/>		
Decimal Longitude:	<input type="text" value="-77.036871"/>		
<input type="button" value="Convert to Degrees Minutes Seconds"/>		<input type="button" value="Clear Values"/>	
Results: Latitude:	<input type="text" value="38° 54' 6.4512"/>	Longitude:	<input type="text" value="-77° 2' 12.7356"/>

Resources – Average Monthly Irradiation and Wind Speed

ATMOSPHERIC SCIENCE DATA CENTER

Surface meteorology and Solar Energy

A renewable energy resource web site (release 6.0)

sponsored by [NASA's Applied Science Program](#) in the Science Mission Directorate
developed by [POWER](#): Prediction of Worldwide Energy Resource Project

- over 200 satellite-derived meteorology and solar energy parameters
- monthly averaged from 22 years of data
- data tables for a particular location
- GIS Web Mapping Application & Services

HIGHLIGHTS





[Join the SSE mailing list](#) to receive updates about the SSE data archive.

Data Retrieval:

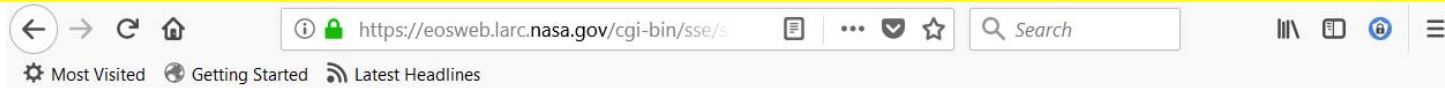
- [Meteorology and Solar Energy](#)
- [GIS Web Mapping Application & Services](#)
- [Renewable Software Application Inputs](#) HOMER
RETScreen

Supporting Documentation:

- [Acknowledgement for data usage](#)
- [Horizontal Grid for Input and Output](#)
- [A](#)



MASA



[Team](#).




Surface meteorology and Solar Energy

A renewable energy resource web site (release 6.0)


sponsored by [NASA's Applied Science Program](#) in the Science Mission Directorate
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- over 200 satellite-derived meteorology and solar energy parameters
- monthly averaged from 22 years of data
- data tables for a particular location
- GIS Web Mapping Application & Services

 [Join the SSE mailing list](#) to receive updates about the SSE data archive.

Data Retrieval:

 [Meteorology and Solar Energy](#)

- [Data tables for a particular location](#)

Tables of all SSE data set parameters for a single site.

- [Regional data subsets](#)

Subsets of data by region.

- [Daily data](#)

Time series plots and data lists of Insolation and Air Temperature for a single site.

- [Global data sets](#)

Text files of monthly averaged data for the entire globe. Some annual averages or annual sums are included.



Next Step



A new POWER home page with enhanced responsive GIS-enabled web data services and mapping capabilities will soon replace the current SSE home page with a target date of May 1, 2018. This current set of SSE web applications and website will no longer be accessible after that date. The new POWER will include improved solar and meteorological data with all parameters available on a 0.5-degree global grid. The beta version of the new home page, featuring the updated parameters, schedule updates and FAQ, can be accessed at [POWER](#). Please direct any questions to [POWER Project Team](#).



NASA Surface meteorology and Solar Energy - Location



Enter BOTH latitude and longitude either in decimal degrees or degrees and minutes separated by a space.

Example:

Latitude?

Longitude?

Latitude 33.5
Longitude -80.75

OR

Latitude 33 30
Longitude -80 45

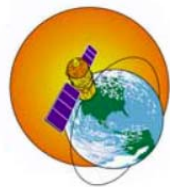
South: -90 to 0

North: 0 to 90

West: -180 to 0

East: 0 to 180

This form is "Reset" if the input is out of range.



[Back to SSE Data Set Home Page](#)

Responsible > Data: Paul W. Stackhouse, Jr., Ph.D.
Officials > Archive: John M. Kusterer
Site Administration/Help: NASA Langley [ASDC User Services \(Contact Us\)](#)
[\[Privacy Policy and Important Notices\]](#)
Document generated on Wed Apr 11 08:55:56 EDT 2018

Select Parameters – Just 2 below are enough

Latitude **38.9** / Longitude **-77.03** was chosen.

Select parameters and press Submit
(Default is ALL types)

Submit

Reset

Geometry

Latitude and longitude (center and boundaries)

Parameters for Solar Cooking

Average insolation

Midday insolation

Clear sky insolation

Clear sky days

Insolation on horizontal surface (Average, Min, Max)

Diffuse radiation on horizontal surface (Average, Min, Max)

Topographic maps of data sets.

Meteorology (Wind)

Wind Speed at 50 m (Average, Min, Max)

Percent of time for ranges of Wind Speed at 50 m

Wind Speed at 50 m for 3-hourly intervals

Wind Direction at 50 m

Wind Direction at 50 m for 3-hourly intervals

Wind Speed at 10 m for terrain similar to airports

Select parameters and press Submit
(Default is ALL types)

Submit

Reset

Monthly Data for Insolation and Wind Speed

Northern boundary
39

Center
Latitude 38.5
Longitude -77.5

Western boundary -78 Eastern boundary -77

Southern boundary
38

Parameters for Solar ~~Estimating~~:

Monthly Averaged Insolation Incident On A Horizontal Surface (kWh/m²/day)

Lat 38.9 Lon -77.03	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22-year Average	2.12	2.87	3.91	4.86	5.40	5.80	5.67	5.00	4.38	3.51	2.36	1.89

Parameter Definition

Meteorology (Wind):

Monthly Averaged Wind Speed At 50 m Above The Surface Of The Earth (m/s)

Lat 38.9 Lon -77.03	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	5.28	5.35	5.40	4.96	4.09	3.97	3.46	3.41	3.88	4.33	5.09	5.33	4.54

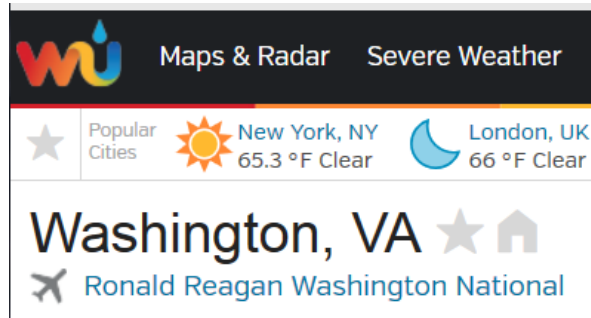
Minimum And Maximum Difference From Monthly Averaged Wind Speed At 50 m (%)

Lat 38.9 Lon -77.03	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Minimum	-10	-12	-12	-9	-11	-9	-12	-11	-6	-14	-8	-7	-10
Maximum	8	7	8	9	14	7	9	9	8	11	11	8	9

Sources for Wind Data

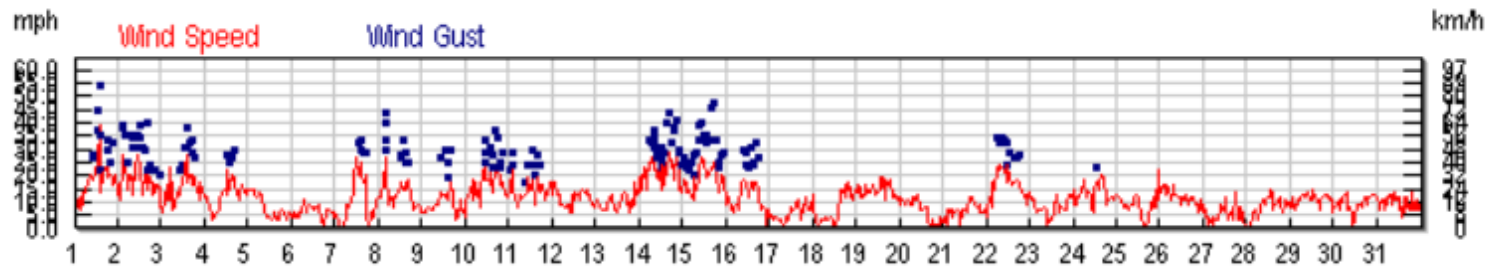
⌘ www.windfinder.com

⌘ www.wunderground.com



$$1 \text{ mph} = 0.44704 \text{ ms}^{-1}$$

$$1 \text{ knot} = 0.514444444 \text{ meters / second}$$

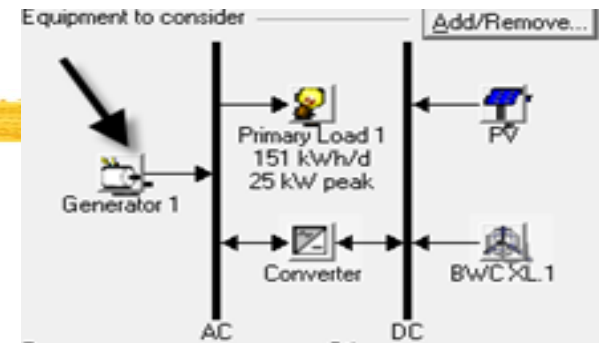


HOMER: Open the file again

⌘ Click the generator

⌘ 25 kW \$10,000

⌘ Minimum running at 30%



Choose a fuel, and enter at least one size, capital cost and operation and maintenance (O&M) value in the Costs table. Note that the capital cost includes installation costs, and that the O&M cost is expressed in dollars per operating hour. Enter a nonzero heat recovery ratio if heat will be recovered from this generator to serve thermal load. As it searches for the optimal system, HOMER will consider each generator size in the Sizes to Consider table.

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

Cost | Fuel | Schedule | Emissions

Costs

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/hr)
25.000	10000	9000	0.500

Sizes to consider

Size (kW)
0.000
25.000
30.000
35.000
40.000

Properties

Description: Generator 1 Type: AC DC

Abbreviation: Gen1

Lifetime (operating hours): 15000

Minimum load ratio (%): 30

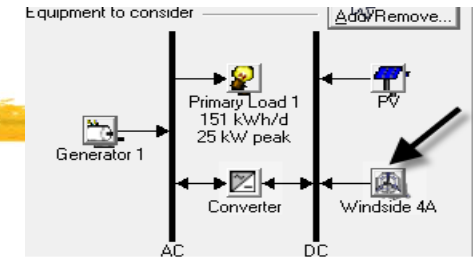
Cost Curve

The Cost Curve graph plots Cost (000 \$) on the y-axis (0 to 16) against Size (kW) on the x-axis (0 to 40). Two lines are shown: a red line for 'Capital' and a blue line for 'Replacement'. Both lines show a linear increase in cost with size. The Capital cost line is consistently higher than the Replacement cost line.

Equipment

⌘ Click Wind Turbine

- From the drop down list click through the wind turbines and look at the power curve. Try to find a Wind Turbine that would best maximize Average Wind Speed (m/s) :3.27



Choose a wind turbine type and enter at least one quantity and capital cost value in the Costs table. Include the cost of the tower, controller, wiring, 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.

Turbine type: **Windside 4A** [Details...] [New...] [Delete]

Turbine properties

- Abbreviation: WS-4A (used for column headings)
- Rated power: 1.2 kW DC
- Manufacturer:
- Website: www.windside.com

Costs

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

Sizes to consider

Quantity
0
1
2
3

Other

Lifetime (yrs) [15] [{}]

Hub height (m) [25] [{}]

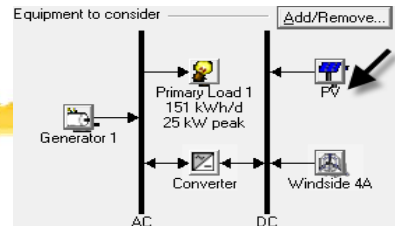
Power Curve

Cost Curve

Help Cancel OK

Equipment

☘ Click PV



☘ Lifetime, De-rating factor, slope, No-tracking

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.

Costs

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/yr)
10.000	35000	25000	0

{.} {:.} {:.}

Properties

Output current AC DC

Lifetime (years) {:.}

Derating factor (%) {:.}

Slope (degrees) {:.}

Azimuth (degrees W of S) {:.}

Ground reflectance (%) {:.}

Sizes to consider

Size (kW)
0.000
10.000
15.000
20.000
25.000

Cost Curve

— Capital — Replacement

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

Resource Information

Resources

-  Solar resource
-  Wind resource
-  Diesel

⌘ Select Solar Resources, Wind Resources, and Diesel

⌘ Type in Solar Radiation

Type in Wind Speed

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: North South Time zone: (GMT+09:00) Japan, North Korea, South Korea

Longitude: East West

Data source: Enter monthly averages Import time series data file

Baseline data

Month	Clearness Index	Daily Radiation (kWh/m ² /d)
January	0.280	2.820
February	0.355	3.690
March	0.427	4.490
April	0.529	5.400
May	0.577	5.570
June	0.536	4.990
July	0.442	4.170
August	0.423	4.190
September	0.362	3.950
October	0.343	3.550
November	0.273	2.760
December	0.257	2.550

Average: 0.401 4.011

Scaled annual average (kWh/m²/d)



Plot... Export... Help Cancel OK

HOMER uses wind resource inputs to calculate the wind power for each hour of the year. Enter the wind speed, and either a scaled data control how HOMER generates the 8760 hours of the year. 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	3.460
February	3.660
March	3.810
April	3.910
May	3.430
June	3.030
July	3.020
August	2.880
September	2.680
October	2.730
November	3.250
December	3.340

Annual average: 3.264

⌘ Diesel Fuel Price

Enter the fuel price. The fuel properties can only be changed when creating a new fuel (click New in the Generator Inputs or Boiler Inputs window). Hold the pointer over an element name or click Help for more information.

Price (\$/L)

Limit consumption to (L/yr)

Fuel properties

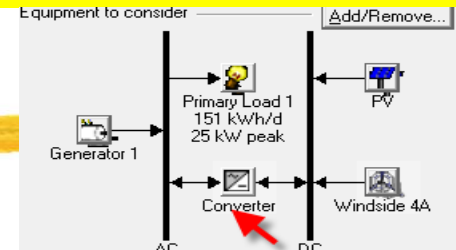
Lower heating value: 43.2 MJ/kg
 Density: 820 kg/m³
 Carbon content: 88 %
 Sulfur content: 0.33 %

Help Cancel OK

Equipment

⌘ Click Converter icon

⌘ 5kW \$4,000



A converter is required for systems in which DC components serve an AC load or vice-versa. A converter can be an inverter (DC to AC), rectifier (AC to DC), or both.

Enter at least one size and capital cost value in the Costs table. Include all costs associated with the converter, such as hardware and labor. As it searches for the optimal system, HOMER considers each converter capacity in the Sizes to Consider table. Note that all references to converter size or capacity refer to inverter capacity.

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

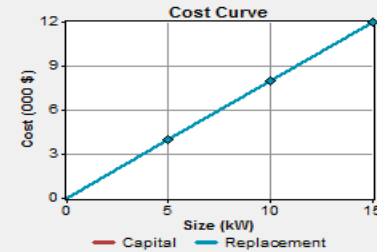
Costs

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/yr)
5.000	4000	4000	0

{.}

Sizes to consider

Size (kW)
0.000
5.000
10.000
15.000



Inverter inputs

Lifetime (years) {.}

Efficiency (%) {.}

Inverter can operate simultaneously with an AC generator

Rectifier inputs

Capacity relative to inverter (%) {.}

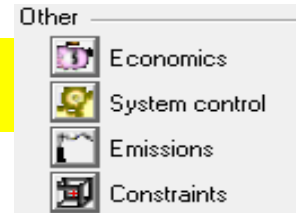
Efficiency (%) {.}

Help

Cancel

OK

Other Information

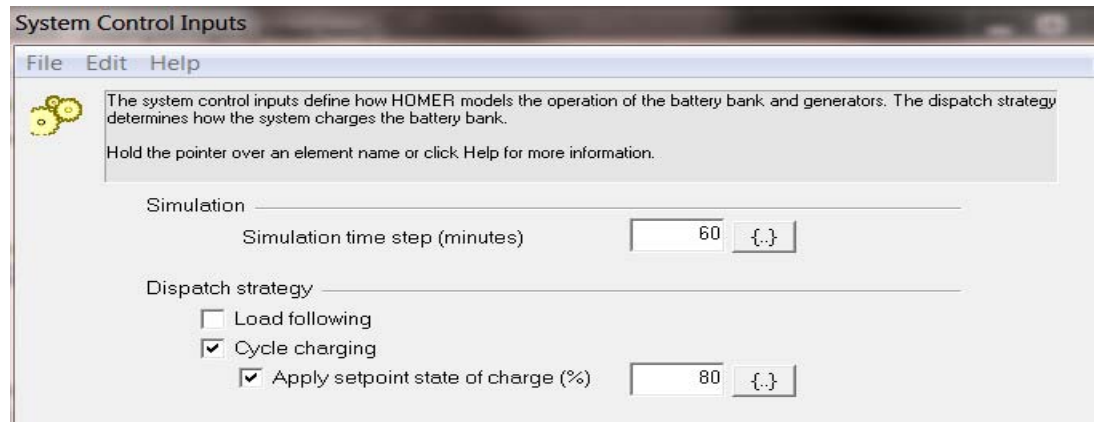
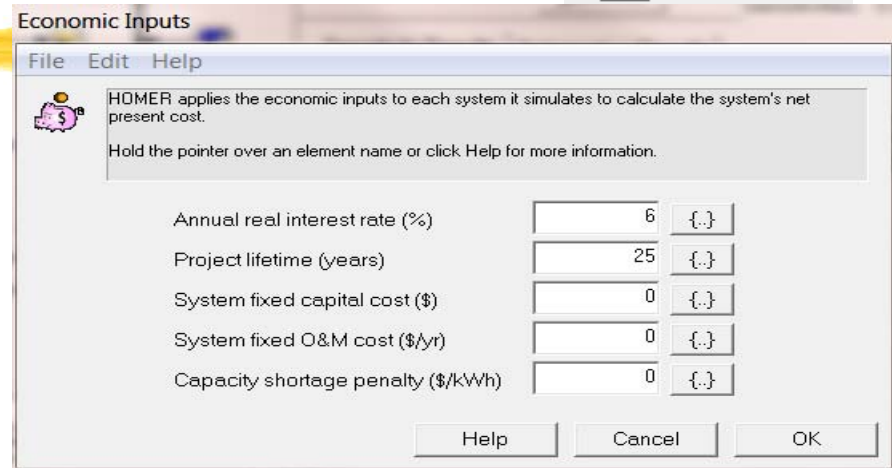


⌘ Economics

- ☑ Real interest 6 %
- ☑ Lifetime 25 years

⌘ System Control

- ☑ Cycle-charging



Other Information

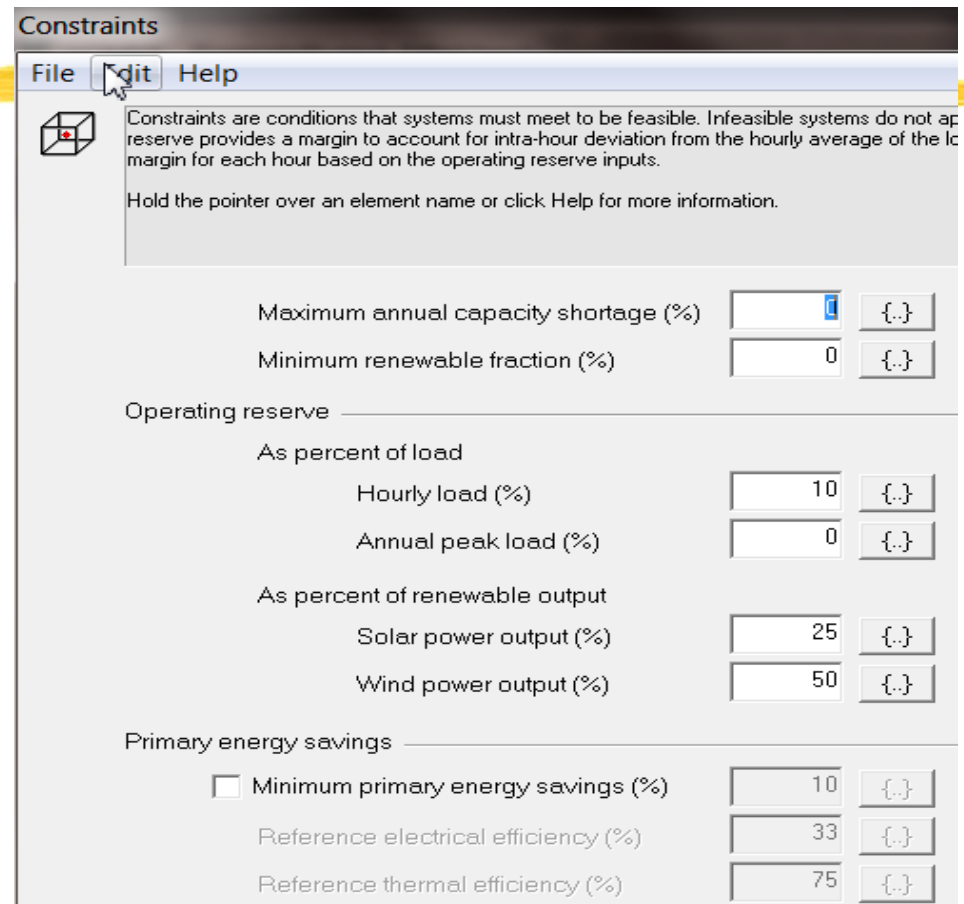
⌘ Emission: all 0

☑ This time

⌘ Constraints

☑ Operating
reserve 10%

☑ Capacity
shortage 0%



Constraints

File Edit Help

Constraints are conditions that systems must meet to be feasible. Infeasible systems do not ap reserve provides a margin to account for intra-hour deviation from the hourly average of the lo margin for each hour based on the operating reserve inputs.
Hold the pointer over an element name or click Help for more information.

Maximum annual capacity shortage (%) {}

Minimum renewable fraction (%) {}

Operating reserve

As percent of load

Hourly load (%) {}

Annual peak load (%) {}

As percent of renewable output

Solar power output (%) {}

Wind power output (%) {}

Primary energy savings

Minimum primary energy savings (%) {}

Reference electrical efficiency (%) {}

Reference thermal efficiency (%) {}

Emission Calculation in HOMER

⌘ Carbon content of fuel

⌘ If CO₂ is only interest

⏏ Set 0 to CO

Fuel properties

Lower heating value: 43.2 MJ/kg
Density: 820 kg/m³
Carbon content: 88 %
Sulfur content: 0.33 %

Help Cancel OK

10080 - Emission calculation

Posted by on 15 December 2010 03:49 PM

How does HOMER calculate emission, especially carbon dioxide?

If the system you are modeling consumes fuel, HOMER calculates the total annual carbon input by multiplying the fuel consumption by the carbon content of the fuel. It assumes that all that carbon gets emitted as either unburned hydrocarbons, CO, or CO₂. You enter the emissions factors for unburned hydrocarbons and CO, so HOMER can calculate how much of the total carbon gets emitted in those two forms. The rest gets emitted as CO₂.

Typically only a tiny fraction of the carbon gets emitted as hydrocarbon and CO, so nearly all of it gets emitted as CO₂. If you are interested only in CO₂, you should set the UHC and CO emissions factors to zero. Note that 3.67 g of CO₂ contains 1 g of carbon. So ignoring UHC and CO emissions, the system will emit 3.67 g of CO₂ for every g of carbon in the consumed fuel.

Generator Inputs

File Edit Help

Choose a fuel, and enter at least one size, capital cost and operation and maintenance (O&M) value in the Costs table. Note that the capital cost includes installation costs, and that the O&M cost is expressed in dollars per operating hour. Enter a nonzero heat recovery ratio if heat will be recovered from this generator to serve thermal load. As it searches for the optimal system, HOMER will consider each generator size in the Sizes to Consider table. Hold the pointer over an element or click Help for more information.

Cost Fuel Schedule Emissions

Emissions factors

Carbon monoxide (g/L of fuel)	6.5	{..}
Unburned hydrocarbons (g/L of fuel)	0.72	{..}
Particulate matter (g/L of fuel)	0.49	{..}
Proportion of fuel sulfur converted to PM (%)	2.2	{..}
Nitrogen oxides (g/L of fuel)	58	{..}

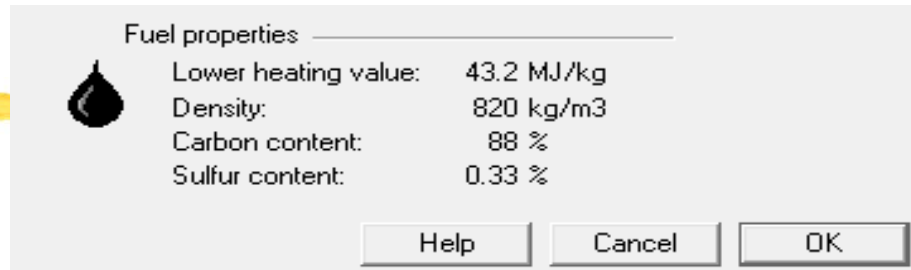
Destination of fuel carbon

Carbon dioxide	99.5 %
Carbon monoxide	0.4 %
Unburned hydrocarbons	0.1 %
Total	100.0 %

Help Cancel OK

Fuel Carbon Content

⌘ Diesel

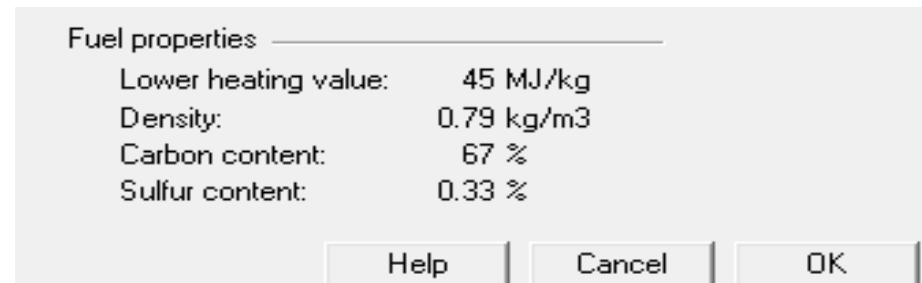


Fuel properties

Lower heating value: 43.2 MJ/kg
Density: 820 kg/m³
Carbon content: 88 %
Sulfur content: 0.33 %

Help Cancel OK

⌘ Natural Gas

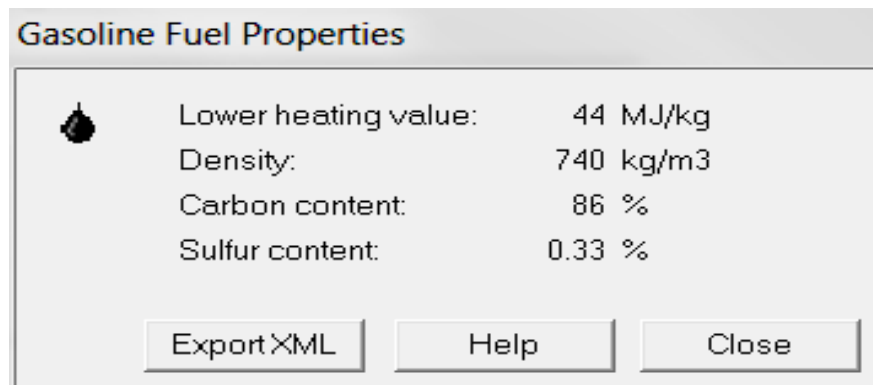


Fuel properties

Lower heating value: 45 MJ/kg
Density: 0.79 kg/m³
Carbon content: 67 %
Sulfur content: 0.33 %

Help Cancel OK

⌘ Gasoline



Gasoline Fuel Properties

Lower heating value: 44 MJ/kg
Density: 740 kg/m³
Carbon content: 86 %
Sulfur content: 0.33 %

Export XML Help Close

Carbon Tax or Penalty

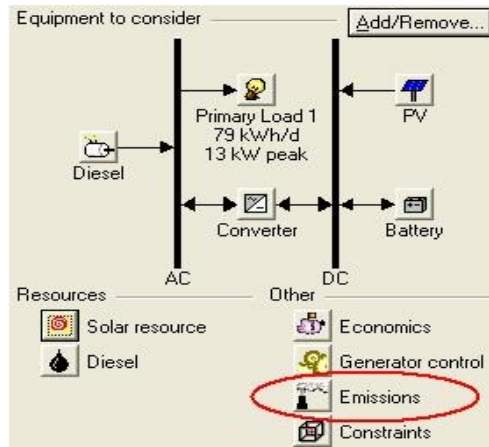
10397 - HOMER and Carbon

Posted by on 04 January 2011 11:50 AM

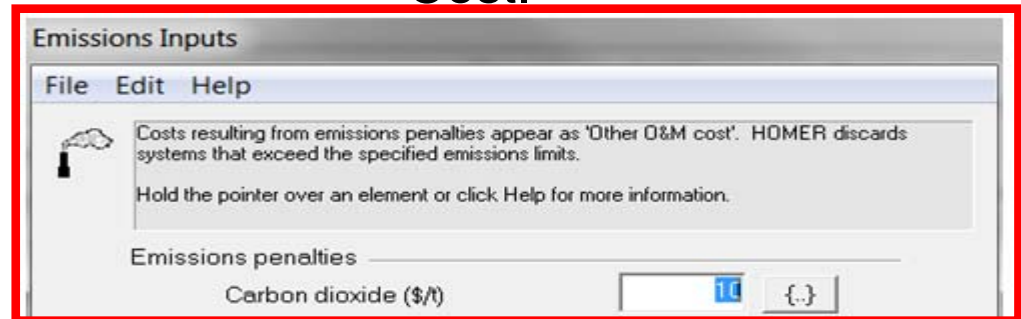


The best way to use HOMER and Carbon? Two scenarios suppose you are carbon capped would you just put in a fuel cap. If you are carbon taxed would you just add cost to fuel.

You can limit or penalize emissions if you click the Emissions button just below the schematic:



⌘ Carbon penalty will appear as "Other" O&M Cost.



To cap carbon dioxide emissions, click the CO2 checkbox in the lower half of the Emissions window and enter the maximum allowable emissions in kg/yr. To apply a carbon tax enter the penalty in \$/tonne in the top half of the window. Just be sure to enter it in terms of \$/tonne of CO2, not per tonne of carbon.

You can limit fuel consumption if you click on the fuel button below the schematic. That would have the same effect as limiting emissions, but you would have to calculate the amount of fuel corresponding to your emission cap. It's easier to just enter the emission cap. Same with the carbon tax – you could calculate the equivalent cost per litre of fuel and increase the fuel price accordingly, but it's easier to just enter the emission penalty.

Example

⌘ 3 Generators only to meet a load

- ☒ Diesel generator – Carbon 88% of 820 kg per 1000 L
- ☒ Gasoline generator – Carbon 86% of 740 kg per 1000L
- ☒ Natural Gas generator – Carbon 67% of 0.79kg per 1 m³

⌘ Total fuel consumption for each

- ☒ Diesel – 10,996 L
- ☒ Gasoline – 1,762 L
- ☒ Natural Gas – 2,613 m³

⌘ Carbon Content

- ☒ Diesel: $820 * 10.996 * 0.88 = 7974$ kg/yr
- ☒ Gasoline: $740 * 1.762 * 0.86 = 1,121$ kg/yr
- ☒ Natural Gas: $0.79 * 2,613 * 0.67 = 1,383$ kg/yr
- ☒ Total = 10,478 kg/yr

⌘ Total CO₂

- ☒ $10,478 \text{ kg} * 3.67 = 38.454$ kg CO₂/year

⌘ Added O&M Cost per year with \$2 per ton of CO₂

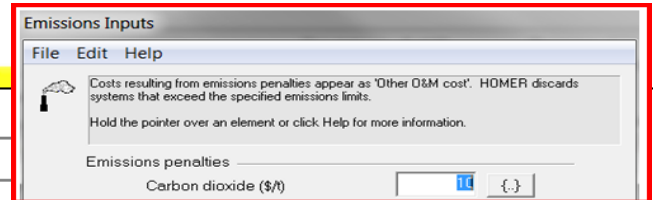
- ☒ $\$2 * 38.454 = \76.9 /yr

Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	38,097
Carbon monoxide	99.9
Unburned hydrocarbons	11.1
Particulate matter	7.53
Sulfur dioxide	79.9
Nitrogen oxides	892

System Report - Example

Project Period = 25 years



Net Present Costs

Component	Capital (\$)	Replacement (\$)	O&M (\$)	Fuel (\$)	Salvage (\$)	Total (\$)
Generator 1	2,000	14,307	22,294,186	112,453	-217	22,422,726
Generator 2	2,000	7,693	6,151,354	33,794	-457	6,194,385
Generator 3	4,000	8,125	7,649,564	33,470	-12	7,695,147
Other	0	0	974	0	0	974
System	8,000	30,126	36,096,072	179,718	-687	36,313,236

36,095,104 for no carbon penalty

Annualized Costs

Component	Capital (\$/yr)	Replacement (\$/yr)	O&M (\$/yr)	Fuel (\$/yr)	Salvage (\$/yr)	Total (\$/yr)
Generator 1	156	1,119	1,744,001	8,797	-17	1,754,056
Generator 2	156	602	481,200	2,644	-36	484,566
Generator 3	313	636	598,400	2,618	-1	601,966
Other	0	0	76	0	0	76
System	626	2,357	2,823,677	14,059	-54	2,840,665

2,823,602 for no carbon penalty

Changed O&M with \$2 per ton of CO2 penalty, for the 38 ton emission per year.
 $\$2 \times 38 = \$76/\text{year}$

Emission Input – Emission Penalty

The screenshot shows the HOMER software interface. The main window displays a system diagram with a Generator 1 connected to an AC bus, which is connected to a Primary Load 1 (43 kWh/d, 4.4 kW peak). The AC bus is also connected to a Converter, which is connected to a DC bus. The DC bus is connected to a PV array and a Windside 4A turbine. The interface includes a menu bar, a toolbar, and a status bar. The Emissions Inputs dialog box is open, showing a table of emissions penalties. The 'Carbon dioxide (\$/t)' field is highlighted with a red circle and contains the value '2.00'. The dialog box also includes a menu bar (File, Edit, Help) and a help text area.

Emissions Inputs

Costs resulting from emissions penalties appear as 'Other O&M cost'. HOMER discards systems that exceed the specified emissions limits. Hold the pointer over an element or click Help for more information.

Emissions penalties	Value	Unit
Carbon dioxide (\$/t)	2.00	{.}
Carbon monoxide (\$/t)	0	{.}
Unburned hydrocarbons (\$/t)	0	{.}
Particulate matter (\$/t)	0	{.}
Sulfur dioxide (\$/t)	0	{.}
Nitrogen oxides (\$/t)	0	{.}

Analysis of the System

⌘ 1. Click “Calculate” to start the analysis

Equipment to consider: Add/Remove...

Simulations: 0 of 400
Sensitivities: 0 of 1

Sensitivity Results | Optimization Results

Double click on a system below for optimization results.

	PV (kW)	WS-...	Gen1 (kW)	Conv. (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC

Resources: AC, DC

Other: Economics, System control, Emissions, Constraints

⌘ Click Overall: view all possible combinations

Calculate

Simulations: 400 of 400
Sensitivities: 1 of 1

Progress:
Status: Completed in 3 seconds.

Sensitivity Results | Optimization Results

Double click on a system below for simulation results.

Category: Overall Overall

	PV (kW)	WS-...	Gen1 (kW)	Conv. (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kW...)	Ren. Frac.	Diesel (L)	Gen1 (hrs)
			25		\$ 10,000	24,713	\$ 325,917	0.464	0.00	38,374	8,7...
	10		25	5	\$ 49,000	24,361	\$ 360,419	0.513	0.12	36,573	8,7...
	10		25	10	\$ 53,000	24,450	\$ 365,558	0.521	0.12	36,530	8,7...
	10		25	15	\$ 57,000	24,557	\$ 370,916	0.528	0.12	36,530	8,7...
		1	25	5	\$ 44,000	25,964	\$ 375,906	0.535	0.00	38,325	8,7...
	15		25	5	\$ 66,500	24,268	\$ 376,727	0.536	0.17	36,038	8,7...
			30		\$ 12,000	28,814	\$ 380,341	0.542	0.00	43,945	8,7...
	15		25	10	\$ 70,500	24,279	\$ 380,866	0.542	0.17	35,813	8,7...
		1	25	10	\$ 48,000	26,070	\$ 381,265	0.543	0.00	38,325	8,7...

Analysis of the System

⌘ Click “Categorized”

Simulations: 400 of 400 Progress:
 Sensitivities: 1 of 1 Status: Completed in 3 seconds.

Sensitivity Results Optimization Results

Double click on a system below for simulation results. Categoriz Overall Export... Details...

	PV (kW)	WS...	Gen1 (kW)	Conv. (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kW...)	Ren. Frac.	Diesel (L)	Gen1 (hrs)
			25		\$ 10,000	24,713	\$ 325,917	0.464	0.00	38,374	8,7...
	10		25	5	\$ 49,000	24,361	\$ 360,419	0.513	0.12	36,573	8,7...
		1	25	5	\$ 44,000	25,964	\$ 375,906	0.535	0.00	38,325	8,7...
	10	1	25	5	\$ 79,000	25,508	\$ 405,075	0.577	0.12	36,531	8,7...

⌘ Now back to “Overall”, and choose any system of interest by clicking/ double clicking

Simulations: 400 of 400 Progress:
 Sensitivities: 1 of 1 Status: Completed in 3 seconds.

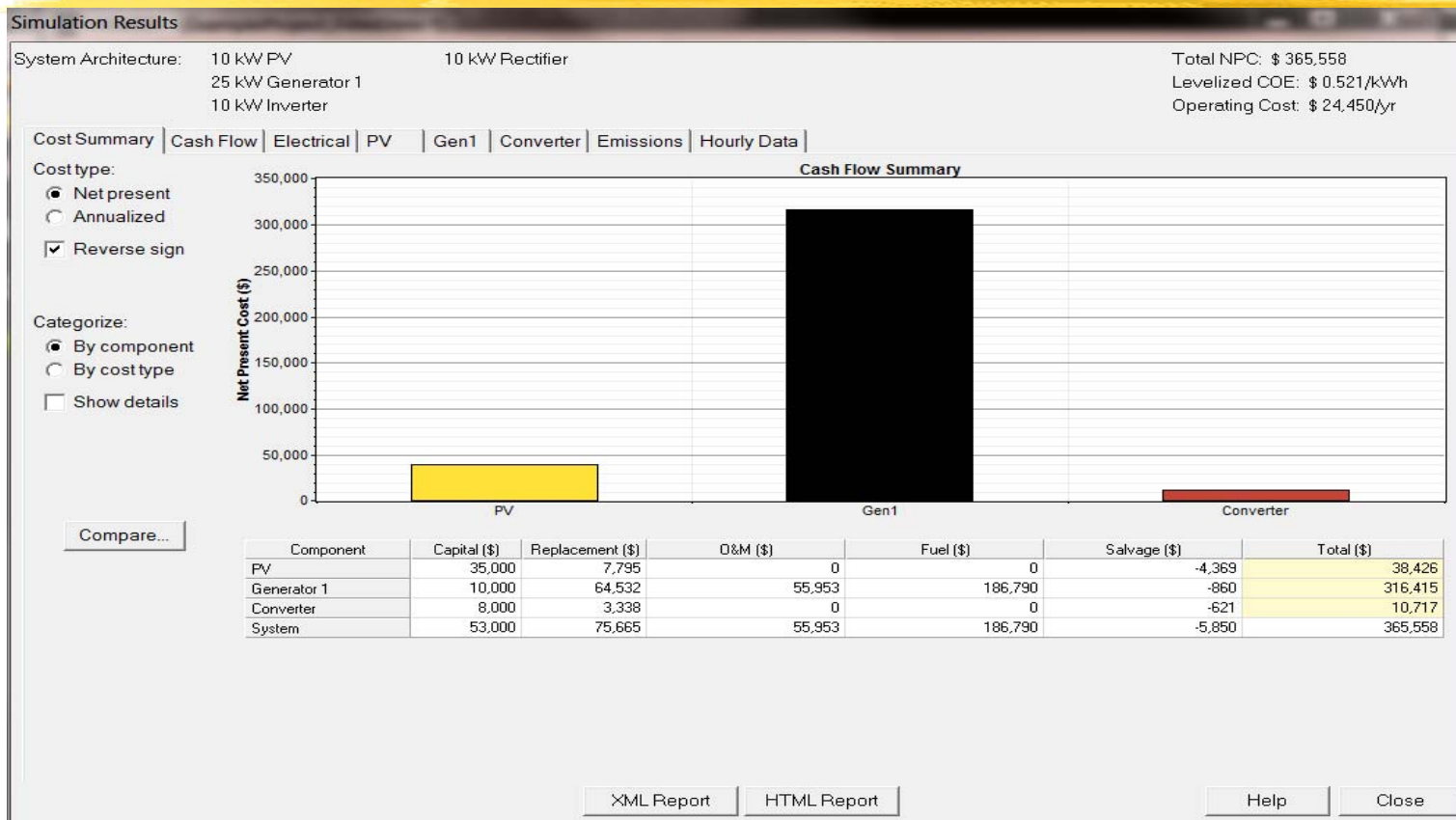
Sensitivity Results Optimization Results

Double click on a system below for simulation results. Categoriz Overall Export... Details...

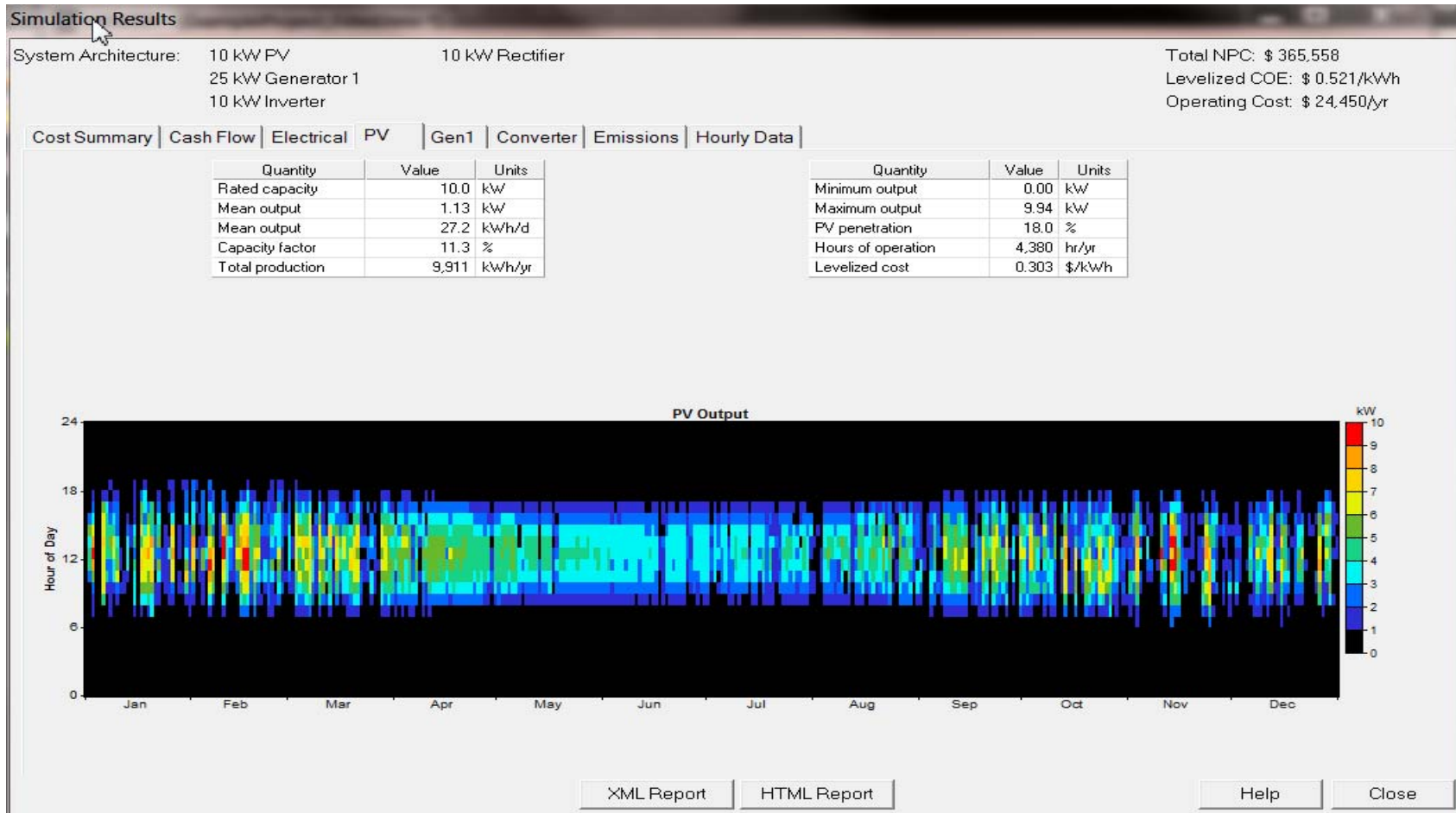
	PV (kW)	WS...	Gen1 (kW)	Conv. (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kW...)	Ren. Frac.	Diesel (L)	Gen1 (hrs)
			25		\$ 10,000	24,713	\$ 325,917	0.464	0.00	38,374	8,7...
	10		25	5	\$ 49,000	24,361	\$ 360,419	0.513	0.12	36,573	8,7...
	10		25	10	\$ 53,000	24,450	\$ 365,558	0.521	0.12	36,530	8,7...
	10		25	15	\$ 57,000	24,557	\$ 370,916	0.528	0.12	36,530	8,7...
		1	25	5	\$ 44,000	25,964	\$ 375,906	0.535	0.00	38,325	8,7...
	15		25	5	\$ 66,500	24,268	\$ 376,727	0.536	0.17	36,038	8,7...

Analysis

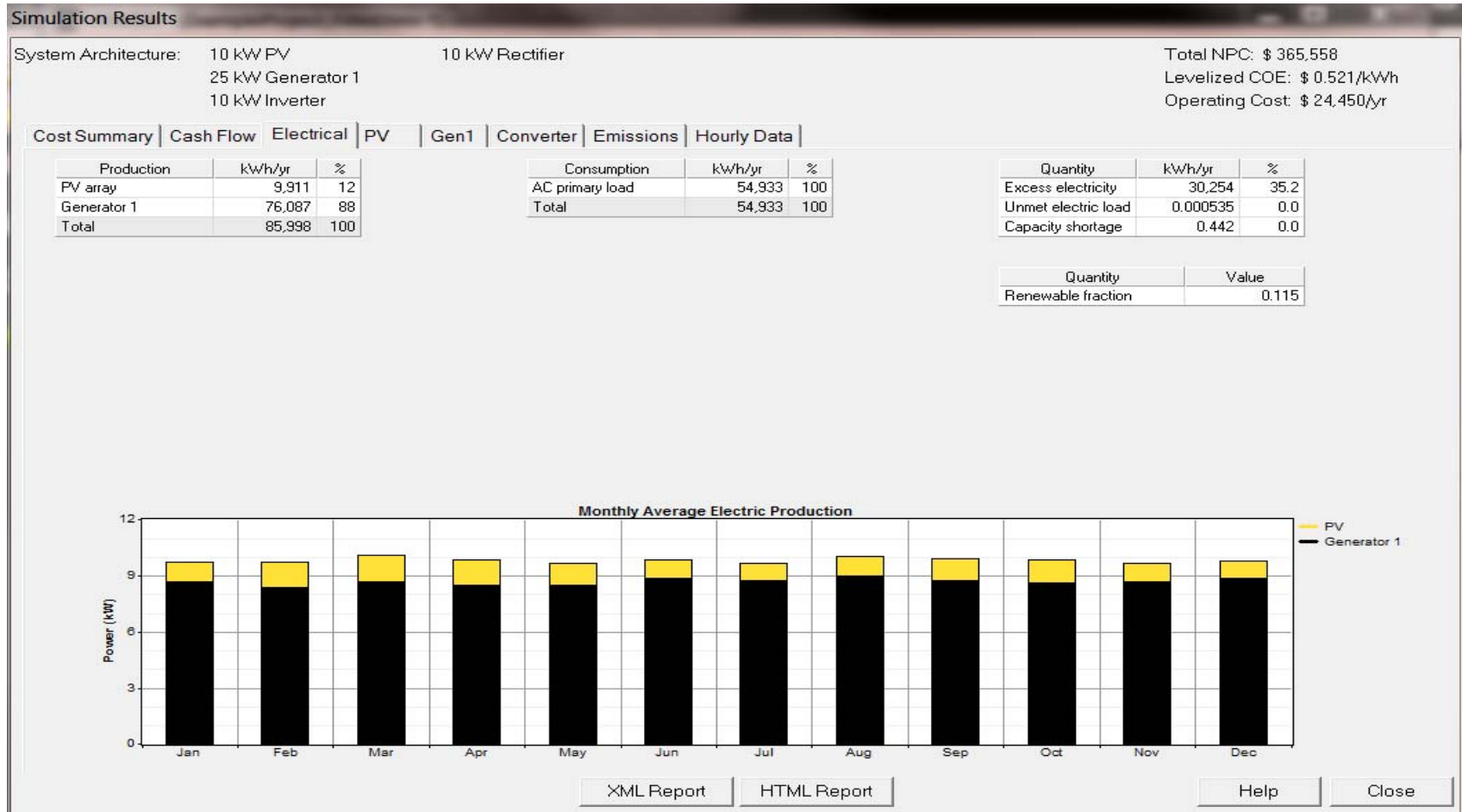
⌘ Simulation Results



PV Output



Electrical Output



Sensitivity Analysis on Wind Power

- ⌘ Click Wind resource
- ⌘ Click “Edit Sensitivity Values” >> **Do so for Load, Solar, and Diesel**
- ⌘ Wind Resources

Sensitivity Values

Variable: Wind Data Scaled Average
Units: m/s
Link with: <none>

Values:

1	3.260
2	5.500
3	7.500
4	9.500
5	
6	
7	
8	
9	
10	
11	
12	

Clear

Help Cancel

Primary Load

Sensitivity Values

Variable: Primary Load 1 Scaled Average
Units: kWh/d
Link with: <none>

Values:

1	150.500
2	100.000
3	50.000
4	25.000
5	
6	
7	
8	
9	
10	
11	
12	

Clear

Help Cancel OK

Solar Resources

Sensitivity Values

Variable: Solar Data Scaled Average
Units: kWh/m²/d
Link with: <none>

Values:

1	4.010
2	8.000
3	12.000
4	16.000
5	
6	
7	
8	
9	
10	
11	
12	

Clear

Help Cancel OK

- ⌘ Diesel Fuel

Sensitivity Values

Variable: Diesel Price
Units: \$/L
Link with: <none>

Values:

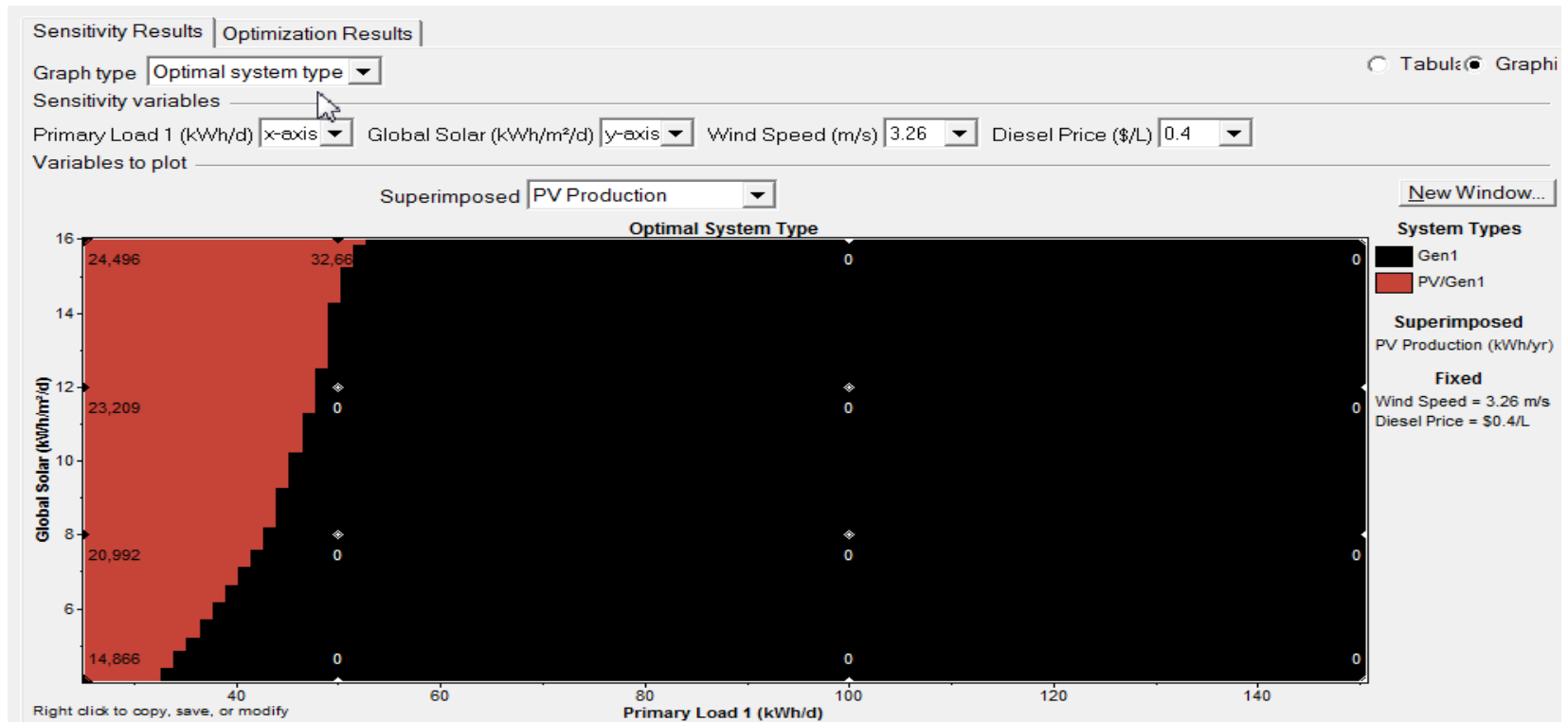
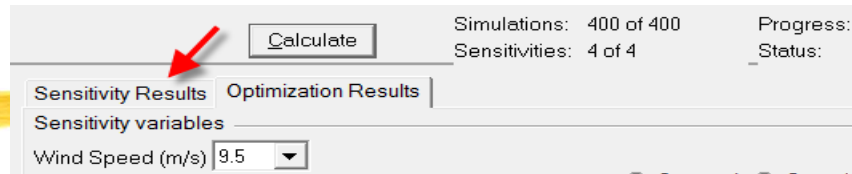
1	0.400
2	0.800
3	1.200
4	
5	
6	
7	
8	
9	
10	
11	
12	

Clear

Help Cancel OK

Sensitivity Analysis

- ⌘ Save and Calculate
- ⌘ New we see the tab for “Sensitivity Results”



HOMER – Input Summary Report

⌘ HOMER Produces An Input Summary Report:

- ☑ Click HTML Input Summary from the File menu, or click the toolbar button:
- ☑ HOMER will create an HTML-format report summarizing all the relevant inputs, and display it in a browser. From the browser, you can save or print the report, or copy it to the clipboard so that you can paste it into a word processor or spreadsheet program.

The screenshot shows the HOMER software interface. The 'HTML Report' button in the toolbar is circled in red. The main workspace displays a system diagram with components: Generator 1, Primary Load 1 (43 kWh/d, 4.4 kW peak), Converter, PV, and Windside 4A. The diagram is divided into AC and DC sections. Below the diagram are 'Resources' (Solar, Wind, Diesel) and 'Other' (Economics, System control, Emissions, Constraints) sections. On the right, there is a 'Calculate' button and simulation status: 'Simulations: 144 of 144', 'Sensitivities: 3 of 3', 'Progress: []', 'Status: Completed in 2 s'. Below this is a 'Sensitivity Results' tab and a table of simulation results.

	PV (kW)	WS-4A	Label (kW)	Conv. (kW)	Initial Capital	Operating Cost (\$/yr)
[] [] [] []	2		5.0	1	\$ 10,600	19,098
[] [] [] []			5.0		\$ 2,000	19,849
[] [] [] []	2	1	5.0	1	\$ 40,600	20,164
[] [] [] []		1	5.0	1	\$ 33,600	20,916

Input summary Report - Example

Practice2.hmr - Mozilla Firefox

File Edit View History Bookmarks Tools Help

Practice2.hmr

file:///C:/Users/ckim/AppData/Local/Temp/Practice2.htm

HOMER Input Summary

File name: Practice2.hmr
 File version: 2.68 beta
 Author: Charles

AC Load: Primary Load 1

Data source: Synthetic
 Daily noise: 15%
 Hourly noise: 20%
 Scaled annual average: 43.4 kWh/d
 Scaled peak load: 4.36 kW
 Load factor: 0.414

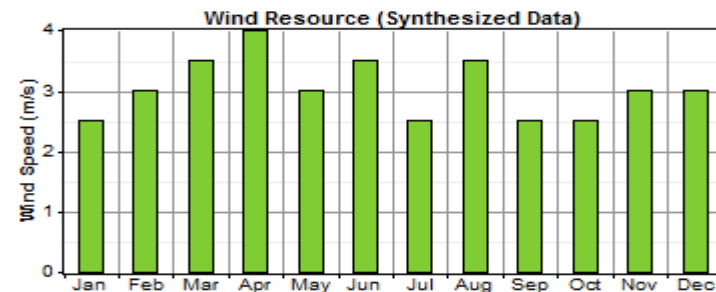
Load Profile (Synthesized Data)

Hour	Demand (kW)
0	1.3
1	1.3
2	1.2
3	1.2
4	1.3
5	1.4
6	1.5
7	1.6
8	1.8
9	2.0
10	2.2
11	2.3
12	2.4
13	2.3
14	2.3
15	2.3
16	2.3
17	2.3
18	2.2
19	2.0
20	1.8
21	1.6
22	1.5
23	1.4
24	1.3

PV

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/yr)
2.000	7,000	7,000	0

Sizes to consider: 0, 2, 4, 6 kW
 Lifetime: 20 yr
 Derating factor: 80%
 Tracking system: No Tracking
 Slope: 0 deg
 Azimuth: 0 deg
 Ground reflectance: 20%

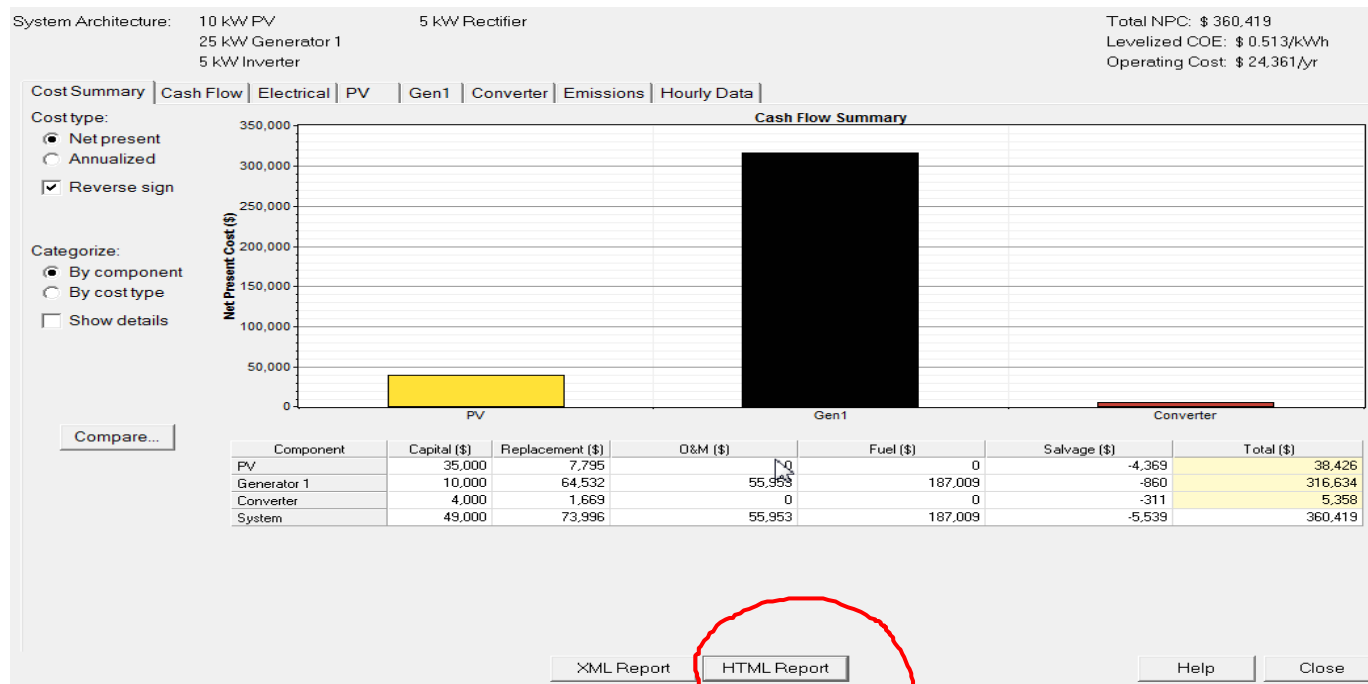


Weibull k: 2.00
 Autocorrelation factor: 0.850
 Diurnal pattern strength: 0.250
 Hour of peak wind speed: 15
 Scaled annual average: 3.04 m/s
 Anemometer height: 10 m
 Altitude: 0 m
 Wind shear profile: Logarithmic
 Surface roughness length: 0.01 m

HOMER – Simulation Result System Report

⌘ HOMER Produces A Report Summarizing The Simulation Results

📄 Just click the HTML Report button in the Simulation Results window:



Example System Report

System Report - Practice2.hmr

Sensitivity case

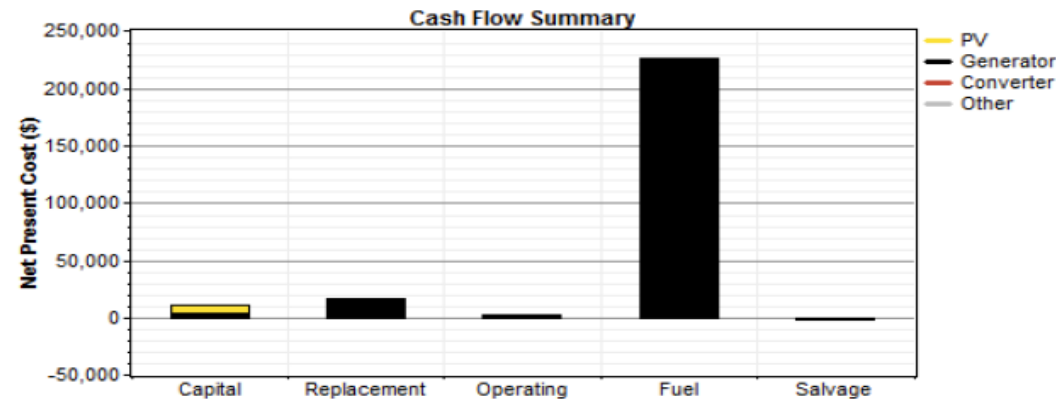
Diesel Price: 2.4 \$/L

System architecture

PV Array	2 kW
Generator	15 kW
Inverter	1 kW
Rectifier	1 kW

Cost summary

Total net present cost	\$ 254,738
Levelized cost of energy	\$ 1.258/kWh
Operating cost	\$ 19,098/yr



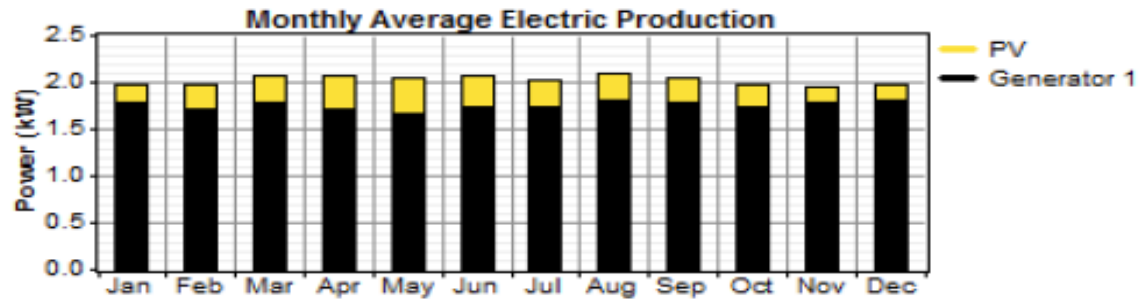
Net Present Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	(\$)	(\$)	(\$)	(\$)	(\$)	(\$)
PV	7,000	2,183	0	0	-1,223	7,959
Generator 1	2,000	14,340	2,238	225,506	-191	243,893
Converter	1,600	668	0	0	-124	2,143
Other	0	0	742	0	0	742
System	10,600	17,191	2,980	225,506	-1,539	254,738

Electrical

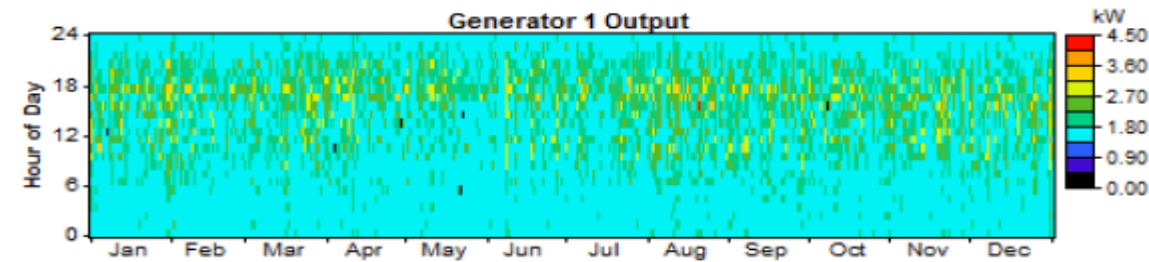
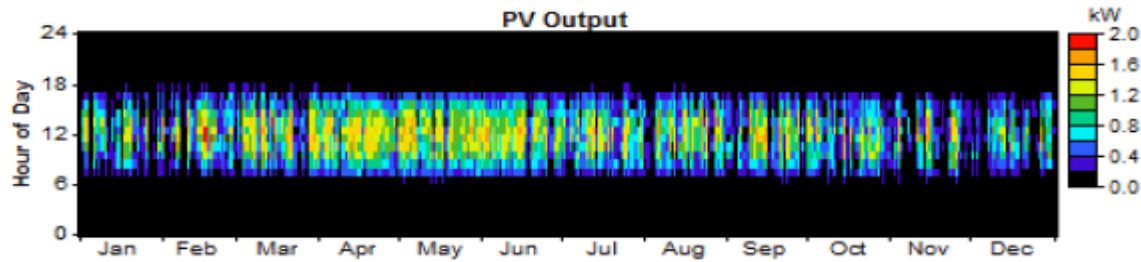
Component	Production	Fraction
	(kWh/yr)	
PV array	2,341	13%
Generator 1	15,396	87%
Total	17,737	100%

System Report



Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	19,356
Carbon monoxide	47.8
Unburned hydrocarbons	5.29
Particulate matter	3.6
Sulfur dioxide	38.9
Nitrogen oxides	426



This message?



Generator 1 search space may be insufficient.



Completed in 3 seconds.

- ⌘ HOMER displays a message suggesting that we add more generator quantities to the sizes to consider.

The screenshot shows the HOMER software interface. At the top, a warning message is displayed: "Generator 1 search space may be insufficient." Below this, a message indicates the search is "Completed in 3 seconds." The main interface is divided into several sections: "Costs", "Fuel", "Schedule", and "Emissions". The "Costs" section contains a table with the following data:

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/hr)
5.000	2000	2000	0.020

Below the table are three input fields for additional sizes, each containing a placeholder "{.}". To the right, the "Sizes to consider" section contains a table with the following data:

Size (kW)
0.000
2.500
5.000

Below this table are three input fields for additional sizes, each containing a placeholder "{.}". The "Properties" section shows the following settings for "Generator 1":

- Description: Generator 1
- Type: AC, DC
- Abbreviation: Label
- Lifetime (operating hours): 15000
- Minimum load ratio (%): 30

On the right side of the interface, a "Cost Curve" graph is displayed. The x-axis is labeled "Size (kW)" and ranges from 0 to 5. The y-axis is labeled "Cost (\$)" and ranges from 0 to 2,000. A blue line represents the "Replacement" cost, starting at (0,0) and ending at (5,2000). A red line represents the "Capital" cost, which is a horizontal line at 0. A legend at the bottom of the graph identifies the red line as "Capital" and the blue line as "Replacement".

Other messages to appear



PV search space may be insufficient.



Converter search space may be insufficient.



Completed in 3:17.

⌘ Those messages mean that:

- ☒ you need to expand your search space to be sure you have found the cheapest system configuration.
- ☒ If the total net present cost varied with the PV size in this way, and you simulated 10, 20, 30, and 40 kW sizes, HOMER would notice that the optimal number of turbines is 40 kW, but since that was as far as you let it look, it would give you the "search space may be insufficient" warning because 50 kW may be better yet.
- ☒ It doesn't know that until you let it try 50kW and 60kW.
- ☒ If you expanded the search space, HOMER would no longer give you that warning, since the price started to go up so you have probably identified the true least-cost point.

Report Submission for Lab 9

- ⌘ Using the Homer Tutorial Part 1
- ⌘ Follow every step from slide page 21
 - ☑ With your own location → Resources are determined
 - ☑ With your own loading condition
- ⌘ Write your report describing
 - ☑ Location,
 - ☑ Load,
 - ☑ Solar Resources
 - ☑ Wind Resources
 - ☑ Optimum result (the Price of energy. \$/kWh)?
 - ☑ Comment and Opinion
 - ☑ Appendix 1: Input report from HOMER
 - ☑ Appendix 2: Output Report from HOMER

APPENDIX Physical Modeling - Components

⌘ HOMER models 10 types of part that generates, delivers, converts, or stores energy

⌘ 3 intermittent renewable resources:

- ⌘ PV modules (dc)
- ⌘ wind turbines (dc or ac)
- ⌘ run-of-river hydro turbines (dc or ac)

⌘ 3 dispatchable energy sources: [control them as needed]

- ⌘ Generators
- ⌘ the grid
- ⌘ boilers

⌘ 2 energy converters:

- ⌘ Converters (dc \leftrightarrow ac)
- ⌘ Electrolyzers (ac,dc \rightarrow electrolysis \rightarrow Hydrogen)

⌘ 2 types of energy storage:

- ⌘ batteries (dc)
- ⌘ hydrogen storage tanks

Physical Modeling - load

⌘ Load: a demand for electric or thermal energy

⌘ 3 types of loads

⊞ **Primary load:** electric demand that must be served according to a particular schedule

⊞ When a customer switches on, the system must supply electricity

⊞ kW for each hour of the load

⊞ Lights, radio, TV, appliances, computers,

⊞ **Deferrable load:** electric demand that can be served at any time within a certain time span

⊞ Tank – drain concept

⊞ Water pumps, ice makers, battery-charging station

⊞ **Thermal load:** demand for heat

⊞ Supply from boiler or waste heat recovered from a generator

⊞ Resistive heating using excess electricity

Physical Modeling - Resources

- ⌘ **Solar Resources:** average global solar radiation on horizontal surface (kWh/m^2 or $\text{kWh/m}^2\text{-day}$) **or** monthly average clearness index (atmosphere vs. earth surface). Inputs – solar radiation values and the latitude and the longitude. Output – 8760 hour data set
- ⌘ **Wind Resources:** Hourly or 12 monthly average wind speeds. Anemometer height. Wind turbine hub height. Elevation of the site.
- ⌘ **Hydro Resources:** Run-of-river hydro turbine. Hourly (or monthly average) stream flow data.
- ⌘ **Biomass Resources:** wood waste, agricultural residue, animal waste, energy crops. Liquid or gaseous fuel.
- ⌘ **Fuel:** density, lower heating value, carbon content, sulfur content. Price and consumption limits

Components- PV, Wind, and Hydro

⌘ PV Array

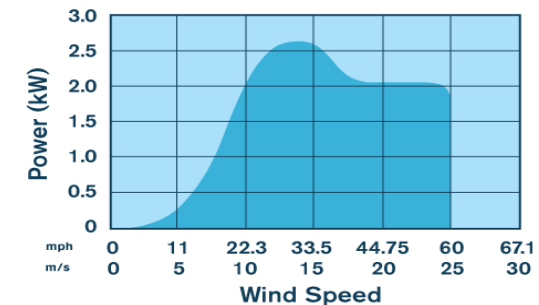
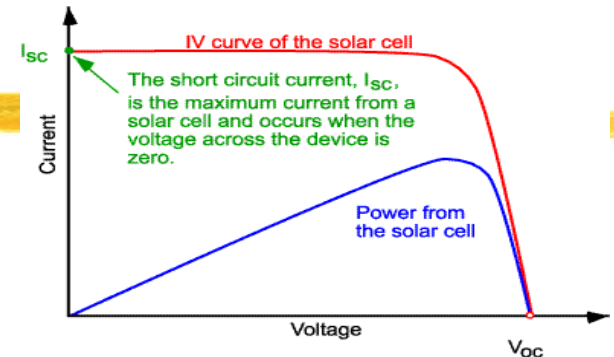
☒ f_{PV} : PV de-rating factor

☒ Y_{PV} : Rated Capacity [kW]

☒ I_T : Global Solar Radiation incidence on the surface of the PV array [kW/m²]

☒ I_S : Standard amount of radiation, 1 kW/m².

$$P_{PV} = f_{PV} Y_{PV} \frac{I_T}{I_S}$$



Data measured and compiled by USDA-ARS Research Lab, Bushland, TX

⌘ Wind Turbine

☒ Wind turbine power curve

⌘ Hydro Turbine

☒ Power Output Eqn = Turbine efficiency, density of water, gravitational acceleration, net head, flow rate through the turbine

$$P_{hyd} = \eta_{hyd} \rho_{water} g h_{net} \dot{Q}_{turbine}$$

$$P(W)_{delivered} = \frac{e Q(gpm) H_N(ft)}{5.30}$$

$$P(kW) = 9.81 e Q(m^3/s) H_N(m)$$

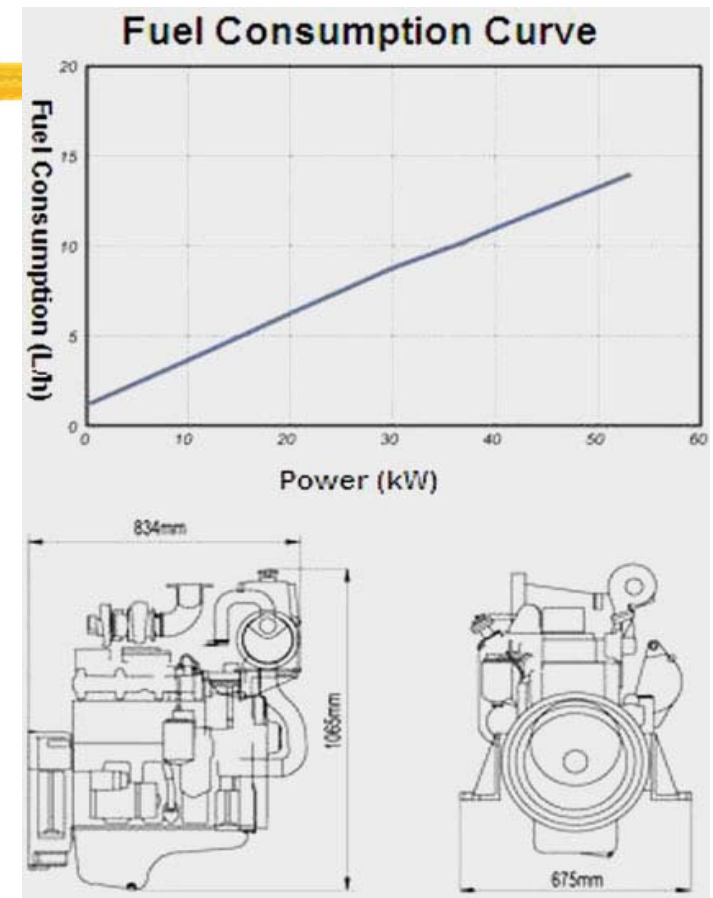
e is the efficiency of the turbine/generator

Components - Generator

⌘ Generators

- ⊞ Principal properties: max and min electrical power output, expected lifetime, type of fuel, fuel curve
- ⊞ **Fuel curve:** quantity of fuel consumed to produce certain amount of electrical power. Straight line is assumed.
- ⊞ Fuel Consumption (**F**) [L/h], [m³/h], or [kg/h]:
 - ⊞ F_0 - fuel curve intercept coefficient [L/h-kW];
 - ⊞ F_1 - fuel curve slope [L/h-kW];
 - ⊞ Y_{gen} - rated capacity [kW];
 - ⊞ P_{gen} - electrical output [kW]

$$F = F_0 Y_{gen} + F_1 P_{gen}$$



Components - Generator

- ⌘ Generator costs: initial capital cost, replacement cost, and annual O&M cost per operating hour (not including fuel cost)
- ⌘ **Fixed cost**: cost per hour of simply running the generator without producing any electricity

$$c_{\text{gen, fixed}} = c_{\text{om, gen}} + \frac{C_{\text{rep, gen}}}{R_{\text{gen}}} + F_0 Y_{\text{gen}} c_{\text{fuel, eff}}$$

$c_{\text{om, gen}}$ is the O&M cost per hour,

$C_{\text{rep, gen}}$ the replacement cost

R_{gen} the generator lifetime in hours.

F_0 the fuel curve intercept coefficient in quantity of fuel per hour per kilowatt.

Y_{gen} the capacity of the generator (kW).

$c_{\text{fuel, eff}}$ the effective price of fuel in dollars per quantity of fuel.

- ⌘ **Marginal cost**: additional cost per kWh of producing electricity from the generator

$$c_{\text{gen, mar}} = F_1 c_{\text{fuel, eff}}$$

F_1 is the fuel curve slope in quantity of fuel per hour per kilowatthour

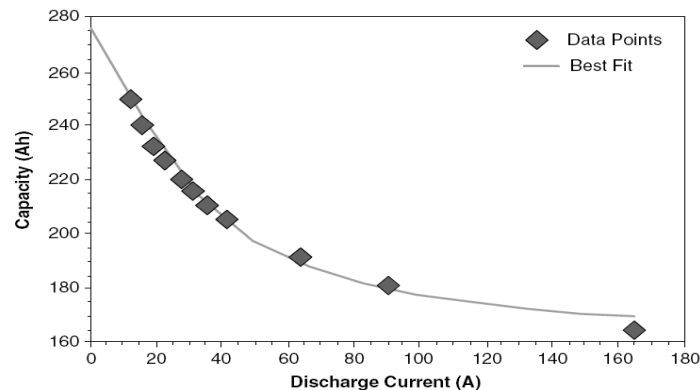
Components – Battery Bank

⌘ Battery Bank

☒ Principal properties:

- ☒ nominal voltage
- ☒ **capacity curve**: discharge capacity in AH vs. discharge current in A
- ☒ **lifetime curve**: number of discharge-charge cycles vs. cycle depth
- ☒ **minimum state of charge**: State of charge below which must not be discharged to avoid permanent damage
- ☒ **round-trip efficiency**: percentage of energy going in to that can be drawn back out

☒ Example capacity curve for a deep-cycle US-250 battery (Left)



Components - Grid

⌘ Grid and Grid Power Cost

- ⊞ Grid power price [\$/kWh]: charges for energy purchase from grid
- ⊞ Demand rate [\$/kW/month]: peak grid demand
- ⊞ Sellback rate [\$/kWh]: price the utility pays for the power sold to grid

⌘ Net Metering: a billing arrangement whereby the utility charges the customer based on the net grid purchases (purchases minus sales) over the billing period.

- ⊞ Purchase > sales: consumer pays the utility an amount equal to the net grid purchases times the grid power cost.
- ⊞ sales > purchases: the utility pays the consumer an amount equal to the net grid sales (sales minus purchases) times the sellback rate, which is typically less than the grid power price, and often zero.

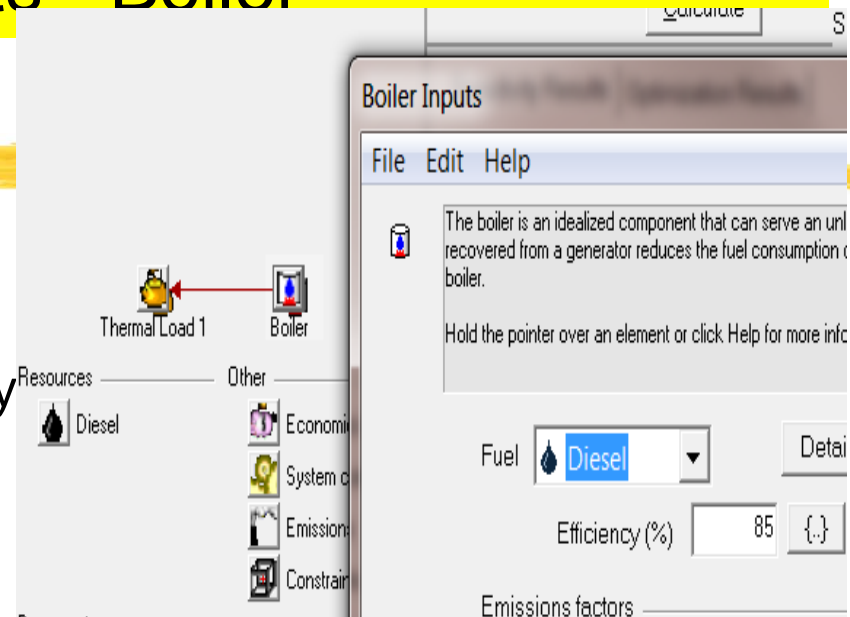
⌘ Grid fixed cost: \$0

⌘ Grid marginal cost: current grid power price plus any cost resulting from emissions penalties.

Components - Boiler

⌘ Boiler

- Assumed to provide unlimited amount of thermal energy on demand
- Input: type of fuel, boiler efficiency emission
- Fixed cost: \$0
- Marginal cost:



$$c_{\text{boiler,mar}} = \frac{3.6c_{\text{fuel,eff}}}{\eta_{\text{boiler}} \text{LHV}_{\text{fuel}}}$$

$c_{\text{fuel,eff}}$ is the effective price of the fuel (including the cost of any penalties on emissions) in dollars per kilogram

η_{boiler} is the boiler efficiency.

LHV_{fuel} is the lower heating value of the fuel in MJ/kg

Components – Converter

⌘ Converter

- ☒ Inversion and Rectification
- ☒ Size: max amount of power it delivers
- ☒ Synchronization ability: parallel run with grid
- ☒ Efficiency
- ☒ Cost: capital, replacement, o&m, lifetime



Components –Fuel Cell

⌘ Electrolyzer:

- ⊞ Size: max electrical input
- ⊞ Min load ratio: the minimum power input at which it can operate, expressed as a percentage of its maximum power input.
- ⊞ Cost: capital, replacement, o&m, lifetime

⌘ Hydrogen Tank

- ⊞ Size: mass of hydrogen it can contain
- ⊞ Cost: capital, replacement, o&m, lifetime



System Dispatch

- ⌘ Dispatchable and non-dispatchable power sources
- ⌘ Dispatchable source: provides operating capacity in an amount equal to the maximum amount of power it could produce at a moment's notice.
 - ⊞ **Generator**
 - ⊞ In operation: dispatchable opr capacity = rated capacity
 - ⊞ non-operation: dispatchable opr capacity = 0
 - ⊞ **Grid:** dispatchable opr capacity = max grid demand
 - ⊞ **Battery:** dispatchable opr capacity = current max discharge power
- ⌘ Non-dispatchable source
 - ⊞ Operating capacity (**PV, Wind, or Hydro**) = the amount the source is currently producing (Not the max amount it can produce)
- ⌘ NOTE: If a system is ever unable to supply the required amount of load plus operating reserve, HOMER records the shortfall as “**capacity shortage**”.
 - ⊞ HOMER calculates the total amount of such shortages over the year and divides **the total annual capacity shortage** by the **total annual electric load**.

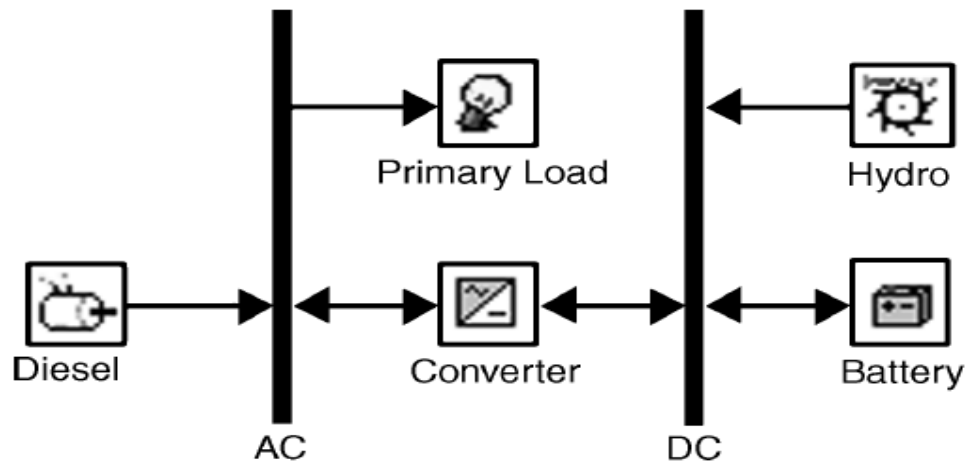
Dispatch Strategy for a system with Gen and Battery

⌘ Dispatch Strategy

- ⊞ Whether and how the generator should charge the battery bank?
- ⊞ HOMER provides 2 simple strategies and lets user model them both to see which is better in any particular situation.
 - ⊞ **Load-following**: a generator produces only enough power to serve the load, and does not charge the battery bank.
 - ⊞ **Cycle-Charging**: whenever a generator operates, it runs at its maximum rated capacity and charges the battery bank with the excess
 - ⊞ It was found that over a wide range of conditions, **the better of these two simple strategies** is virtually as cost-effective as the ideal predictive strategy.
- ⊞ **“Set-point state charge”**: in the cycle-charging strategy, generator charges until the battery reaches the set-point state of charge.

Control of Dispatchable System Components

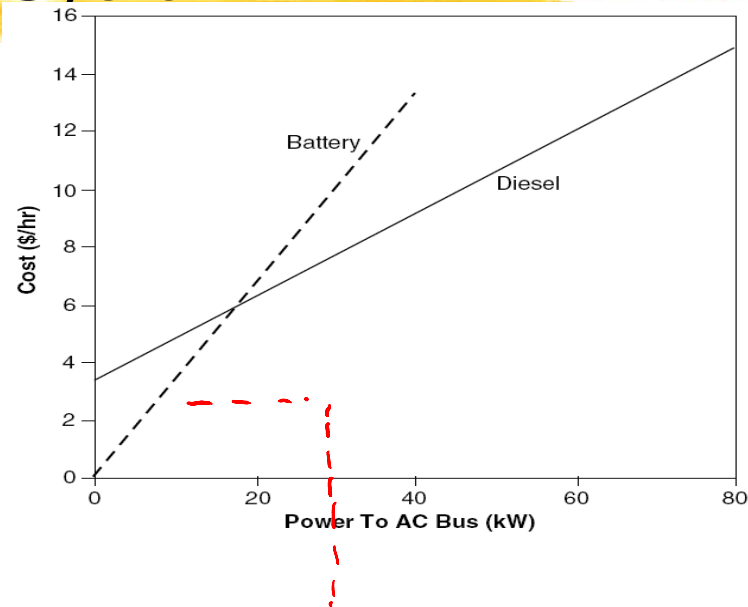
- ⌘ Fundamental principle: cost minimization – fixed cost and marginal cost
- ⌘ Example: Hydro-Diesel-Battery System



- ⌘ Dispatchable sources: diesel generator [80kW] and battery [40kW]
- ⌘ If net load is negative: excess power **charges battery**
- ⌘ If net load is positive: **operate diesel OR discharge battery**

Dispatch Control Example

⌘ Hydro-Diesel-Battery System




⌘ Net load < 20kW: Discharge the battery

⌘ Net load > 20kW: Operate the diesel generator


Load Priority

- ⌘ Decisions on allocating electricity
- ⌘ Presence of ac and dc buses
- ⌘ Electricity produced on one bus will serve
 - ☑ First, primary load on the same bus
 - ☑ Then, primary load on the opposite bus
 - ☑ Then, deferrable load on the same bus
 - ☑ Then, charge battery bank
 - ☑ Then, sells to grid
 - ☑ Then, electrolyzer
 - ☑ Then, dump load

Dump Loads


 Protect your batteries from over-charging using diversion/dump loads to dissipate excess energy produced by your generator that can't be stored in a battery. Dump load systems are all available for 12 or 24 Volt configurations.

300 Watt Dump Load for 12 Volt Systems



\$21.98
[Add to cart](#)

300 Watt Dump Load for 24 Volt Systems



\$21.98
[Add to cart](#)

Economic Modeling

- ⌘ Conventional sources: low capital and high operating costs
- ⌘ Renewable sources: high initial capital and low operating costs
- ⌘ Life-cycle costs= capital + operating costs
- ⌘ HOMER uses NPC for life-cycle cost
 - ⊞ NPC is the opposite of NPV (Net present value)
- ⌘ NPC includes: initial construction, component replacements, maintenance, fuel, cost of buying grid, penalties, and revenues (selling power to grid + salvage value at the end of the project lifetime)

$$S = C_{\text{rep}} \frac{R_{\text{rem}}}{R_{\text{comp}}}$$

S is the salvage value,

C_{rep} the replacement cost of the component.

R_{rem} the remaining life

R_{comp} the lifetime of the component.

Real Cost

- ⌘ All price escalates at the same rate over the lifetime
- ⌘ Inflation can be factored out of analysis by using the real (inflation-adjusted) interest rate (rather than nominal interest rate) when discounting the future cash flows to the present
- ⌘ Real interest rate = nominal interest rate – inflation rate
- ⌘ Real cost → in terms of constant dollars

NPC and COE

⌘ Total NPC

$$C_{\text{NPC}} = \frac{C_{\text{ann,tot}}}{\text{CRF}(i, N)}$$

$C_{\text{ann,tot}}$ is the total annualized cost.
 i the annual real interest rate (the discount rate)
 N the project lifetime.

$\text{CRF}(\cdot)$ is the capital recovery factor

$$\text{CRF}(i, N) = \frac{i(1+i)^N}{(1+i)^N - 1}$$

⌘ Levelized Cost of Energy (COE): average cost/kWh

$$\text{COE} = \frac{C_{\text{ann,tot}}}{E_{\text{prim}} + E_{\text{def}} + E_{\text{grid,sales}}}$$

$C_{\text{ann,tot}}$ is the total annualized cost,

E_{prim} total amounts of primary load.

E_{def} total amounts of deferrable load.

$E_{\text{grid,sales}}$ is the amount of energy sold to the grid