

8. Modeling using HOMER – Part 2

Practice 2 & Grid-Connected Micropower System

Course Contents and Schedule

⌘ Day 4

☒ HOMER Simulation 2

☒ Grid Data Details

☒ Grid-Connected System Design

☒ Team Practice

☒ **Isolated** or **Grid-Connected** Power System Design

⌘ Day 5

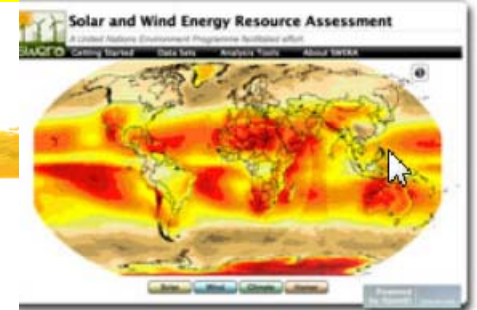
☒ Team Presentation

☒ Summary and Conclusions

On SWERA

⌘ 2001: The Solar and Wind Energy Resource Assessment (SWERA)

- ☑ began with support from the Global Environment Facility within the **United Nations Environment Program** (UNEP) with contributions by many national agencies.
- ☑ SWERA was initially a country-centric project focused on the production of National Solar and Wind Assessments supporting renewable energy decision makers in 13 countries within a global framework that included several continental datasets.
- ☑ Ethiopia, Kenya, Ghana, Bangladesh, China, Nepal, Sri Lanka, Brazil, Cuba, El Salvador, Guatemala, Hondurans, and Nicaragua



Agency/Company /Organization	United Nations Environment Programme
Partner	National Renewable Energy Laboratory, German Aerospace Center (DLR), Risoe National Laboratory for Sustainable Energy, Brazil's National Institute for Space Research (INPE), State University of New York (SUNY), Technical University of Denmark (DTU), UNEP Global Resource Information Database (UNEP/GRID), NASA, Global Environment Facility (GEF)
Sector	Energy
Focus Area	Solar, Wind
Topics	Resource assessment, Pathways analysis
Resource Type	Software/modeling tools, Maps, Dataset
User Interface	Website
Website	http://openei.org/SWERA

SWERA

⌘ 2005: support from NASA, SWERA began the transition into a global decision support system (DSS) with integrated tools including prototype small hydropower assessments to complement the solar and wind assessments.

☒ NASA global renewable energy assessments and climate data were integrated into SWERA to provide global coverage and a more complete portfolio of information needed to assess the global renewable energy potential.

☒ United States National Renewable Energy Laboratory (NREL) contributed renewable energy expertise and 27 national data sets.

Data Set



Solar and Wind Energy Resource Assessment (SWERA)

Data Sets Used in SWERA

Poi

Getting Started

Data Sets

Analysis Tools

About SWERA

- ⌘ Data obtained from the NASA Science Mission Directorate's satellite and re-analysis research programs
- ⌘ Parameters were validated based on recommendations from partners in the energy industry
- ⌘ Continued to adapt and tailor updated and new data sets from NASA's satellite observation analysis and modeling program.
- ⌘ The **Clouds and Earth's Radiant Energy System** (CERES) computes the most accurate global surface radiation fluxes using radiance and retrievals to date. These fluxes include the computation of direct and diffuse fluxes.
- ⌘ Other data: tilt irradiance, direct normal irradiance, global horizontal irradiance, wind, relative humidity, atmospheric pressure, air temperature, etc.
- ⌘ For Solar, NASA data exist for 22 years globally.
- ⌘ Other data sets: 40-km data available for much of the world, and 10-km data for countries and regions.

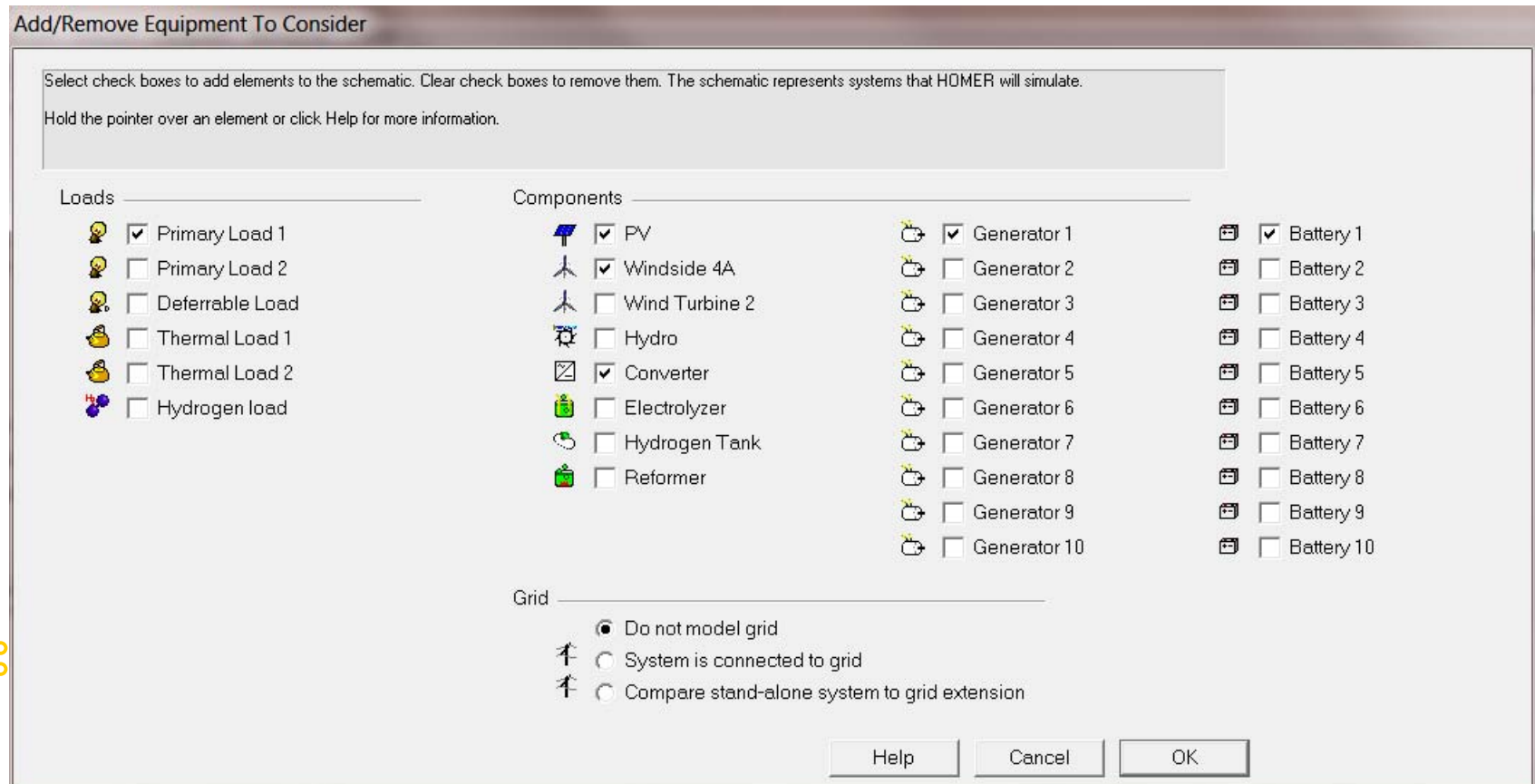
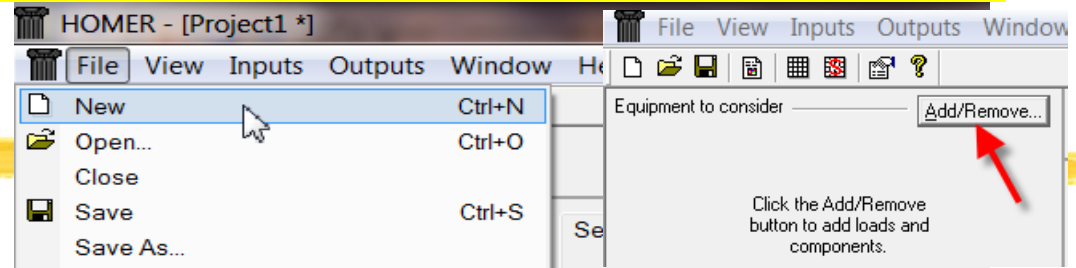
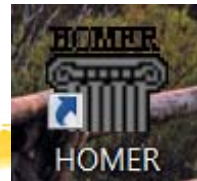
HOMER practice 2: Making a New file from scratch

⌘ HOMER

⌘ File > New

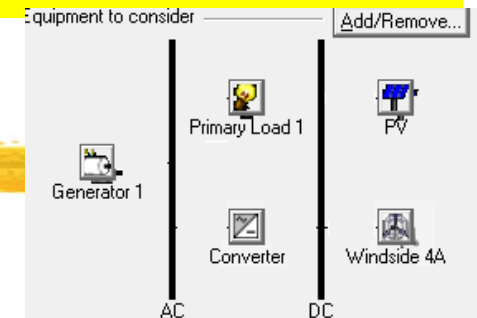
⌘ Click “Add/Remove”

⌘ Select: Primary Load, PV, Wind Turbine 1, Converter, and Generator1



Load Data

- ⌘ HOMER buttons appear
- ⌘ NOW click the load button
- ⌘ Type in the load [kW] every hour period



Primary Load Inputs

File Edit Help

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

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

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

Baseline data

Month: January Day type: Weekday

Hour	Load (kW)
09:00 - 10:00	2.180
10:00 - 11:00	2.330
11:00 - 12:00	2.360
12:00 - 13:00	2.350
13:00 - 14:00	2.310
14:00 - 15:00	2.310
15:00 - 16:00	2.330
16:00 - 17:00	2.370
17:00 - 18:00	2.280
18:00 - 19:00	1.980
19:00 - 20:00	1.860
20:00 - 21:00	1.810
21:00 - 22:00	1.640
22:00 - 23:00	1.430
23:00 - 00:00	1.330

Daily Profile

DMap

Seasonal Profile

Random variability

Day-to-day: 15 %

Time-step-to-time-step: 20 %

Scaled annual average (kWh/d): 43.4

	Baseline	Scaled
Average (kWh/d)	43.4	43.4
Average (kW)	1.81	1.81
Peak (kW)	4.37	4.36
Load factor	0.414	0.414

Efficiency Inputs...

Plot... Export... Help Cancel OK

Load Profile Example

⌘ Load Data Example

Small Commercial Load Profile [kW]

0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
1.31	1.30	1.27	1.27	1.30	1.39	1.54	1.67	1.90	2.18	2.33	2.36
1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
2.35	2.31	2.31	2.33	2.37	2.28	1.98	1.86	1.81	1.64	1.43	1.33

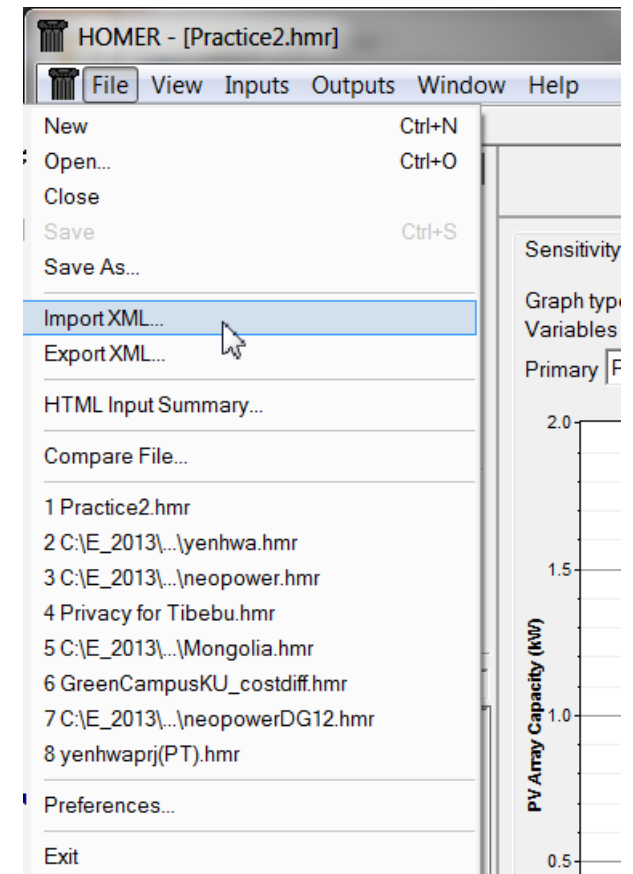
Daily Total [kW]44.60

Stret Light Load Profile [kW]

0000	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100
3.24	3.24	3.24	3.24	3.24	2.62	1.40	0.18	1.90	0.00	0.00	0.00
1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300
0.00	0.00	0.00	0.00	0.00	0.42	0.88	1.28	2.47	3.24	3.24	3.24

Alternative way for Solar and Wind Resources --- Import XLM File from SWERA

- ⌘ 1. Find Lat & Lon of your location
- ⌘ 2. On SWERA
 - ☑ Type in Lat & Long
 - ☑ Click “Get Homer”
 - ☑ From the XLM data screen
 - ☑ CTRL+S (save to an XLM file)
- ⌘ 3. Now with HOMER
 - ☑ File>”Import XLM”
 - ☑ Wind Resources are automatically filled
 - ☑ Solar Resources are automatically filled
 - ☑ Lat N, Long E → marking error
 - ☑ But kWh/m2 is kept the same.



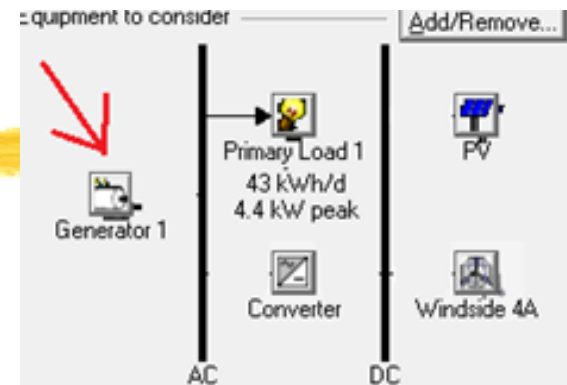
How about Load Profile for this Mobile Security on Demand?

- ⌘ Mobile security: 2 PV, 4 cameras, Digital recording, battery charger circuits, battery status of charge monitoring and wireless alerting.



Generator Information

- ⌘ Now arrow appears from AC bus to load
- ⌘ Click “Generator”
- ⌘ Size: 5.0 kW
- ⌘ Capital: \$2000
- ⌘ Replacement: \$2000
- ⌘ O&M: \$0.02/hr
- ⌘ Sizes to consider: 0, 2.5kW, 5.0kW
- ⌘ Minimum load capacity: 30%



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

Costs

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

Sizes to consider

Size (kW)
0.000
2.500
5.000

Properties

Description: Generator 1 Type: ☒ AC ☐ DC

Abbreviation: Label

Lifetime (operating hours): 15000

Minimum load ratio (%): 30

Cost Curve

Cost (\$)

Size (kW)

Capital Replacement

Help Cancel OK

Wind Turbine Information

⌘ Click Wind Turbine 1

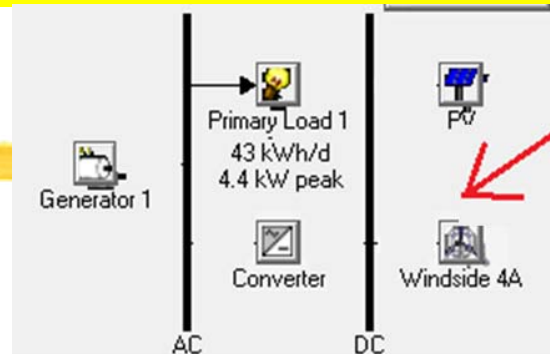
⌘ Quantity: 1

⌘ Capital: \$30000

⌘ Replacement: \$25000

⌘ O&M: \$500/yr

⌘ Sizes to consider
(Qty): 0, 1, 2, and 3



Wind Turbine Inputs

File Edit Help

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: 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 (\$)	O&M (\$/yr)
1	30000	25000	500

Other

Lifetime (yrs) {}

Hub height (m) {}

Sizes to consider

Quantity
0
1
2

Power Curve

Cost Curve

Help Cancel **12** OK

Wind Resources

⌘ Click Wind Resources Button

⌘ Location of your choice

☑ Your small store

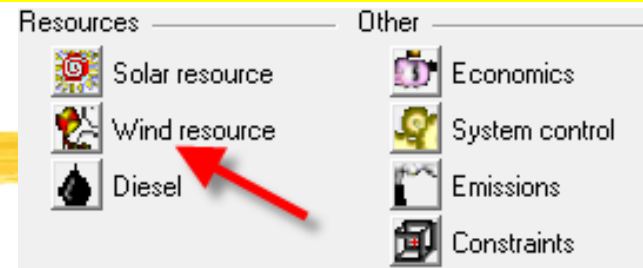
☑ Your side of street lights

☑ Your (future) vacation home

⌘ Find **Latitude and Longitude**

⌘ Find Wind Speed [m/s] using **SWERA** or **WINDFINDER**

⌘ Type in the speed



Wind Resource Inputs

File Edit Help

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

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

Data source: ☒ Enter monthly averages ☐ Import time series data file

Baseline data

Month	Wind Speed (m/s)
January	0.000
February	0.000
March	0.000
April	0.000
May	0.000
June	0.000
July	0.000
August	0.000
September	0.000
October	0.000
November	0.000
December	0.000

Annual average: 0.000

Scaled annual average (m/s)

Wind Resource

Other parameters

Altitude (m above sea level)

Anemometer height (m)

Advanced parameters

Weibull k


Autocorrelation factor

Diurnal pattern strength

Hour of peak windspeed

PV Information

- ⌘ Click “PV”
- ⌘ Size: 2kW
- ⌘ Capital: \$7000
- ⌘ Replacement: \$7000
- ⌘ O&M: \$0/yr
- ⌘ Sizes to consider: 0, 2kW, 4kW



PV

PV Inputs

File Edit Help

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

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

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

Costs

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/yr)
2.000	7000	7000	0

Sizes to consider

Size (kW)
0.000
2.000
4.000

Cost Curve

Properties

Output current ☐ AC ☒ DC

Lifetime (years)

Derating factor (%)

Slope (degrees)

Azimuth (degrees W of S)

Ground reflectance (%)

Advanced

Tracking system

☐ Consider effect of temperature

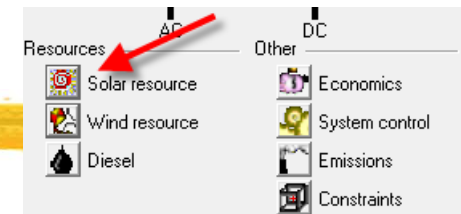
Temperature coeff. of power (%/°C)

Nominal operating cell temp. (°C)

Efficiency at std. test conditions (%)

Solar Resources Information

⌘ Type in the solar radiation data
obtained from **SWERA**



Solar Resource Inputs

File Edit Help

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

Location

Latitude: North ☐ South Time zone: (GMT) Iceland, UK, Ireland, West Africa

Longitude: East ☐ West

Data source: ☒ Enter monthly averages ☐ Import time series data file [Get Data Via Internet](#)

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	0.382	3.950
October	0.343	3.550
November	0.273	2.760
December	0.257	2.550

Average: 0.401 4.011

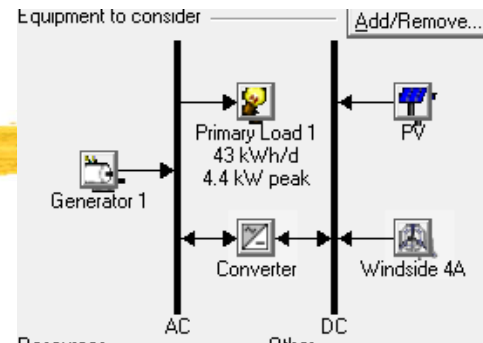
Scaled annual average (kWh/m²/d) {..}

Global Horizontal Radiation

Plot... Export... Help Cancel OK

Converter Information

- ⌘ Converter (DC→ AC)
- ⌘ Size: 1kW
- ⌘ Capital: \$800
- ⌘ O&M: \$0
- ⌘ Sizes to consider: 0, 1, 2 kW



Converter Inputs

File Edit Help

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)
1.000	800	800	0

{.} {.} {.}

Sizes to consider

Size (kW)
0.000
1.000
2.000

Cost Curve

— Capital — Replacement

Inverter inputs

Lifetime (years) {.}

Efficiency (%) {.}

☒ Inverter can operate simultaneously with an AC generator

Rectifier inputs

Capacity relative to inverter (%) {.}

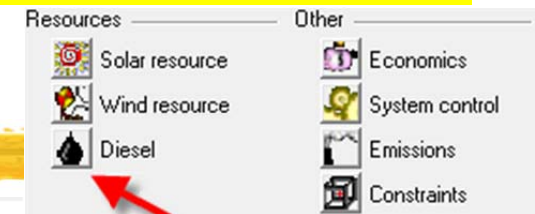
Efficiency (%) {.}

Help Cancel OK

Diesel Resources Information

⌘ Fuel Price: \$0.8/L

⌘ Sensitivity Price: \$0.8, 1.6, 2.4/L



Diesel Inputs

File Edit Help

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

Sensitivity Values

Variable: Diesel Price

Units: \$/L

Link with: <none>

Values:

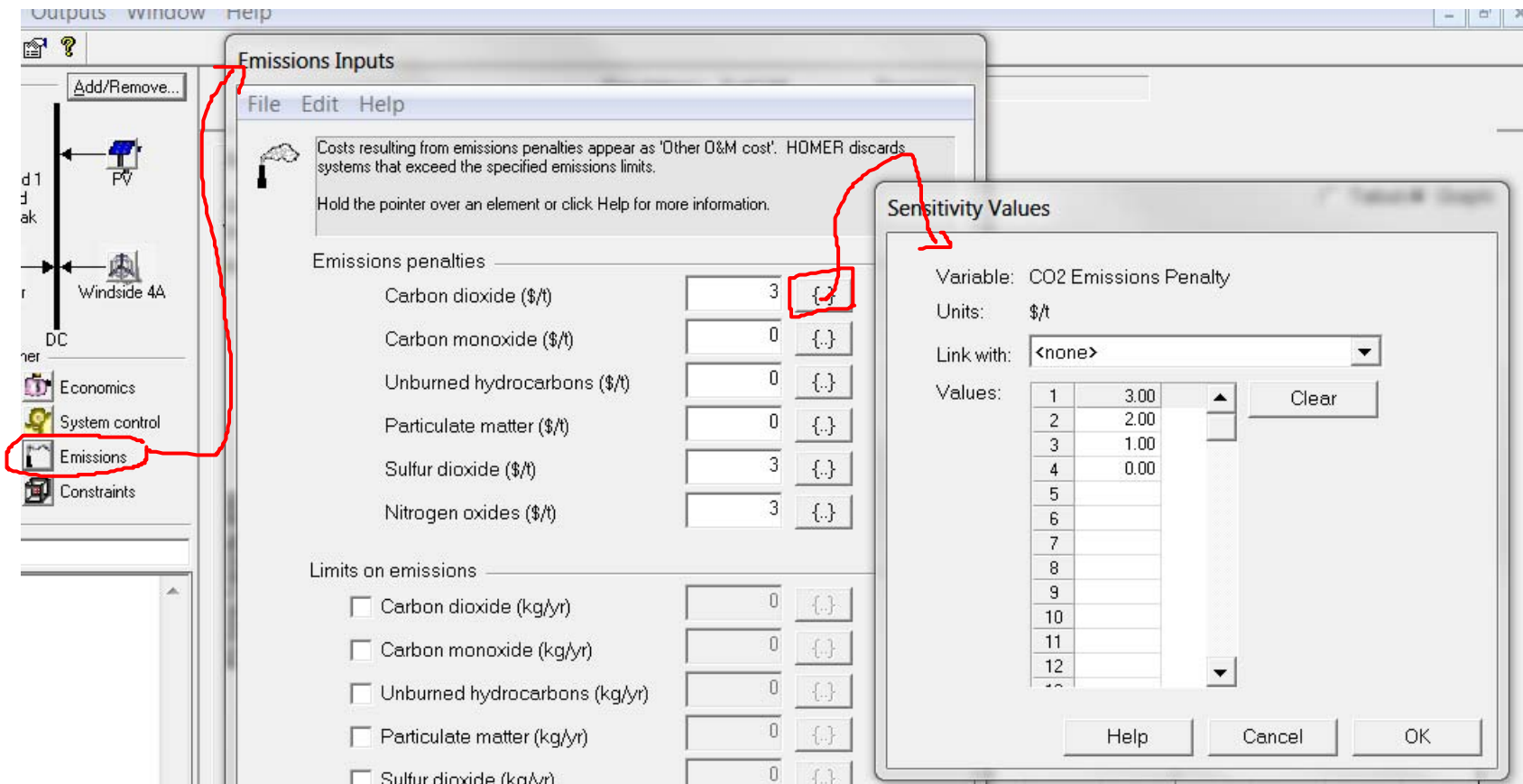
1	0.800
2	1.600
3	2.400
4	
5	
6	
7	
8	
9	
10	
11	
12	

Clear

Help Cancel OK

Emission Information

- ⌘ CO2: \$3/ton
- ⌘ CO: \$0
- ⌘ CO2: Sensitivity Data {0, 1, 2, 3}

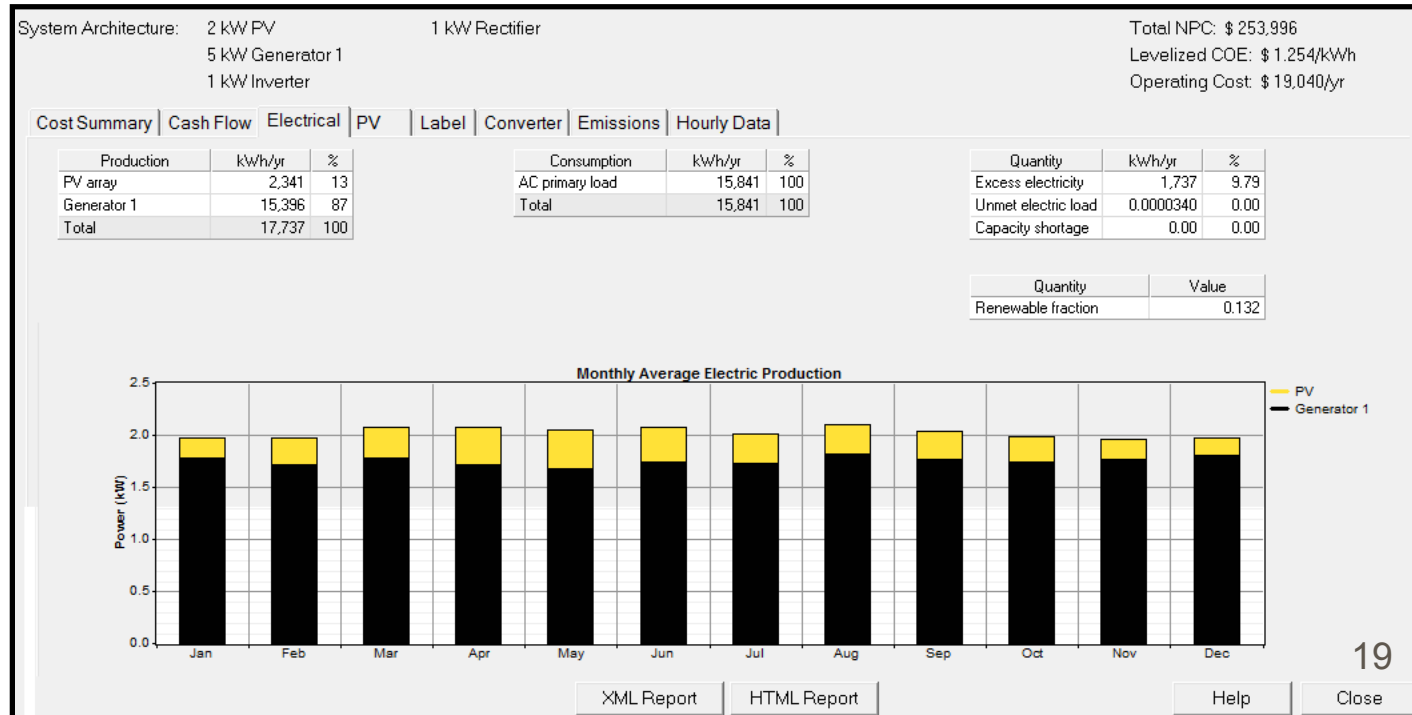


Simulation

⌘ Optimization Result

Sensitivity Results Optimization Results												
Sensitivity variables												
Diesel Price (\$/L) 2.4												
Double click on a system below for simulation results.												
	PV (kW)	WS-...	Label (kW)	Conv. (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kWh)	Ren. Frac.	Diesel (L)	Label (hrs)	
	2		5.0	1	\$ 10,600	19,040	\$ 253,996	1.254	0.13	7,350	8,754	
			5.0		\$ 2,000	19,788	\$ 254,962	1.259	0.00	7,711	8,759	
	2		5.0	2	\$ 12,200	19,056	\$ 255,798	1.263	0.13	7,339	8,754	
	4		5.0	2	\$ 19,200	18,596	\$ 256,925	1.269	0.24	7,123	8,658	
	4		5.0	1	\$ 17,600	18,836	\$ 258,390	1.276	0.24	7,235	8,743	
	6		5.0	2	\$ 26,200	18,239	\$ 259,355	1.281	0.33	6,952	8,517	
	6		5.0	1	\$ 24,600	18,781	\$ 264,687	1.307	0.32	7,181	8,735	
	2	1	5.0	1	\$ 40,600	20,107	\$ 297,631	1.470	0.15	7,310	8,753	
	2	1	5.0	2	\$ 42,200	20,116	\$ 299,351	1.478	0.15	7,296	8,753	
		1	5.0	1	\$ 33,600	20,856	\$ 300,205	1.482	0.02	7,653	8,759	
	4	1	5.0	2	\$ 49,200	19,673	\$ 300,683	1.485	0.26	7,086	8,652	
	4	1	5.0	1	\$ 47,600	19,927	\$ 302,339	1.493	0.25	7,204	8,742	
		1	5.0	2	\$ 35,200	20,898	\$ 302,348	1.493	0.02	7,653	8,759	
	6	1	5.0	2	\$ 56,200	19,333	\$ 303,343	1.498	0.34	6,923	8,514	
	6	1	5.0	1	\$ 54,600	19,885	\$ 308,802	1.525	0.33	7,156	8,735	

⌘ Electrical

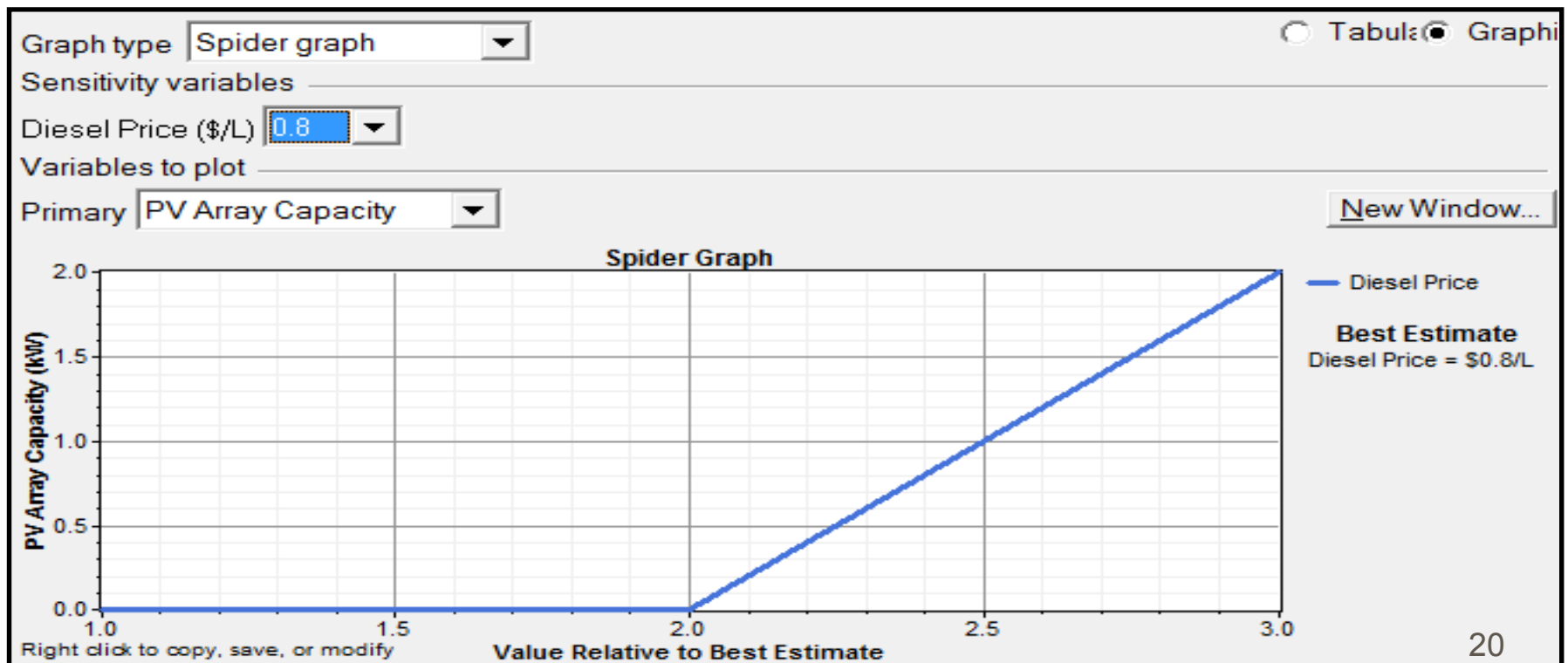


Sensitivity Analysis

Double click on a system below for optimization results

☒ Table
 ☐ Graph
 [Export...](#)
[Details...](#)

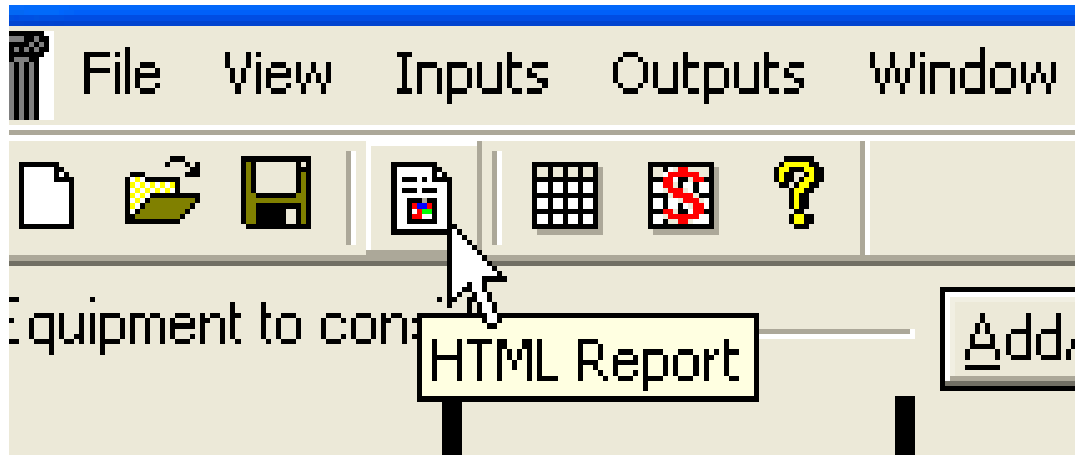
Diesel (\$/L)		PV (kW)	WS-... (kW)	Label (kW)	Conv. (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kW...)	Ren. Frac.	Diesel (L)	Label (hrs)
0.800				5.0		\$ 2,000	7,451	\$ 97,252	0.480	0.00	7,711	8,7...
1.600				5.0		\$ 2,000	13,620	\$ 176,107	0.870	0.00	7,711	8,7...
2.400		2		5.0	1	\$ 10,600	19,040	\$ 253,996	1.254	0.13	7,350	8,7...



HOMER – Input Summary Report

⌘ HOMER Produces An Input Summary Report:

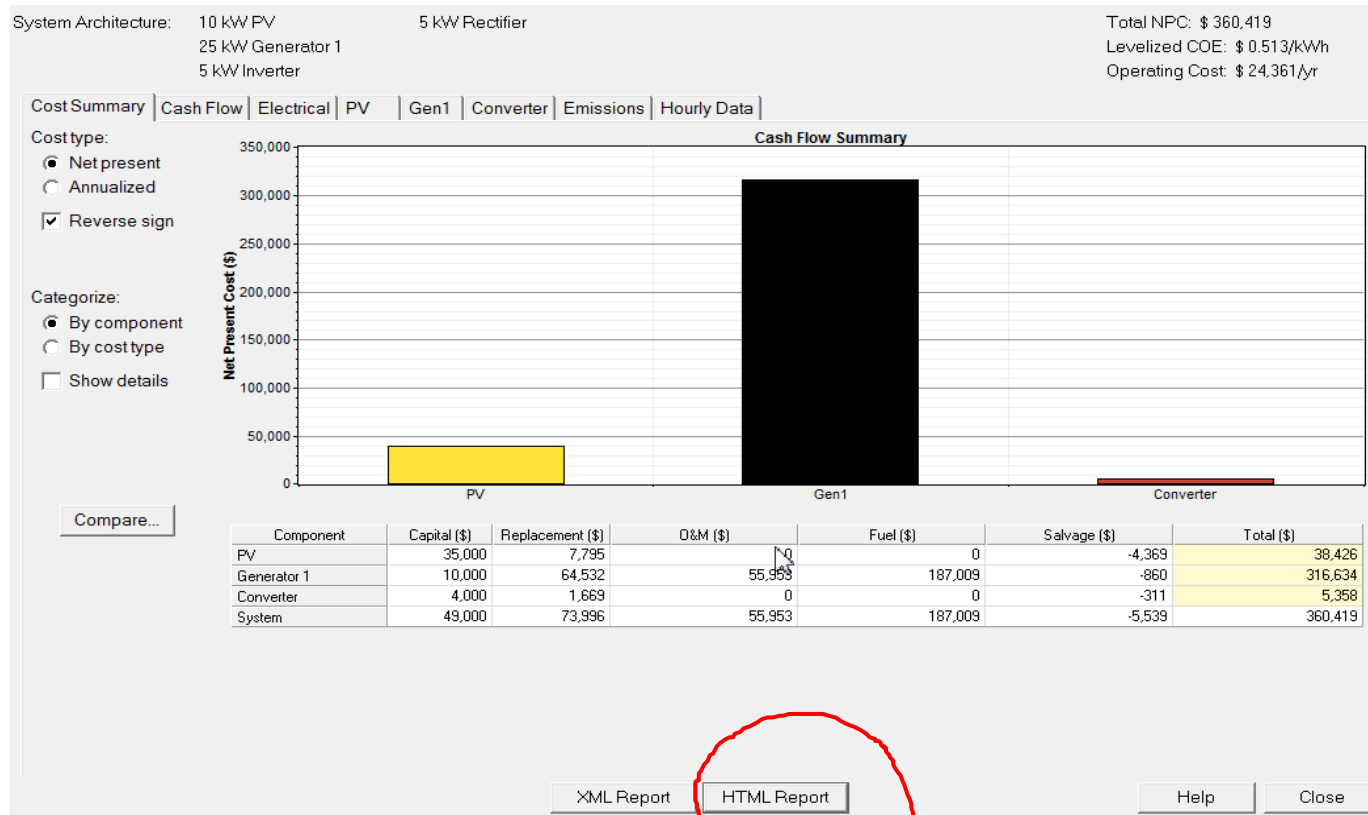
- ☑ Click HTML Input Summary from the File menu, or click the toolbar button:
- ☑ HOMER will create an HTML-format report summarizing all the relevant inputs, and display it in a browser. From the browser, you can save or print the report, or copy it to the clipboard so that you can paste it into a word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



HOMER – Simulation Result Report

⌘ HOMER Produces A Report Summarizing The Simulation Results

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



What is this message for?



PV search space may be insufficient.



Converter search space may be insufficient.



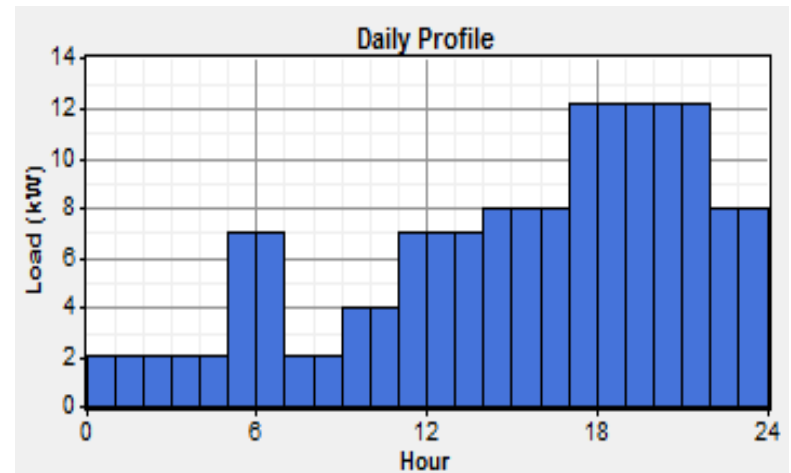
Completed in 3:17.

⌘ 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.

HOMER: Grid-Connected Micro-Power system

- ⌘ Place: A commercial/retail in Seoul/Cheonan/Byungchon
- ⌘ This project investigates the options for providing electricity to the commercial/small store using wind, solar, or diesel power.
- ⌘ It also analyzes the impact of different assumptions about the wind resource, fuel price, and required system reliability.
- ⌘ Solar Resources: Actual data via Internet
- ⌘ Wind Resources: Wind speed data
- ⌘ Load: 35kWh/d and 4.5 kW peak



Components and Constraints

⌘ Components:

- ⏏ PV: Default performance: 1kW [0, 2, 4 kW]
- ⏏ Wind Turbine: 3kW [Qty 0 1 2 3]
- ⏏ Diesel Generator: 5 kW is considered (peak load is 4.5 kW)
 - ⏏ Fuel: \$0.3/L [0.3, 0.5, 0.7]
 - ⏏ Limit Consumption: 5000 L/year
- ⏏ Batteries: Marine Battery [6V, 1167 Ah] [0 10 20 30]
- ⏏ Inverter: 10kW size. (cost: \$1250/kW) [0, 2, 4, 6, 8 kW]
- ⏏ Grid: Single rate at \$0.15/kWh; Sellback at \$0.15/kWh; Demand Charge at \$5.0/kW/month

⌘ Economics:

- ⏏ Real interest rate: 8%
- ⏏ Project lifetime: 25 years
- ⏏ System fixed capital cost: \$6000
 - ⏏ It represents balance of system and distribution system costs that cannot be allocated to a specific component.

⌘ Reliability:

- ⏏ Maximum Annual Capacity Shortage: 0% [0.0, 0.1]

Start HOMER

⌘ New File

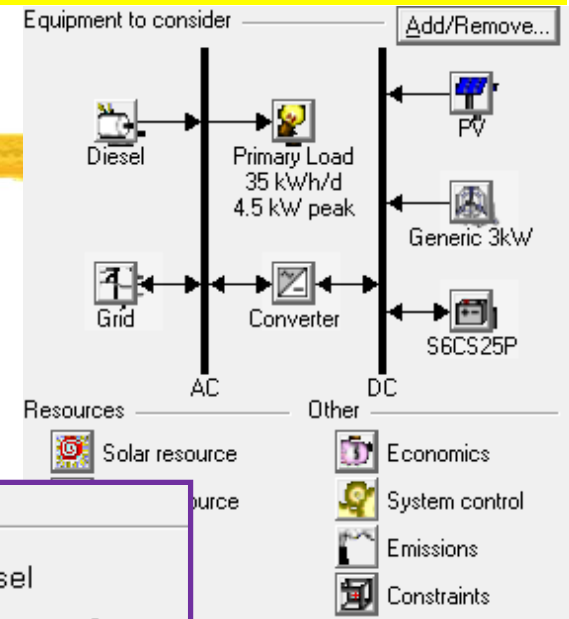
⌘ Component and Resources

☑ Load, Diesel

☑ PV, Battery

☑ Wind

☑ "System is connected to grid"



Loads		Components	
	<input checked="" type="checkbox"/> Primary Load		<input checked="" type="checkbox"/> PV
	<input type="checkbox"/> Primary Load 2		<input type="checkbox"/> Wind Turbine 1
	<input type="checkbox"/> Deferrable Load		<input checked="" type="checkbox"/> Generic 3kW
	<input type="checkbox"/> Thermal Load 1		<input type="checkbox"/> Hydro
	<input type="checkbox"/> Thermal Load 2		<input checked="" type="checkbox"/> Converter
	<input type="checkbox"/> Hydrogen load		<input type="checkbox"/> Electrolyzer
			<input type="checkbox"/> Hydrogen Tank
			<input type="checkbox"/> Reformer

Grid	
<input type="radio"/>	Do not model grid
<input checked="" type="radio"/>	System is connected to grid
<input type="radio"/>	Compare stand-alone system to grid extension

Solar Resources

⌘ Latitude, Longitude, Time Zone, Get Data of **your location**

Solar Resource Inputs

File Edit Help

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

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

Location

Latitude ° ' ☒ 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	0.477	2.264
February	0.467	2.851
March	0.497	3.966
April	0.533	5.243
May	0.522	5.777
June	0.491	5.681
July	0.455	5.135
August	0.503	5.161
September	0.516	4.436
October	0.530	3.524
November	0.512	2.582
December	0.475	2.056

Average: 0.499 4.062

Scaled annual average (kWh/m²/d) {..}

Global Horizontal Radiation

Plot... Export... Help Cancel OK

Wind Resources

⌘ Type in Wind Speed Data

Wind Resource Inputs

File Edit Help

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

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

Data source: ☒ Enter monthly averages ☐ Import time series data file

Baseline data

Month	Wind Speed (m/s)
January	4.700
February	4.900
March	4.700
April	4.100
May	3.600
June	3.400
July	3.400
August	3.800
September	3.500
October	3.300
November	3.700
December	4.200

Annual average: 3.937

Scaled annual average (m/s) {3}

Wind Resource

Other parameters

Altitude (m above sea level)

Anemometer height (m)

Advanced parameters

Weibull k

Autocorrelation factor

Diurnal pattern strength

Hour of peak windspeed

$$f(v) = \frac{k}{c} \left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^k\right]$$

The **diurnal pattern strength** simply indicates how **strongly the wind speed depends on the time of day**. If the wind speed tends to peak at the same time as the load, then a strong daily pattern would be a good thing. It would mean the wind blows when you need the power. If the wind speed peak was out of sync with the load peak, then a strong daily pattern would be a negative.

Diesel Resources

⌘ \$0.5/L

⌘ Sensitivity: [\$0.3, 0.5, 0.7]/L

The image shows two overlapping windows from a software application. The background window is titled "Diesel Inputs" and contains a menu bar (File, Edit, Help), a fuel drop icon, and instructional text. It has input fields for "Price (\$/L)" (0.3) and "Limit consumption to (L/yr)" (5000), both with unit selection buttons. Below these are "Fuel properties" listed: Lower heating value (43.2 MJ/kg), Density (820 kg/m3), Carbon content (88 %), and Sulfur content (0.33 %). At the bottom are "Help" and "Cancel" buttons. A red arrow points from the "{3}" unit button of the Price field to the "Sensitivity Values" window. This foreground window has a title bar and contains the following fields: "Variable: Diesel Price", "Units: \$/L", and "Link with: <none>". Below these is a "Values:" section with a table containing three rows of values (0.300, 0.500, 0.700) and a "Clear" button.

Diesel Inputs

File Edit Help

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) 0.3 {3}

☒ Limit consumption to (L/yr) 5000 {..}

Fuel properties

Lower heating value: 43.2 MJ/kg

Density: 820 kg/m3

Carbon content: 88 %

Sulfur content: 0.33 %

Help Cancel

Sensitivity Values

Variable: Diesel Price

Units: \$/L

Link with: <none>

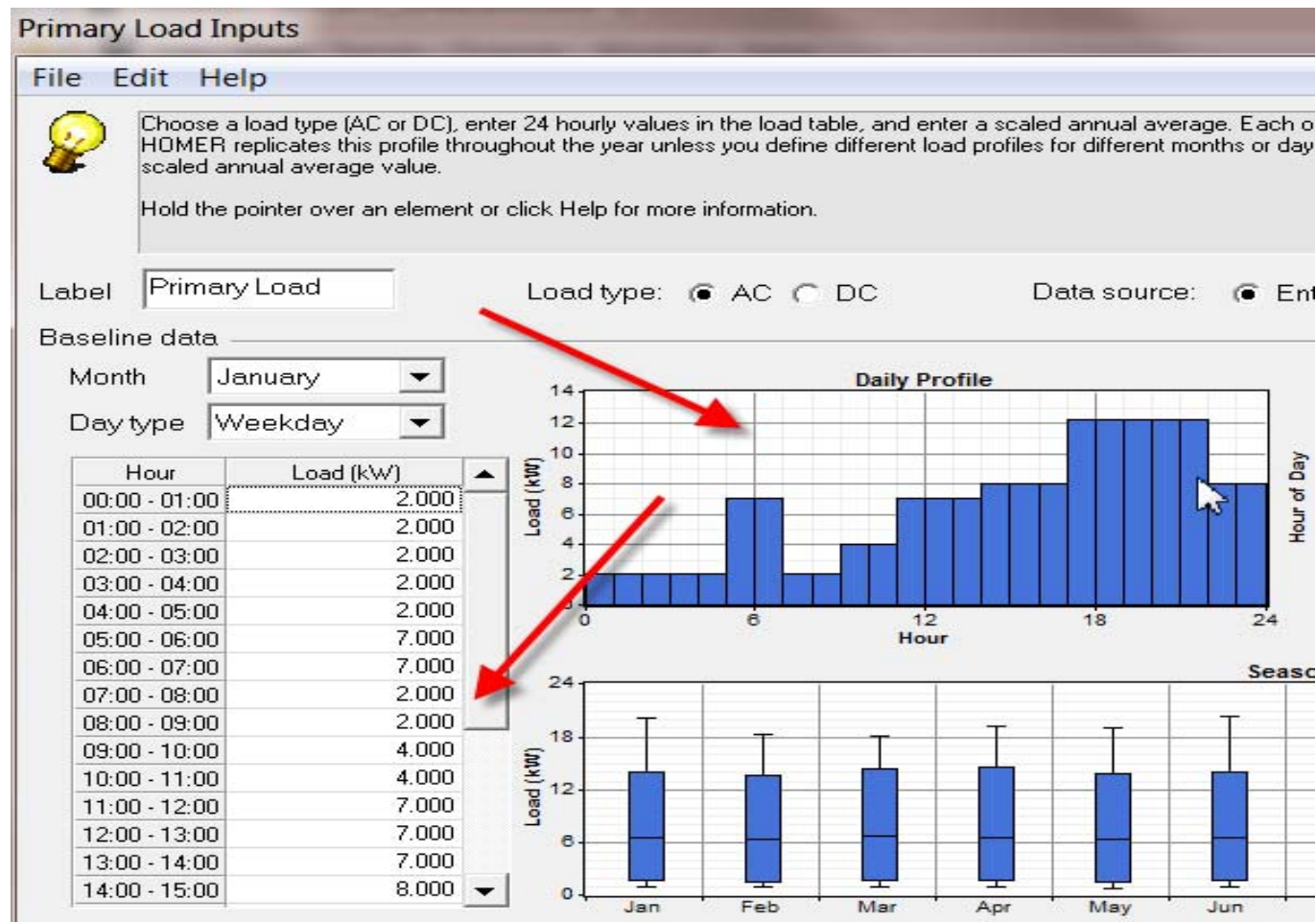
Values:

1	0.300
2	0.500
3	0.700
4	
5	
6	

Clear

Component: Load Input

- ⌘ Type in hourly load [kW]
- ⌘ [0000 – 1200]: 2, 2, 2, 2, 2, 7, 7, 2, 2, 4, 4, 7 kW
- ⌘ [1300 - 0000]: 7, 7, 8, 8, 8, 12, 12, 12, 12, 12, 8, 8 kW



Component: Diesel Input

- ⌘ 8kW generator
- ⌘ Sensitivity: [0, 2, 4] kW

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

Costs

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/hr)
8.000	6500	5500	0.200

{..} {..} {..}

Properties

Description: Diesel Type: ☒ AC ☐ DC

Abbreviation: Dsl

Lifetime (operating hours): 15000 {..}

Minimum load ratio (%): 30 {..}

Sizes to consider

Size (kW)
0.000
2.000
4.000

Cost Curve

The graph shows two linear cost curves starting from the origin (0,0). The x-axis is 'Size (kW)' ranging from 0 to 8. The y-axis is 'Cost (000 \$)' ranging from 0 to 7. A red line represents 'Capital' cost, and a blue line represents 'Replacement' cost. The Capital curve has a steeper slope than the Replacement curve. Data points are marked at 2, 4, and 8 kW.

Size (kW)	Capital Cost (000 \$)	Replacement Cost (000 \$)
0	0	0
2	1.5	1.0
4	3.0	2.0
8	6.0	4.0

Help Cancel OK 32

Component: Grid Input

Grid Inputs

File Edit Help

Click Add to add as many rates as necessary. Select a rate and click on the diagram to indicate when each rate applies.
Hold the pointer over an element or click Help for more information.

Rates | Emissions | Advanced | Forecasting

☒ Scheduled rates
☐ Real time prices

Rate schedule

Step 1: Define and select a rate

Rate	Price (\$/kWh)	Sellback (\$/kWh)	Demand (\$/kW/mo)
Rate 1	0.150	0.150	5.000

Add Remove Edit..

Step 2: Select a time period

All Week Weekdays Weekends

Step 3: Click on the chart to indicate when the selected rate applies.

☐ Net metering

☒ Net purchases calculated monthly
☐ Net purchases calculated annually

Rate Properties

Enter a name for this rate period, and the corresponding power price, sellback rate, and demand rate.
Hold the pointer over an element or click Help for more information.

Label: Rate 1 Color:

Grid power price (\$/kWh): 0.15 { }

Sellback rate (\$/kWh): 0.15 { }

Demand rate (\$/kW/month): 5 { }

This rate applies:

Months	Days	Hours
Jan-Dec	All week	00:00-24:00

Help Cancel OK

24:00 Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

Rate 1
All week
Weekdays
Weekends

Help Cancel OK

Component: PV Input

⌘ 1kW, \$6900, \$6900, \$0/yr

⌘ [0, 2, 4] kW for sensitivity analysis

PV Inputs

File Edit Help

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

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

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

Costs

Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/yr)
1.000	6900	6900	0

{.}

Sizes to consider

Size (kW)
0.000
2.000
4.000

Cost Curve

Cost (000 \$)

Size (kW)

— Capital — Replacement

Properties

Output current ☐ AC ☒ DC

Lifetime (years) {.}

Derating factor (%) {.}

Slope (degrees) {.}

Azimuth (degrees W of S) {.}

Ground reflectance (%) {.}

Advanced

Tracking system

☐ Consider effect of temperature

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

Nominal operating cell temp. (°C) {.}

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

Help Cancel OK

Component: Wind Turbine Input

- ⌘ Generic 3kW DC
- ⌘ Quantity [0, 1, 2, 3] for sensitivity analysis
- ⌘ Cost: \$11000, \$7000, \$200/yr

Wind Turbine Inputs

File Edit Help

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: Generic 3kW [Details... New... Delete]

Turbine properties:

- Abbreviation: G3 (used for column headings)
- Rated power: 3 kW DC
- Manufacturer:
- Website:

Costs

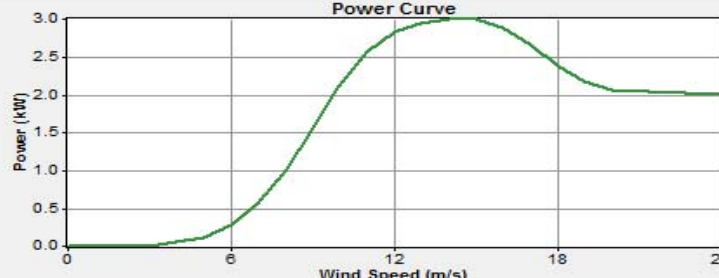
Quantity	Capital (\$)	Replacement (\$)	O&M (\$/yr)
1	11000	7000	200
2	20000	12000	375

Other

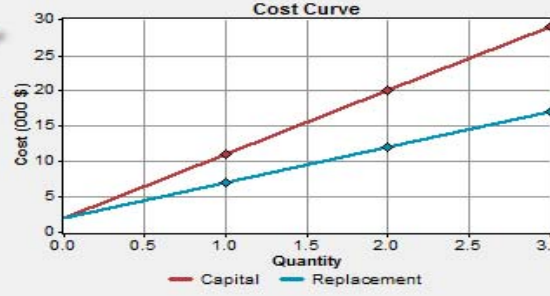
Lifetime (yrs): 15

Hub height (m): 19.9526

Power Curve



Cost Curve



Help Cancel OK

Component: Battery Input

- ⌘ Rolls/Surrette 1156 Ah 6V
- ⌘ Cost per unit: \$1200, \$1100, \$50/yr
- ⌘ Quantity [0, 10, 20, 30] for Sensitivity
- ⌘ 1 per string



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

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

Battery type: Surrette 6CS25P Details... New... Delete

Battery properties

Manufacturer: Rolls/Surrette
Website: www.rollsbattery.com

Nominal voltage: 6 V
Nominal capacity: 1,156 Ah (6.94 kWh)
Lifetime throughput: 9,645 kWh

Costs

Quantity	Capital (\$)	Replacement (\$)	O&M (\$/yr)
1	1200	1100	50.00

Sizes to consider

Batteries
0
10
20
30

Advanced

Batteries per string: 1 (6 V bus)

☐ Minimum battery life (yr): 4

Help Cancel OK

Cost Curve

Quantity	Capital Cost (000 \$)	Replacement Cost (000 \$)
0	0	0
10	12	11
20	24	22
30	36	33

Battery Sizing

10291 - System configuration, battery sizing

Posted by on 22 December 2010 10:28 AM



Is there any particular criteria for sizing of battery storage in HOMER ? How do we size a converter ?

We have found that there is no reliable rule of thumb for determining optimal value of battery autonomy. It depends on many factors, including the daily and seasonal patterns of the load, the daily and seasonal patterns and the intermittency of the relevant renewable resources, the correlation between the load and renewable resources, the fuel price, the size of the backup generator relative to the peak and average load, etc.

So we always rely on HOMER's ability to optimize the size of the battery bank, rather than using some pre-defined size. One possibility is to calculate the number of batteries corresponding to a comfortably long autonomy such as 4 days, and specify a range of possible values from that value down to zero. In truth, I usually rely on trial and error, using HOMER's feedback to revise the battery search space over several runs. This process is much easier in version 2.1 that it was previously because in version 2.1 the information on "winning sizes" appears in the Optimization Inputs window. So you can specify some battery sizes, hit Calculate, then check the bottom half of the Optimization Inputs window to see which battery size was optimal, and use the top half of the window to revise the battery search space if necessary. You can do the same for any other component as well.

Sizing the converter is somewhat easier than the battery bank because there is a clear upper limit to the converter size, namely the peak load. For example, if the load is AC and its peak value is 6 kW, it is very unlikely that the optimal converter size will exceed 6 kW. I might try a size range such as 6, 4, 3, 2, 1, and 0 kW.

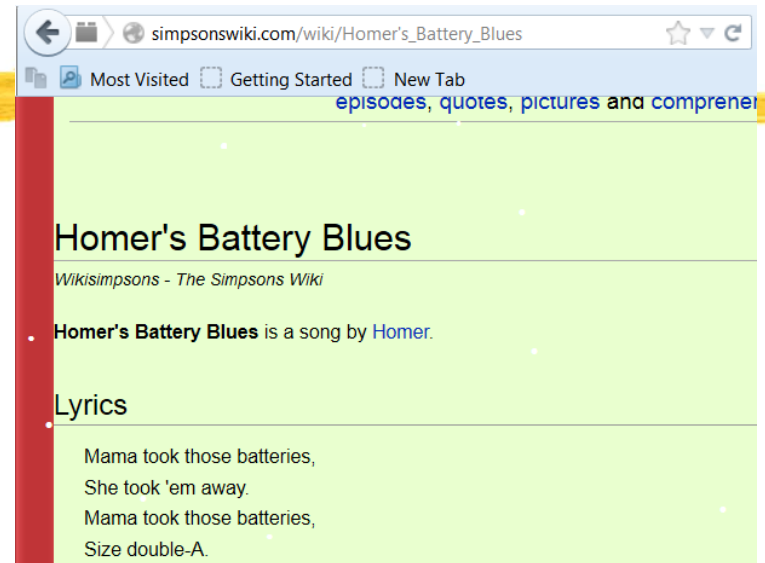
Battery Blues ?

⌘ Batteries from Remote

⌘ Youtube link:

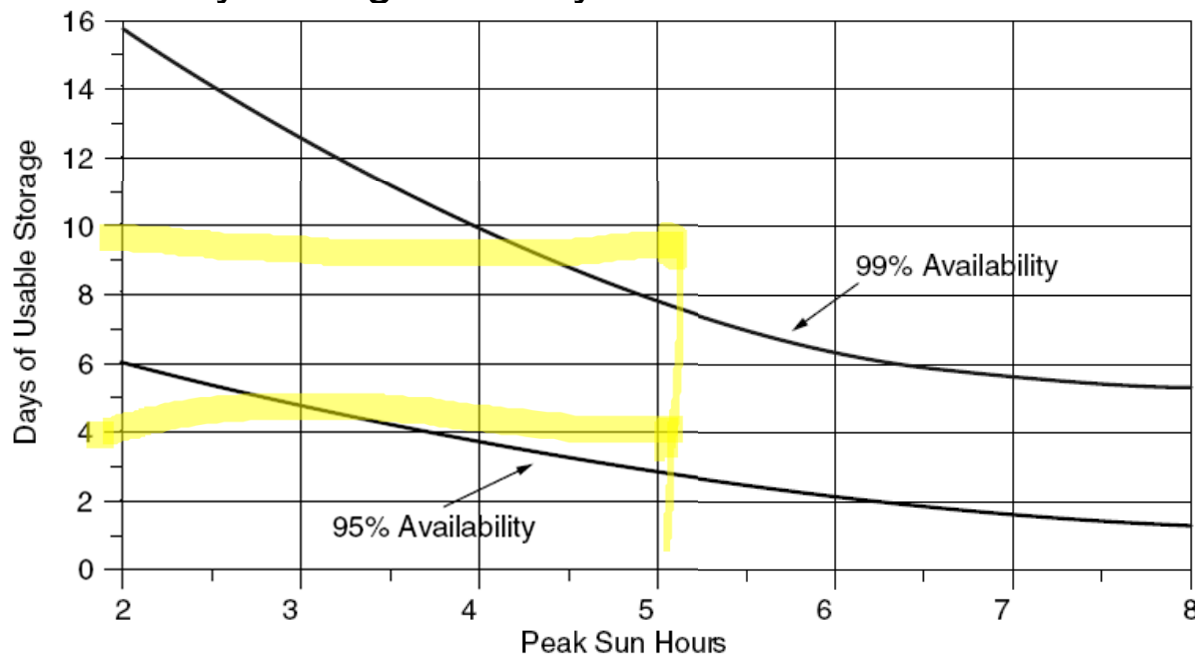
http://www.youtube.com/watch?feature=player_detailpage&v=63mn4iDYL_c

⌘ Refer Battery Sizing examples in the lectures on Solar Energy --- “the number of usable days” requirement/suggestion



Review - Battery Sizing

- ⌘ Statistical nature of weather
- ⌘ No set rules about how best to size battery storage except the cost trade-off
- ⌘ Battery system of meeting demand 99% of the time may be 3 times higher in cost than that of meeting 95% of the time.
- ⌘ The number of days of storage to supply a load in the design month [the month with the worst combination of insolation and load]
- ⌘ **Days of “usable battery storage”** needed for a stand-alone system
- ⌘ Nominal Battery Storage -- 3 days



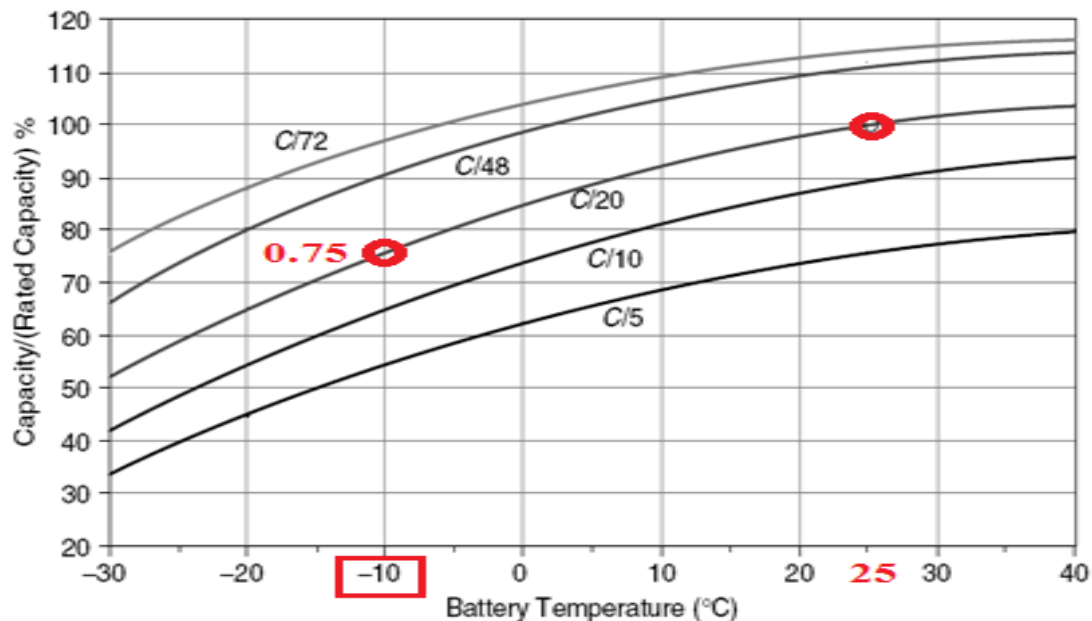
Review - Battery Sizing

⌘ Nominal rated storage vs. usable storage:

$$\text{Nominal (C/20, 25°C) battery capacity} = \frac{\text{Usable battery capacity}}{(\text{MDOD})(T, \text{DR})}$$

⌘ Variables:

- ⌘ MDOD (maximum depth of discharge): 0.8 for lead-acid;
0.25 for auto SLI
- ⌘ (T,DR): **Discharge Rate Factor** under a given
Temperature



Review - Battery Sizing Example

⌘ A cabin near Salt Lake City, Utah, has an ac demand of 3000 Wh/day in the winter months. A decision has been made to size the batteries such that a 95% system availability will be provided, and a back-up generator will be kept in reserve to cover the other 5%. The batteries will be kept in a ventilated shed whose temperature may reach as low as -10°C . The system voltage is to be 24 V, and an inverter with overall efficiency of 85% will be used.

⌘ SOLUTION APPROACH

- ☒ 1. AC load \rightarrow DC load demand (with 85% inverted efficiency)
- ☒ 2. Battery Capacity (Ah)
- ☒ 3. Usable storage (Ah) – Use the nominal 3 day storage
- ☒ 4. Nominal capacity (Ah)
 - ☒ Assumption: 80% deep discharge \leftarrow MDOD
 - ☒ Assumption: 97% discharge rate \leftarrow (T,DR)
- ☒ 5. Battery Bank Design

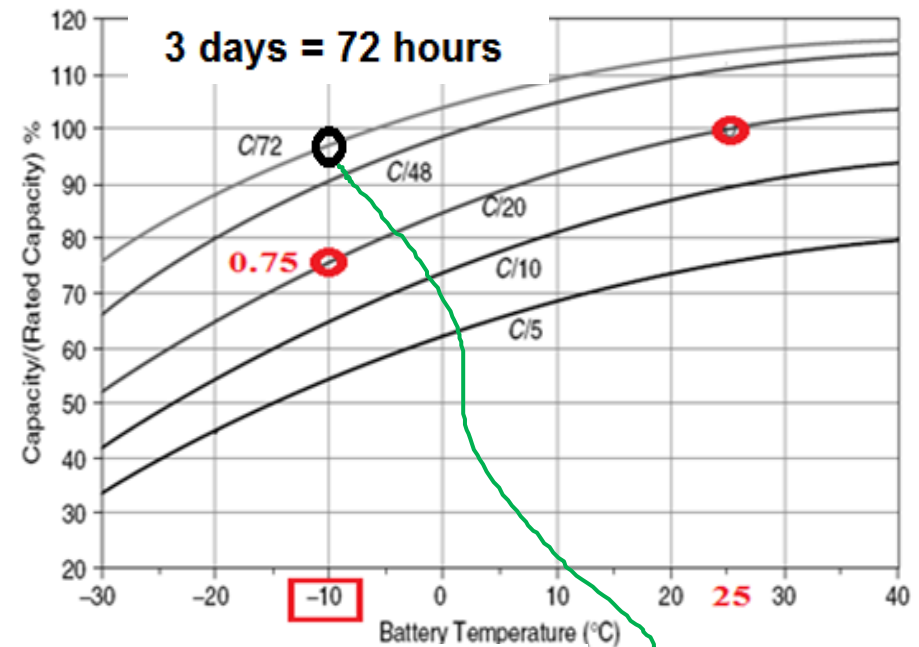
Review - SOLUTION - details

$$\text{DC load} = \frac{\text{AC load}}{\text{Inverter efficiency}} = \frac{3000 \text{ Wh/day}}{0.85} = 3529 \text{ Wh/day}$$

$$\text{Load} = \frac{3529 \text{ Wh/day}}{24 \text{ V}} = 147 \text{ Ah/day @ 24 V}$$

Nominal 3-day storage

$$\text{Usable storage} = 147 \text{ Ah/day} \times 3 \text{ day} = 441 \text{ Ah}$$



$$\text{Nominal (C/20, 25°C) battery capacity} = \frac{441 \text{ Ah}}{0.80 \times 0.97} = 568 \text{ Ah (at 24 V)}$$

Review - MathCad Solution

Battery Sizing.xmcd Charles Kim 2013

A Cabin near Salt Lake City, Utah, has an AC energy demand of 3 kWh per day in the winter months. With a battery system, a 95% availability will be provided, while a back-up generator will be kept to cover the other 5%. The battery system will be kept in a ventilated shed where the temperature may go as low as - 10 C degrees. The system voltage is 24 V, and an inverter efficiency is 85%. Assume 80% deep discharge (MDOD) and 97 % discharge rate (T,DR)

(Q) Calculate the size of the battery system.

$$MDOD := 0.8$$

$$TDR := 0.97$$

$$E_{ac} := 3 \text{ kWh / day}$$

$$D2A := 0.85 \quad \text{Inverter Efficiency}$$

$$B_{volt} := 24 \quad \text{Battery System Voltage}$$

40.7500° N, 111.8833° W

Salt Lake City, Coordinates

SOLUTION

=====

1. DC energy demand (Edc):

$$E_{dc} := \frac{E_{ac}}{D2A} = 3.5294 \text{ kWh / day}$$

2. Expression of the energy demand in terms of Amp-Hour per day. Remember that
Energy=Power*Time = V*A*time,
=> A*hour = Wh/V

$$AH := \frac{E_{dc} \times 1000}{B_{volt}} = 147.0588 \text{ Ah/day}$$

Review- MathCad Solution

3. Find the usable storage Ah at -10 C degree (use the graph)

a. Peak-Sun-Hour information

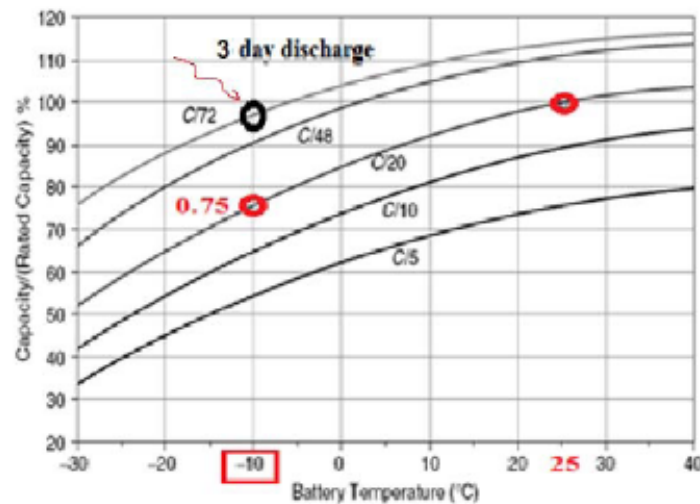
b. Find the # of days of usable storage(Dus) --- Use nominal 3-day storage

Dus := 3 days

c. Now we calculate the Usuable Storage Amp-Hour (AHus)

AHus := AH × Dus = 441.1765 Ah

d. Finally, the nominal (C/20, 25 C) capacity:



MDOD = 0.8000 Nominal 3-day storage

TDR = 0.9700

MDOD × TDR = 0.7760

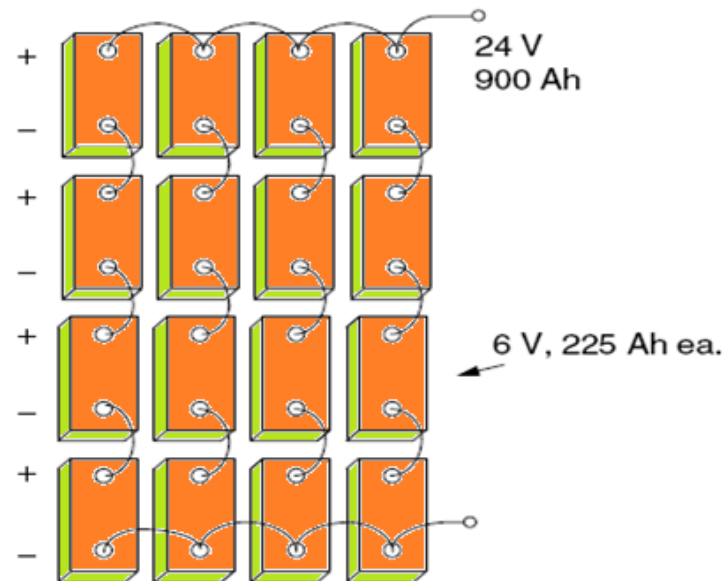
AHnorm := $\frac{AHus}{MDOD \times TDR}$ Ah

AHnorm = 568.5264

Review - Battery Selection - Example

⌘ 871 Ah @ 24V

BATTERY	Voltage	Weight (lbs)	Ah @ C/20	Ah @ C/100
Concorde PVX 5040T	2	57	495	580
Trojan T-105	6	62	225	250
Trojan L16	6	121	360	400
Concorde PVX 1080	12	70	105	124
Surette 12CS11PS	12	272	357	503




Component: Converter Input

- ⌘ 10kW
- ⌘ Cost: \$12500, \$12500, \$100/yr
- ⌘ [0, 2, 4, 6, 8kW] for sensitivity analysis
- ⌘ Inversion Efficiency 90%
- ⌘ Rectification Efficiency 85%



Converter Inputs

File Edit Help

 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

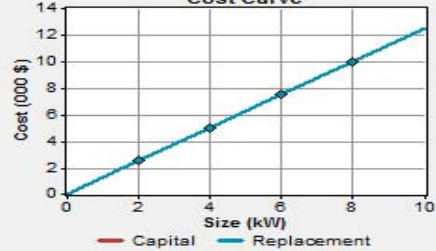
Size (kW)	Capital (\$)	Replacement (\$)	O&M (\$/yr)
10.000	12500	12500	100

{.}

Sizes to consider

Size (kW)
0.000
2.000
4.000
6.000
8.000

Cost Curve



Cost (000 \$)

Size (kW)

— Capital — Replacement

Inverter inputs

Lifetime (years) {.}

Efficiency (%) {.}

☒ Inverter can operate simultaneously with an AC generator

Rectifier inputs

Capacity relative to inverter (%) {.}

Efficiency (%) {.}

Help Cancel OK

Other: Economics

- ⌘ Real annual interest: 8%
- ⌘ Project Lifetime: 25 years
- ⌘ System fixed cost: \$6000
 - ☒ It represents balance of system and distribution system costs that cannot be allocated to a specific component.

Economic Inputs

File Edit Help

HOMER applies the economic inputs to each system it simulates to calculate the system's net present cost.
Hold the pointer over an element name or click Help for more information.

Annual real interest rate (%)		{.}	
Project lifetime (years)	25	{.}	
System fixed capital cost (\$)	6000	{.}	
System fixed O&M cost (\$/yr)	0	{.}	
Capacity shortage penalty (\$/kWh)	0	{.}	

Help Cancel OK

Other: System Control

⌘ Simulation Time Step: 1 hr (60 min)

⌘ Dispatch Strategies:

☒ load following

☒ cycle charging

☒ Charge state set point: 80%

System Control Inputs

File Edit Help

The system control inputs define how HOMER models the operation of the battery bank and generators. The dispatch strategy determines how the system charges the battery bank.

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

Simulation

Simulation time step (minutes) 60 {..}

Dispatch strategy

☒ Load following

☒ Cycle charging

☒ Apply setpoint state of charge (%) 80 {..}

Generator control

☒ Allow systems with multiple generators

☒ Allow multiple generators to operate simultaneously

☒ Allow systems with generator capacity less than peak load

Other: Constraints Input

- ⌘ Max annual capacity storage: 0% [0.0, 0.1] for sensitivity analysis
- ⌘ Operating Reserve: 10% of hourly load

The screenshot shows the 'Constraints' dialog box in HOMER software. It has a menu bar (File, Edit, Help) and a text area explaining constraints. Below this are input fields for various constraints. Red arrows point to the following fields:

- 'Maximum annual capacity shortage (%)' with a value of 0 and a range of {2}.
- 'Minimum renewable fraction (%)' with a value of 0 and a range of {..}.
- 'Operating reserve' section, specifically 'As percent of load' with 'Hourly load (%)' set to 10 and a range of {..}.
- 'Sensitivity Values' dialog box, which is open and shows 'Variable: Maximum Annual Capacity Shortage', 'Units: %', 'Link with: <none>', and a table of values.

The 'Sensitivity Values' dialog box contains the following table:

Variable	Units	Link with	Values
Maximum Annual Capacity Shortage	%	<none>	1 0.0
			2 0.1
			3
			4
			5
			6
			7
			8
			9
			10

Emission Input (Optional)

⌘ CO2 Emission Limit

Emissions Inputs

File Edit Help

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

Carbon dioxide (\$/t)	3	{4}
Carbon monoxide (\$/t)	0	{.}
Unburned hydrocarbons (\$/t)	0	{.}
Particulate matter (\$/t)	0	{.}
Sulfur dioxide (\$/t)	3	{.}
Nitrogen oxides (\$/t)	3	{.}

Limits on emissions

<input checked="" type="checkbox"/> Carbon dioxide (kg/yr)	10000	{.}
<input type="checkbox"/> Carbon monoxide (kg/yr)	0	{.}
<input type="checkbox"/> Unburned hydrocarbons (kg/yr)	0	{.}
<input type="checkbox"/> Particulate matter (kg/yr)	0	{.}
<input type="checkbox"/> Sulfur dioxide (kg/yr)	0	{.}
<input type="checkbox"/> Nitrogen oxides (kg/yr)	0	{.}

Sensitivity Values

Variable: Maximum CO2 Emissions
Units: kg/yr
Link with: <none>

Values:

1	10000
2	20000
3	30000
4	40000
5	
6	
7	
8	
9	
10	
11	
12	

Clear

Help Cancel OK

Simulation

⌘ Calculate: Optimization Result

⌘ Categorized

Sensitivity Results

Optimization Results

Sensitivity variables

Wind Speed (m/s)

3

Diesel Price (\$/L)

0.3

Max. Annual Capacity Shortage (%)

0









Double click on a system below for simulation results.

☒ Categoriz

☐ Overall

Export...

Details...

		PV (kW)	G3	Dsl (kW)	S6CS2...	Conv. (kW)	Disp. Strgy	Grid (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kW...	Ren. Frac.	Capacity Shorta..	Diesel (L)	Dsl (hrs)
				2	10	2	CC	1	\$ 22,125	3,152	\$ 55,776	0.409	0.00	0.00	2,904	4,400
		2		2	10	2	CC	1	\$ 35,925	2,670	\$ 64,428	0.472	0.22	0.00	2,031	3,077
			1	2	10	2	CC	1	\$ 33,125	3,401	\$ 69,434	0.509	0.06	0.00	2,646	4,009
		2	1	2	10	2	CC	1	\$ 46,925	2,927	\$ 78,175	0.573	0.28	0.00	1,796	2,721

⌘ Overall

Sensitivity Results

Optimization Results

Sensitivity variables

Wind Speed (m/s)

3

Diesel Price (\$/L)

0.3

Max. Annual Capacity Shortage (%)

0





















Double click on a system below for simulation results.

Categoriz

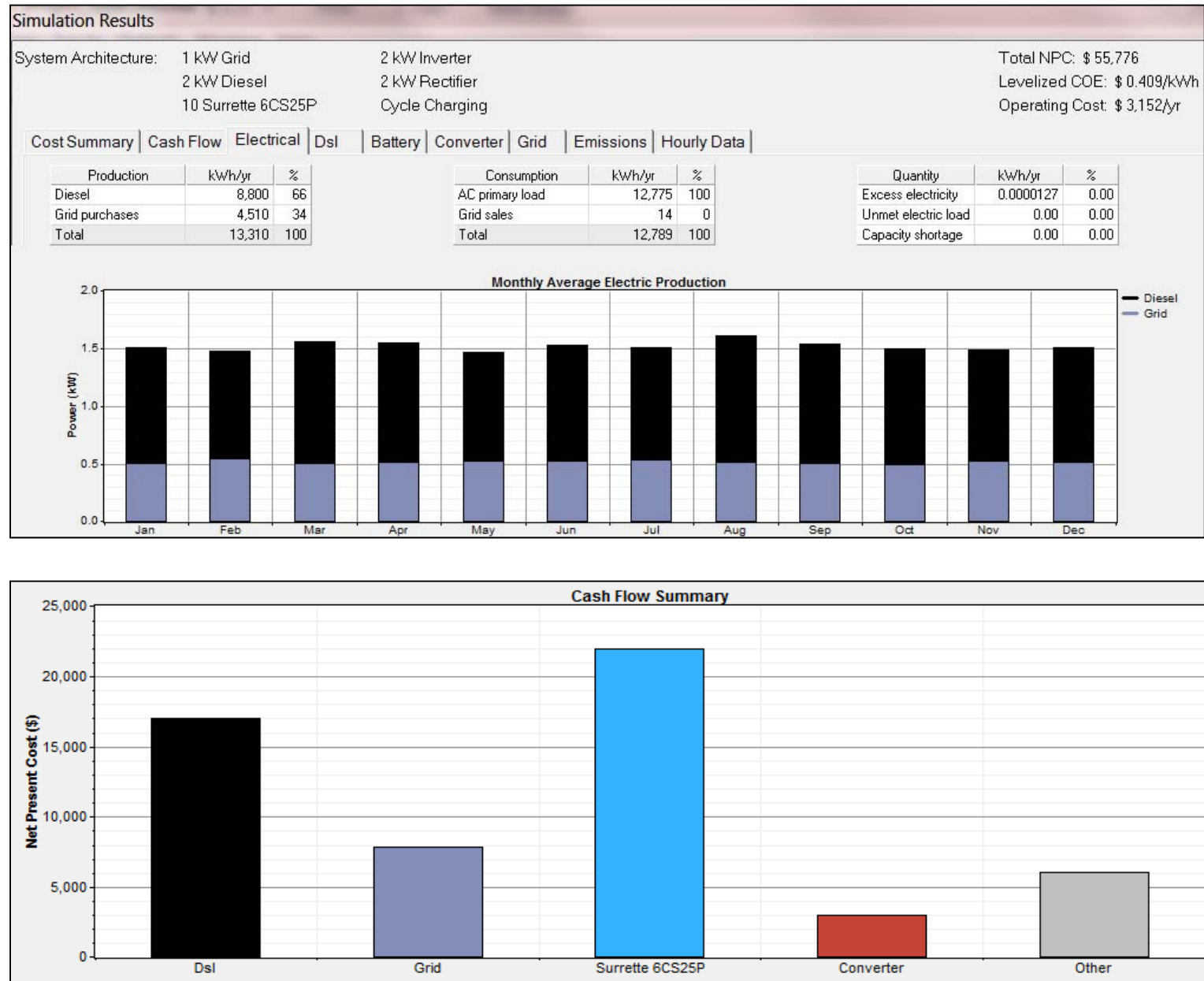
Overall

Export...

Details

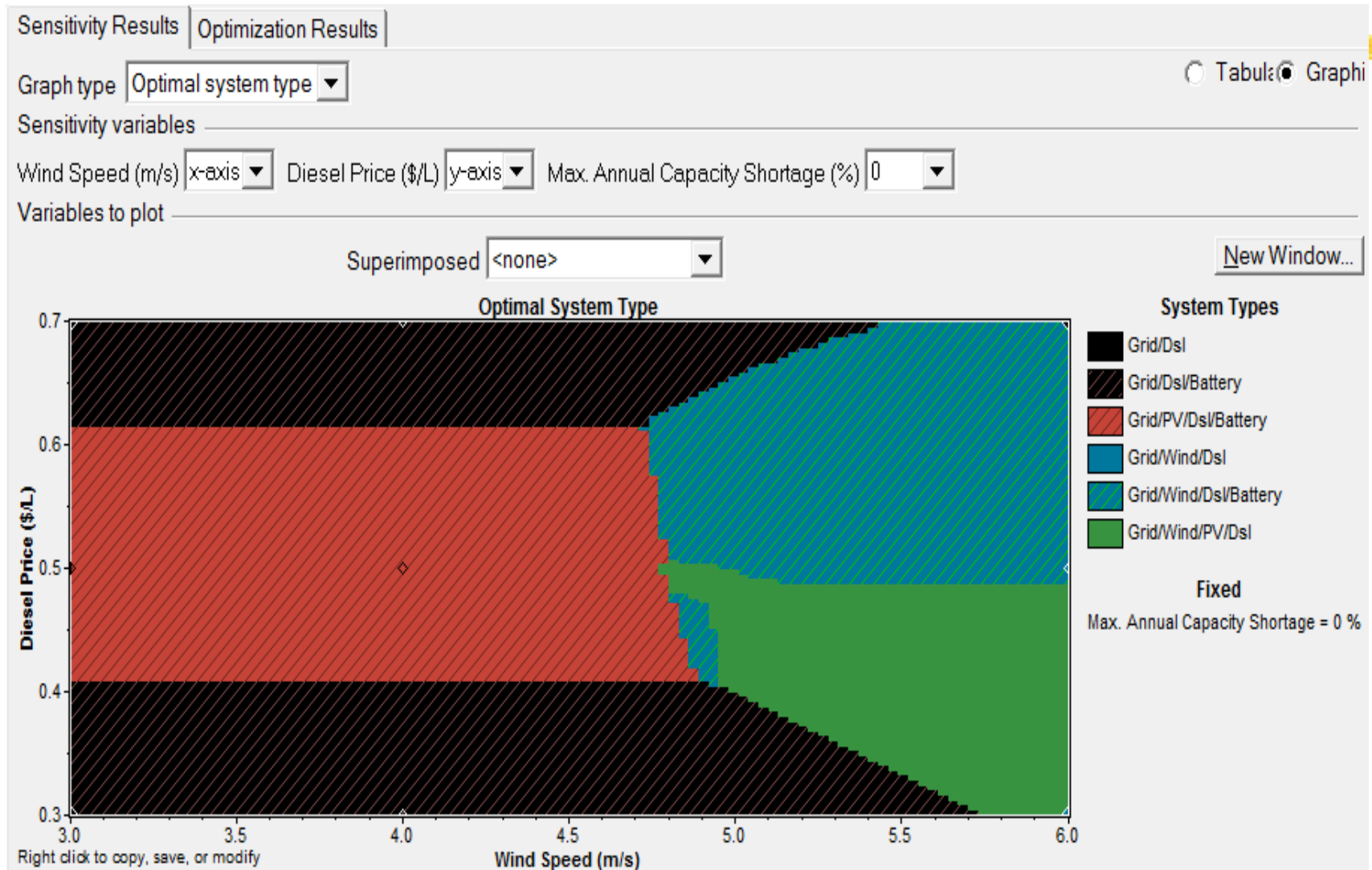
		PV (kW)	G3	Dsl (kW)	S6CS2...	Conv. (kW)	Disp. Strgy	Grid (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kW...	Ren. Frac.	Capacity Shortage	Diesel (L)	Dsl (hrs)
				2	10	2	CC	1	\$ 22,125	3,152	\$ 55,776	0.409	0.00	0.00	2,904	4,400
				2	10	4	CC	1	\$ 24,625	3,204	\$ 58,824	0.431	0.00	0.00	2,921	4,426
		2		2	10	2	CC	1	\$ 35,925	2,670	\$ 64,428	0.472	0.22	0.00	2,031	3,077
				2	10	6	CC	1	\$ 27,125	3,613	\$ 65,693	0.482	0.00	0.00	4,660	7,061
		2		4	10	2	LF	1	\$ 37,550	2,917	\$ 68,686	0.504	0.16	0.00	4,883	3,699
				2	10	8	CC	1	\$ 29,625	3,693	\$ 69,048	0.506	0.00	0.00	4,929	7,468
			1	2	10	2	CC	1	\$ 33,125	3,401	\$ 69,434	0.509	0.06	0.00	2,646	4,009
		2		2	10	4	CC	1	\$ 38,425	3,107	\$ 71,592	0.525	0.17	0.00	3,708	5,618
		2		4	10	4	LF	1	\$ 40,050	3,002	\$ 72,101	0.529	0.16	0.00	4,723	3,578
			1	2	10	4	CC	1	\$ 35,625	3,450	\$ 72,454	0.531	0.06	0.00	2,660	4,031

Result: Electrical & Cash Flow



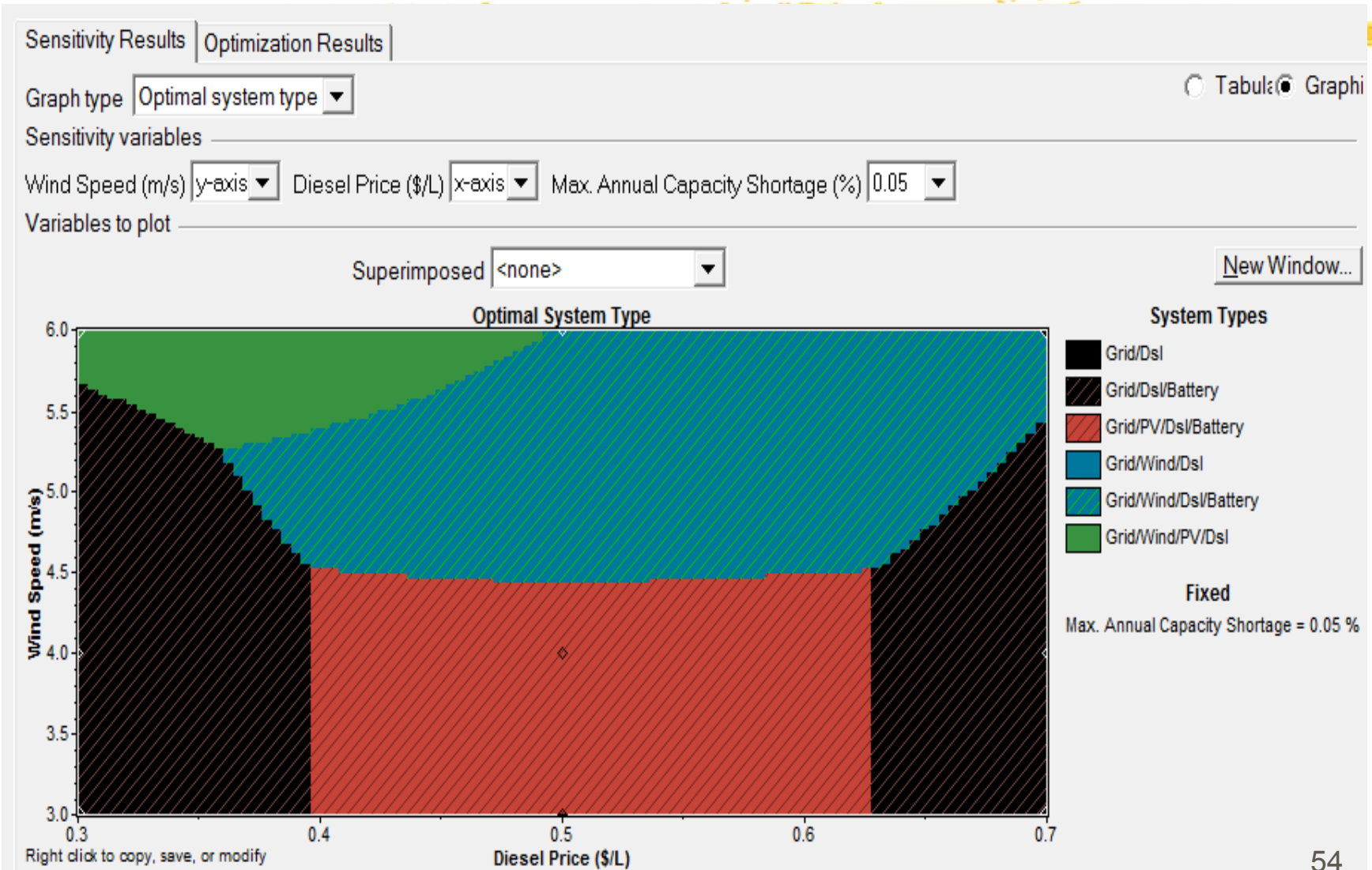
Sensitivity Analysis

⌘ Wind Speed (x) vs. Diesel Price with 0% capacity shortage

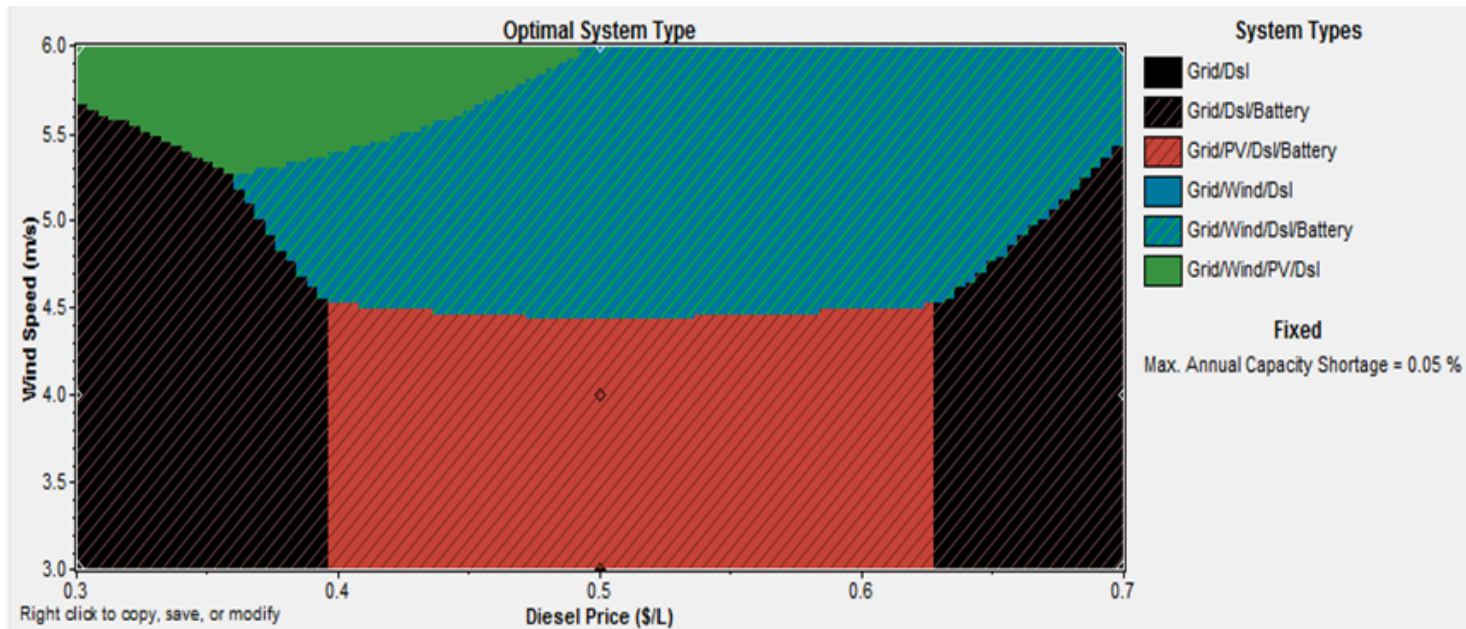
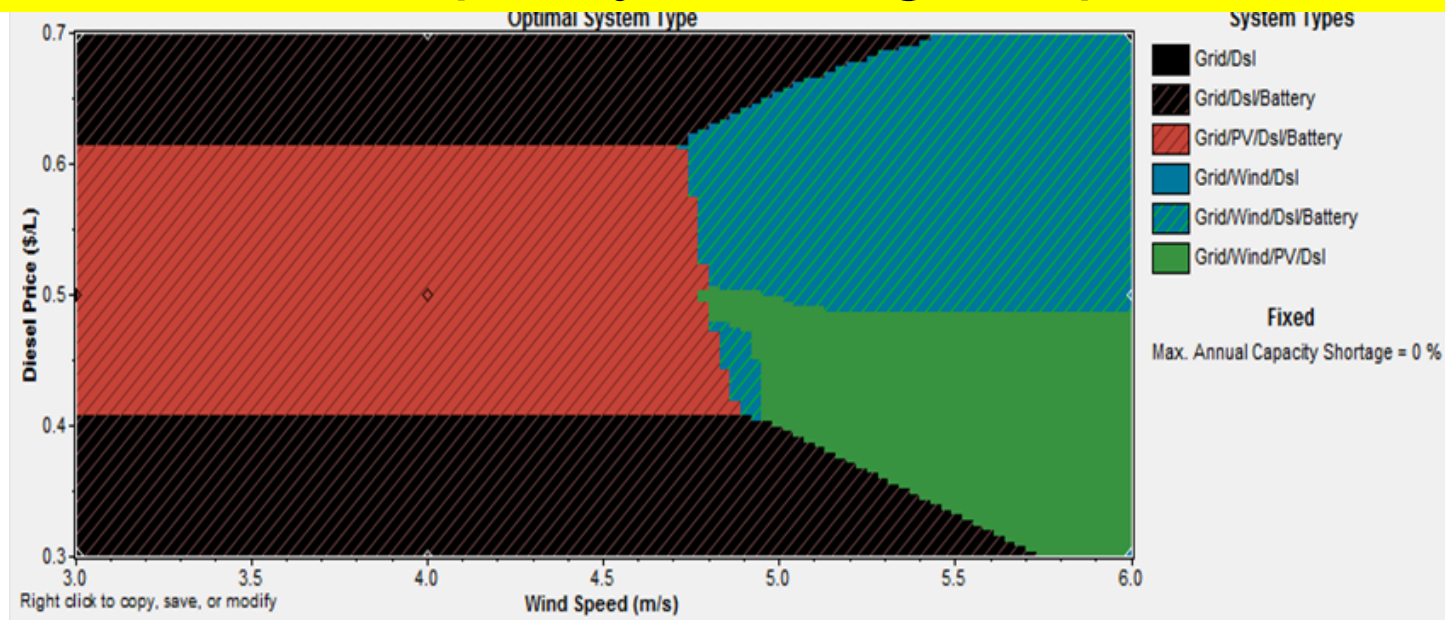


Sensitivity Analysis

⌘ Diesel Price(x) vs. Wind Speed (y) with 0.05% capacity shortage

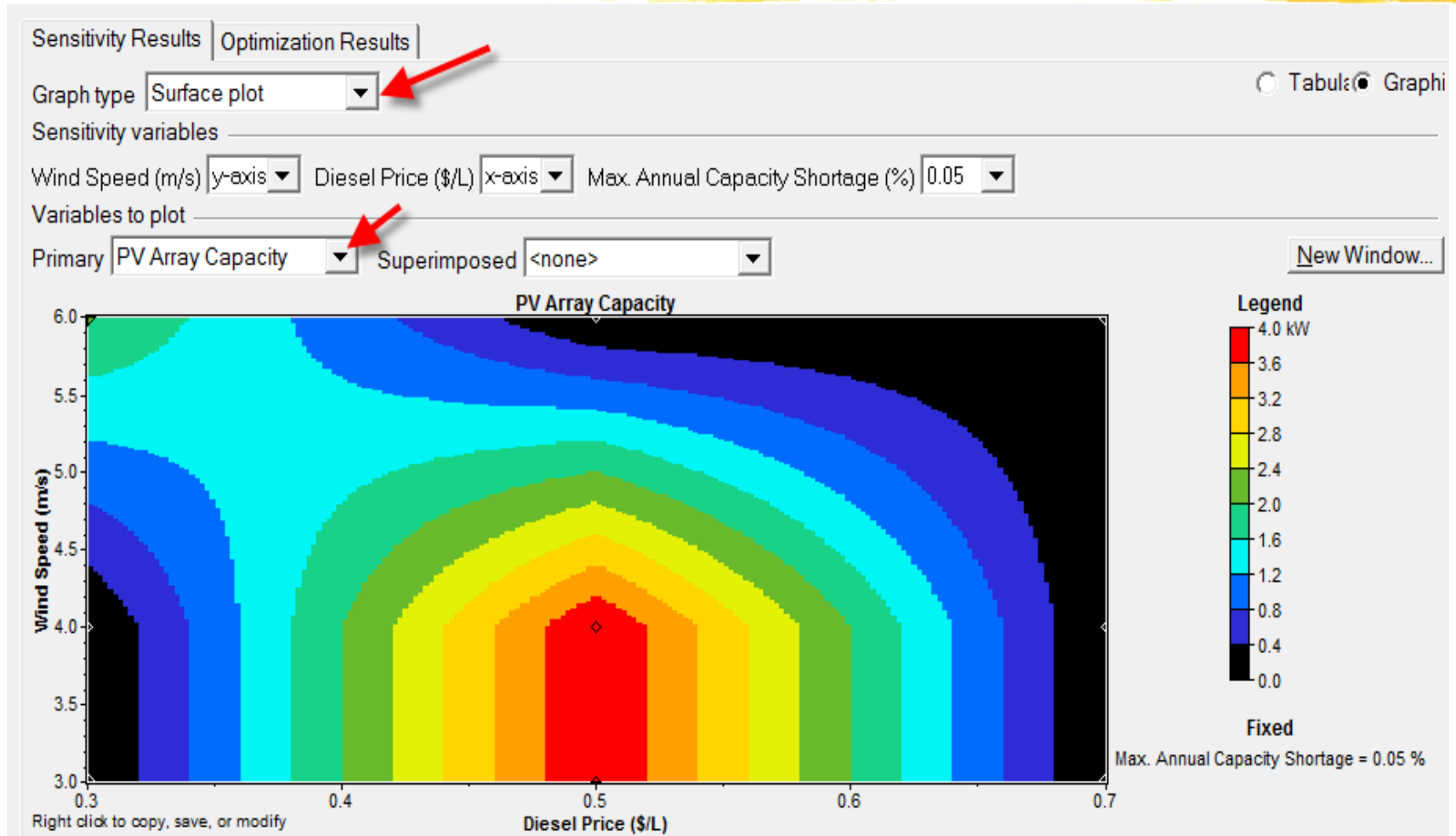


Capacity Shortage Impact



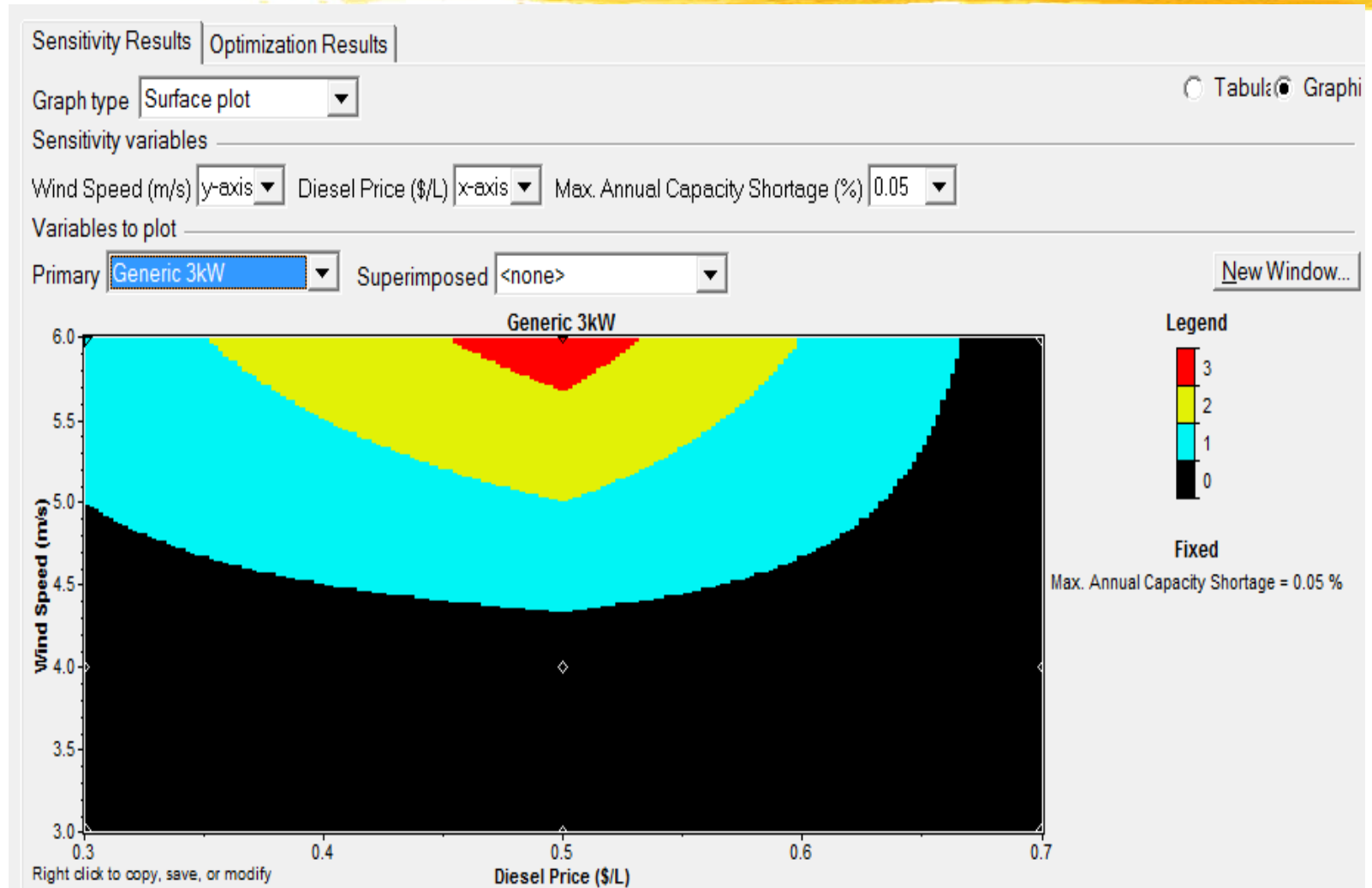
Surface Plot View

⌘ PV Array Capacity



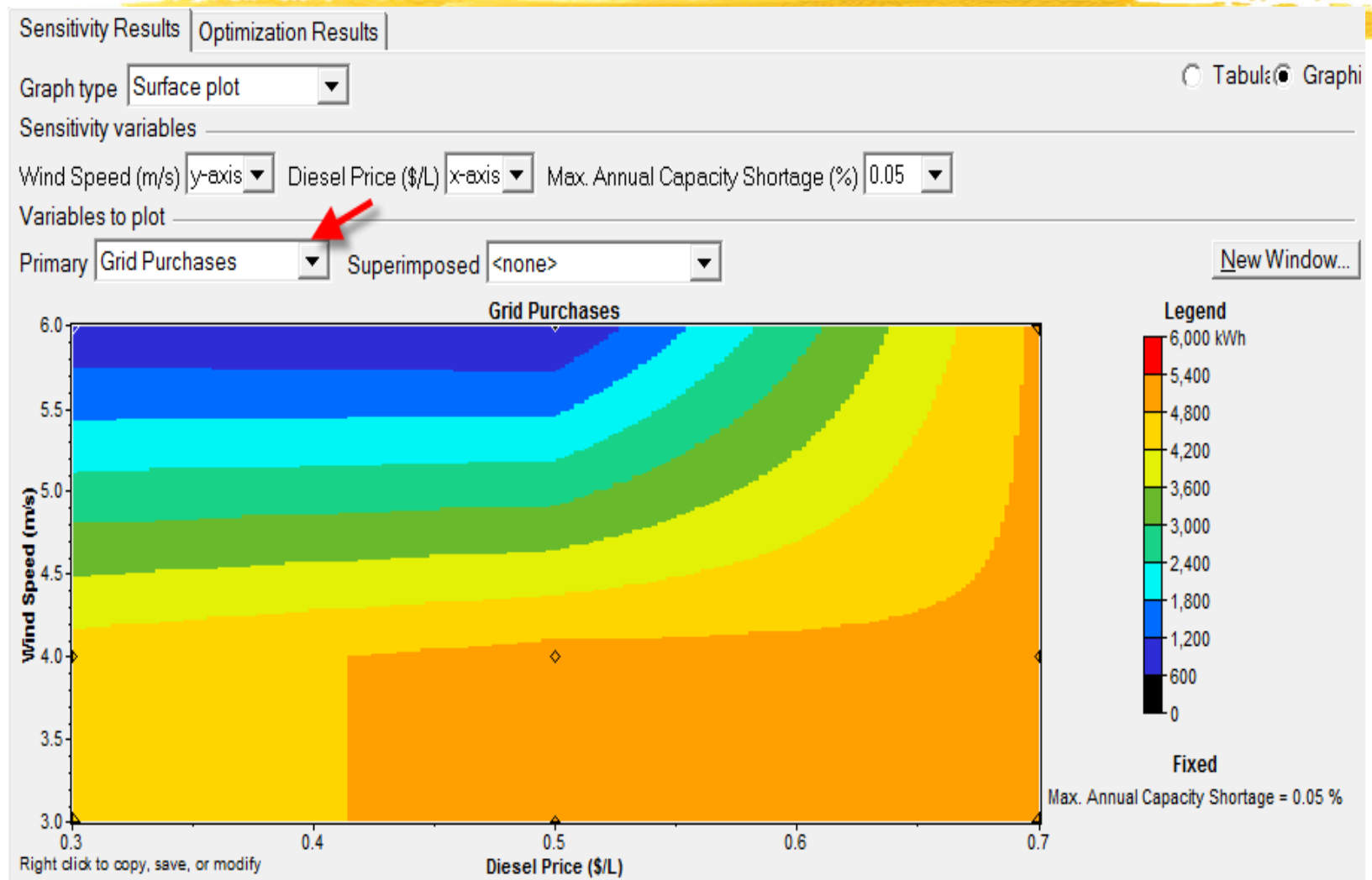
Surface Plot View

⌘ Wind Power



Surface Plot View

⌘ Grid Purchase



What we have learned so far

⌘ HOMER

☒ Editing an example code

- ☒ Resources and components
- ☒ Simulation (“calculate”) and Optimization
- ☒ Result interpretation

☒ Creating a design of code

- ☒ For your system
- ☒ Resources and components
- ☒ Simulation and optimization

⌘ We are ready to do something more our own !!

☒ Team Project (Now)

☒ Team Project Demonstration/Presentation (Tomorrow)