Design and Simulation of Micro-Power System of Renewables

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  - Note: This lecture note is a compilation of a 5-day lecture given at the Korean University of Technology Education in January 2013.

5. Modeling using HOMER – Part 2
Practice 2 & Grid-Connected Micropower System

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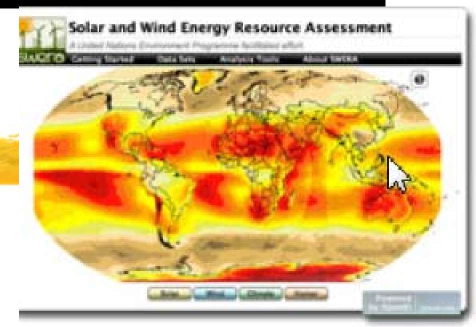
January 21-25, 2012

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

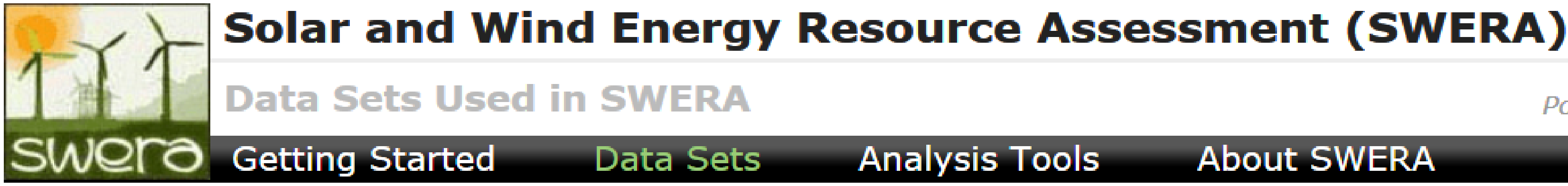


Agency/Company /Organization	United Nations Environment Programme
Partner	National Renewable Energy Laboratory, German Aerospace Center (DLR), Risoe National Laboratory for Sustainable Energy, Brazil's National Institute for Space Research (INPE), State University of New York (SUNY), Technical University 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.

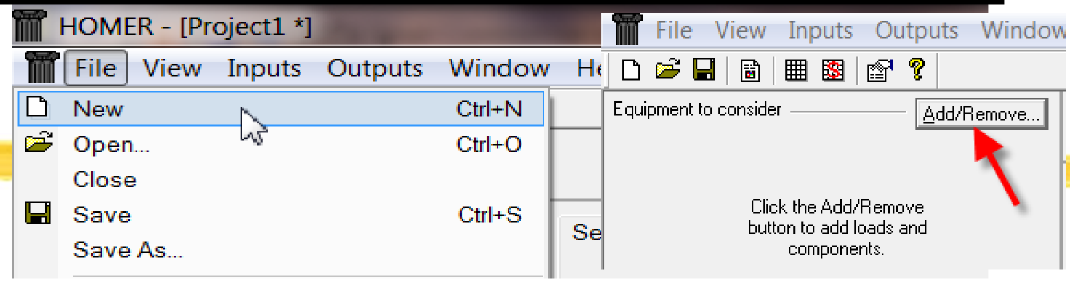
Data Set



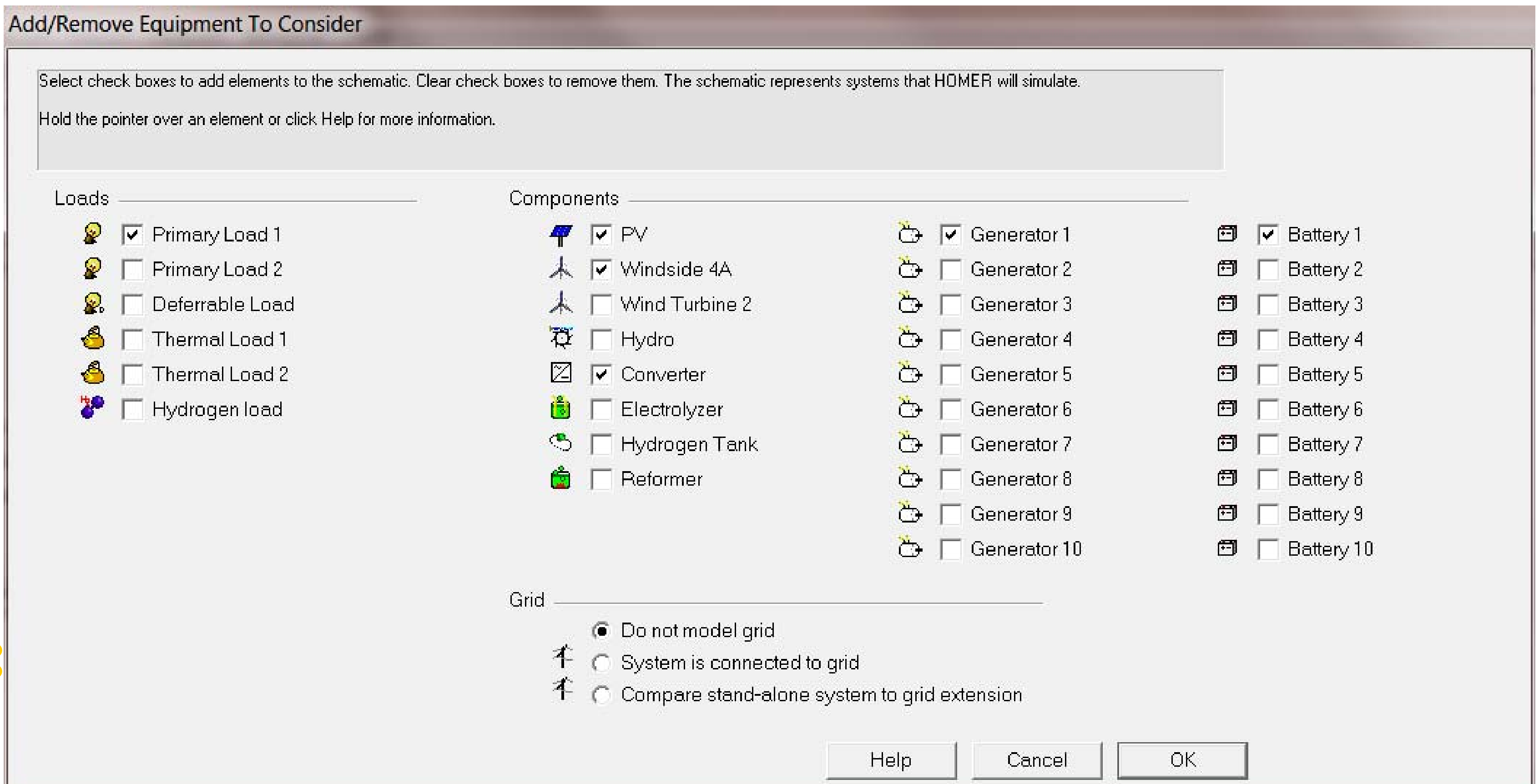
- Data obtained from the NASA Science Mission Directorate's satellite and re-analysis research programs
- Parameters were validated based on recommendations from partners in the energy industry
- Continued to adapt and tailor updated and new data sets from NASA’s satellite observation analysis and modeling 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



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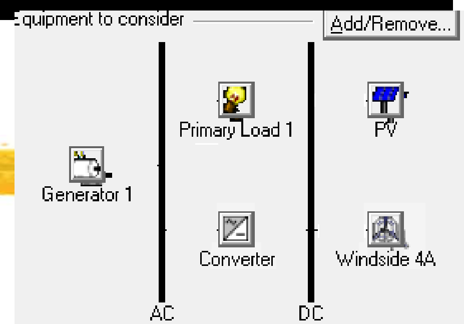
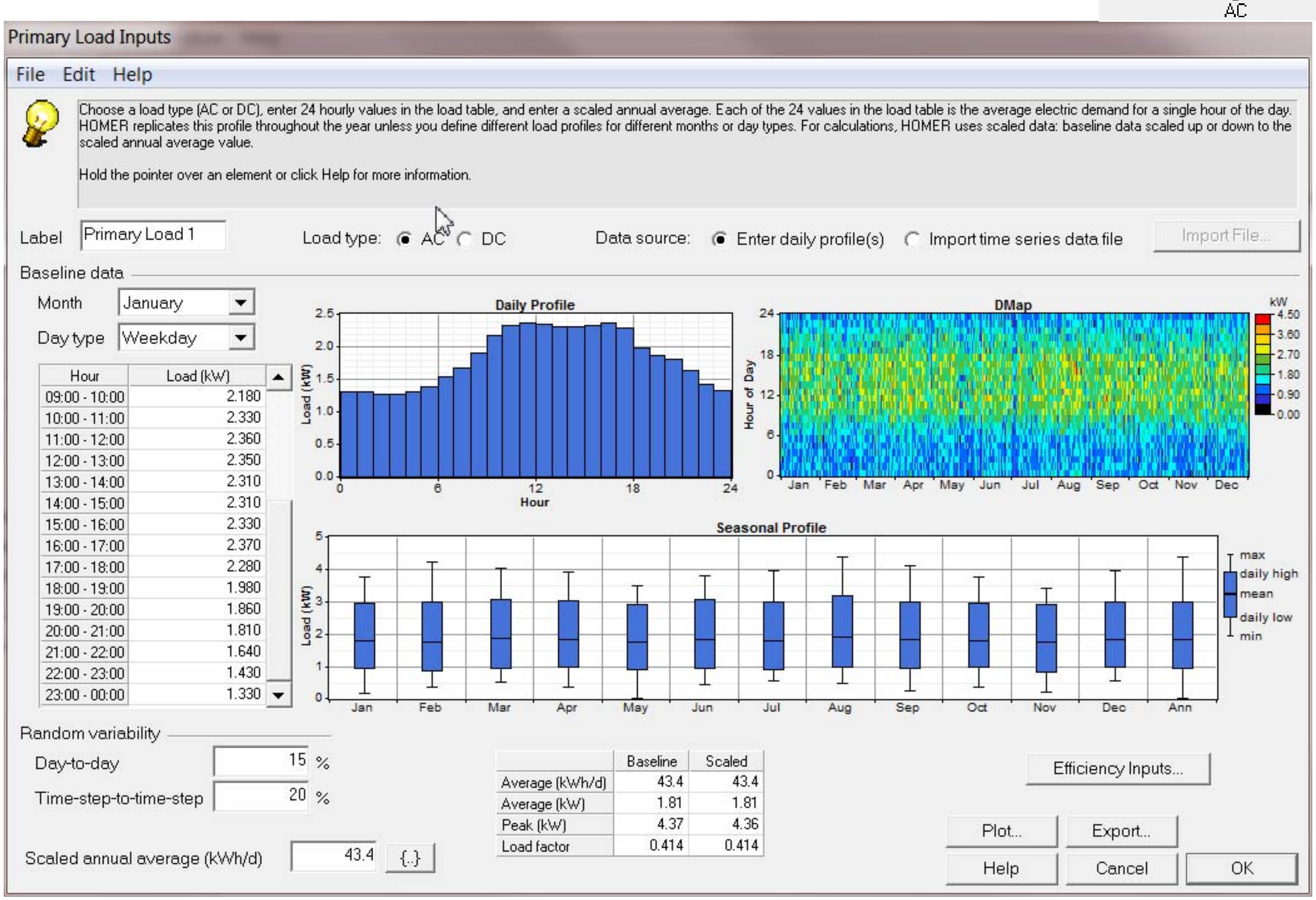
Load Data

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





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
```

How about Load Profile for this Mobile Security on Demand?

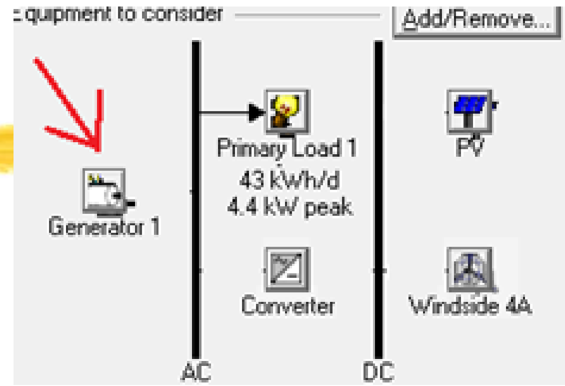
- Mobile security: 2 PV, 4 cameras, Digital recording, battery charger circuits, battery status of charge monitoring and wireless alerting.

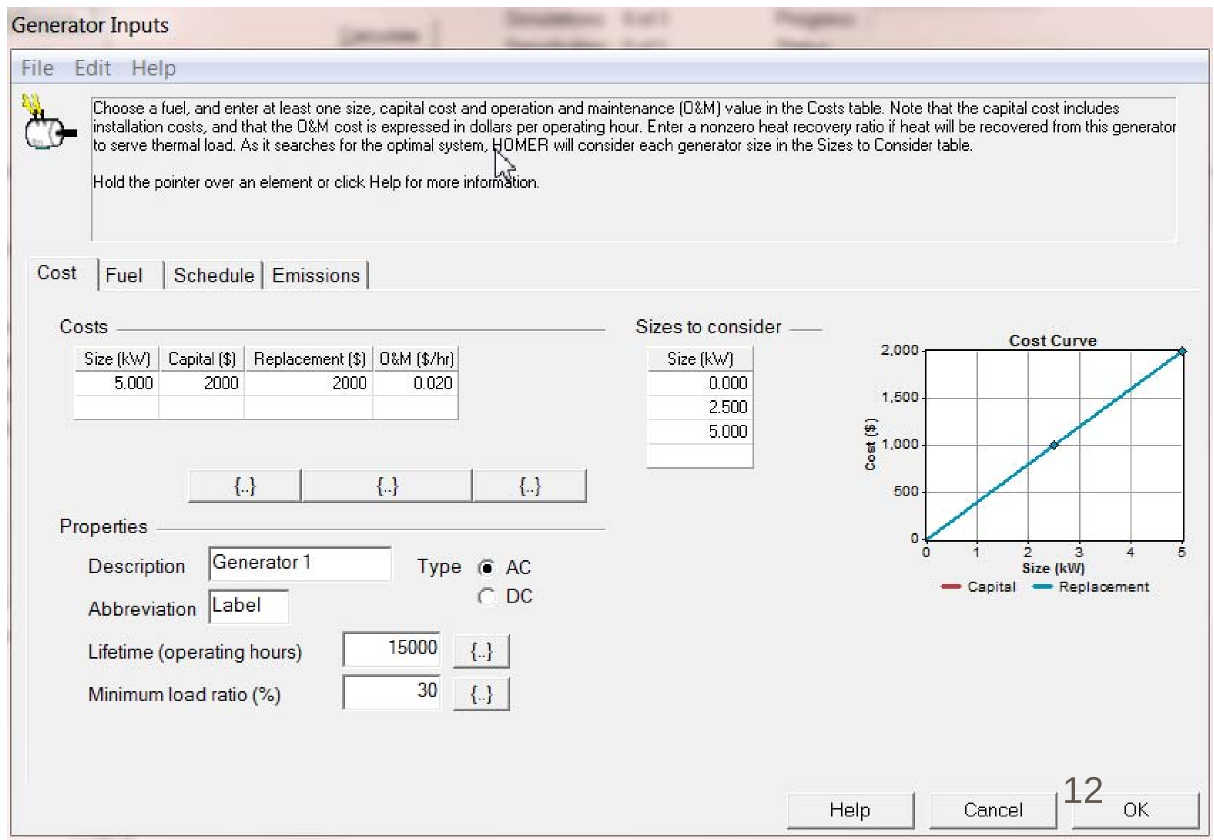
Import XLM File from SWERA

- SWERA
  - Lat & Longs → Get Homer
  - From the XLM data screen
    - CTRL+S (save to a xlm file)
- 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.

Generator Information

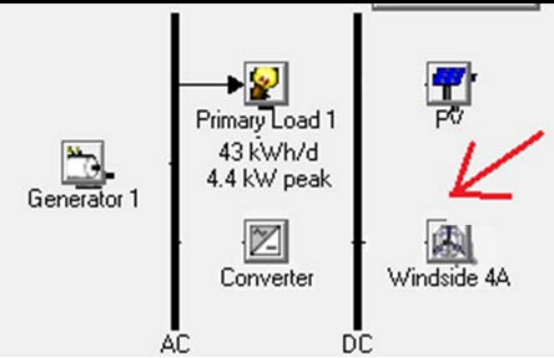
- Now arrow appears from AC bus to load
- Click “Generator”
- Size: 5.0 kW
- Capital: $2000
- Replacement: $2000
- O&M: $0.02/hr
- Sizes to consider: 0, 2.5kW, 5.0kW
- Minimum load capacity: 30%



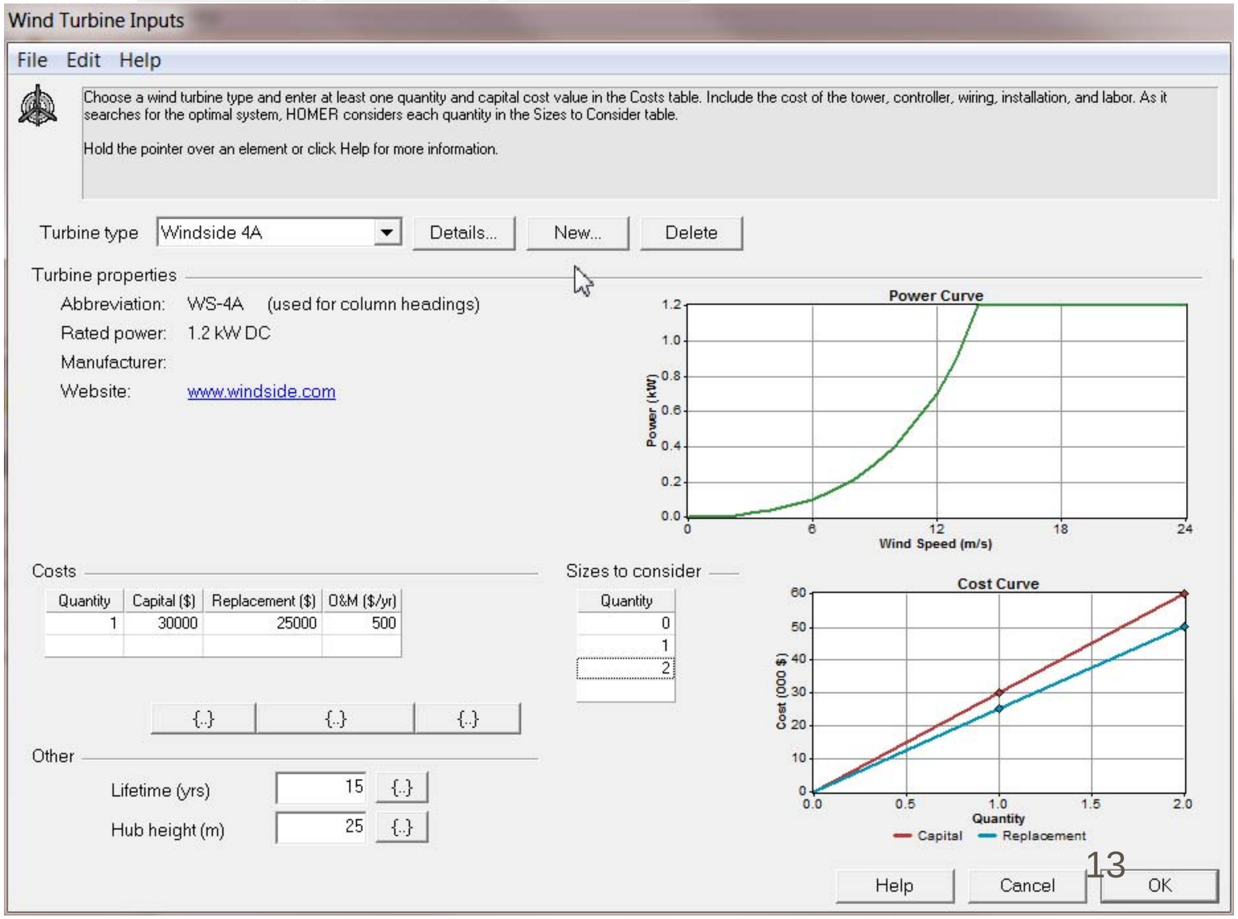


Wind Turbine Information

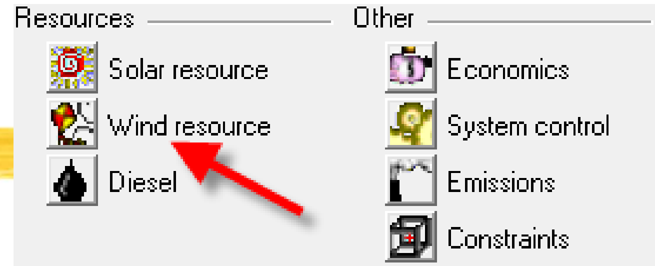
- Click Wind Turbine 1



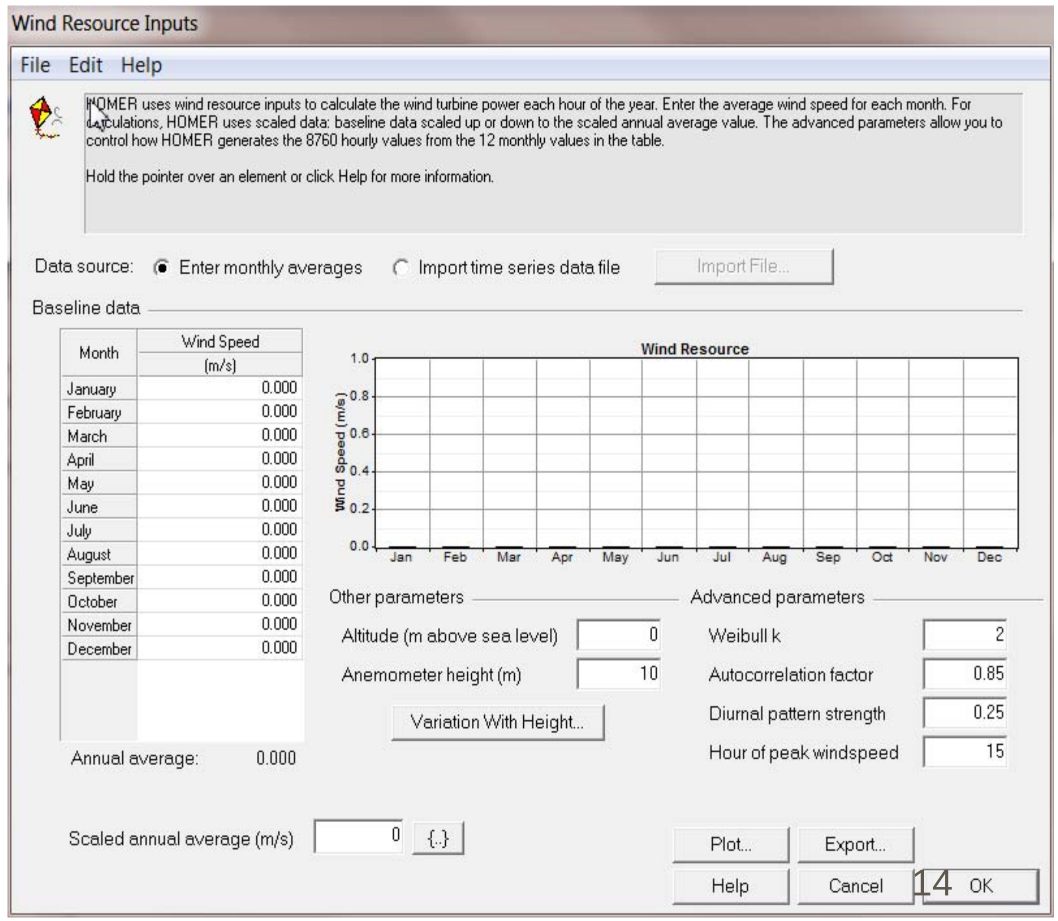
- Quantitty:1
- Capital: $30000
- Replacement: $25000
- O&M: $500/yr
- Sizes to consider (Qty): 0, 1, 2, and 3



Wind Resources

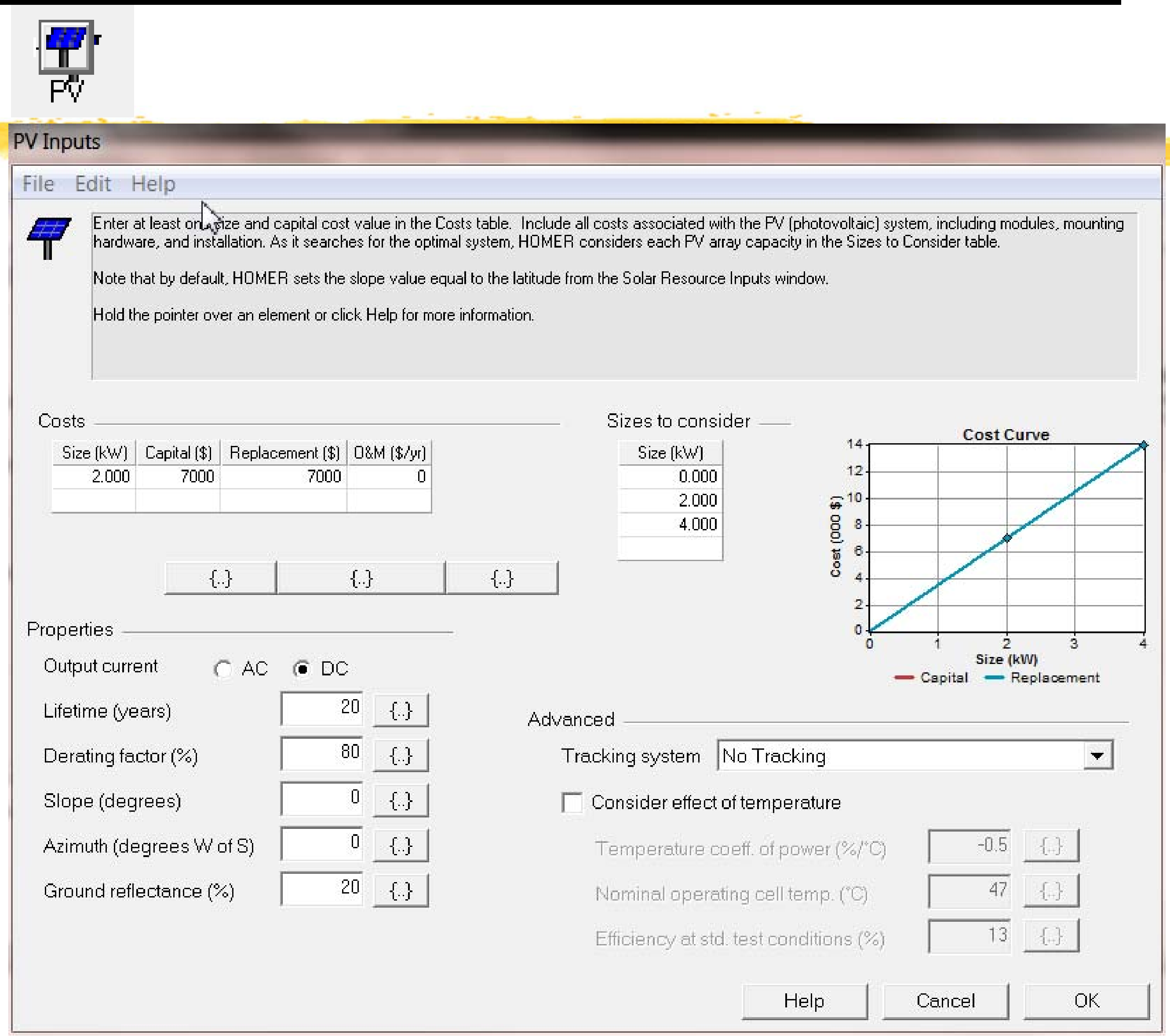


- Click Wind Resources Button
- **Location of your choice**
  - Your small store
  - Your side of street lights
  - Your (future) vacation home
- Find **Latitude and Longitude**
- Find Wind Speed [m/s] using SWERA or WINDFINDER
- Type in the speed



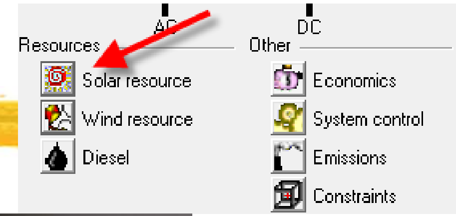
PV Information

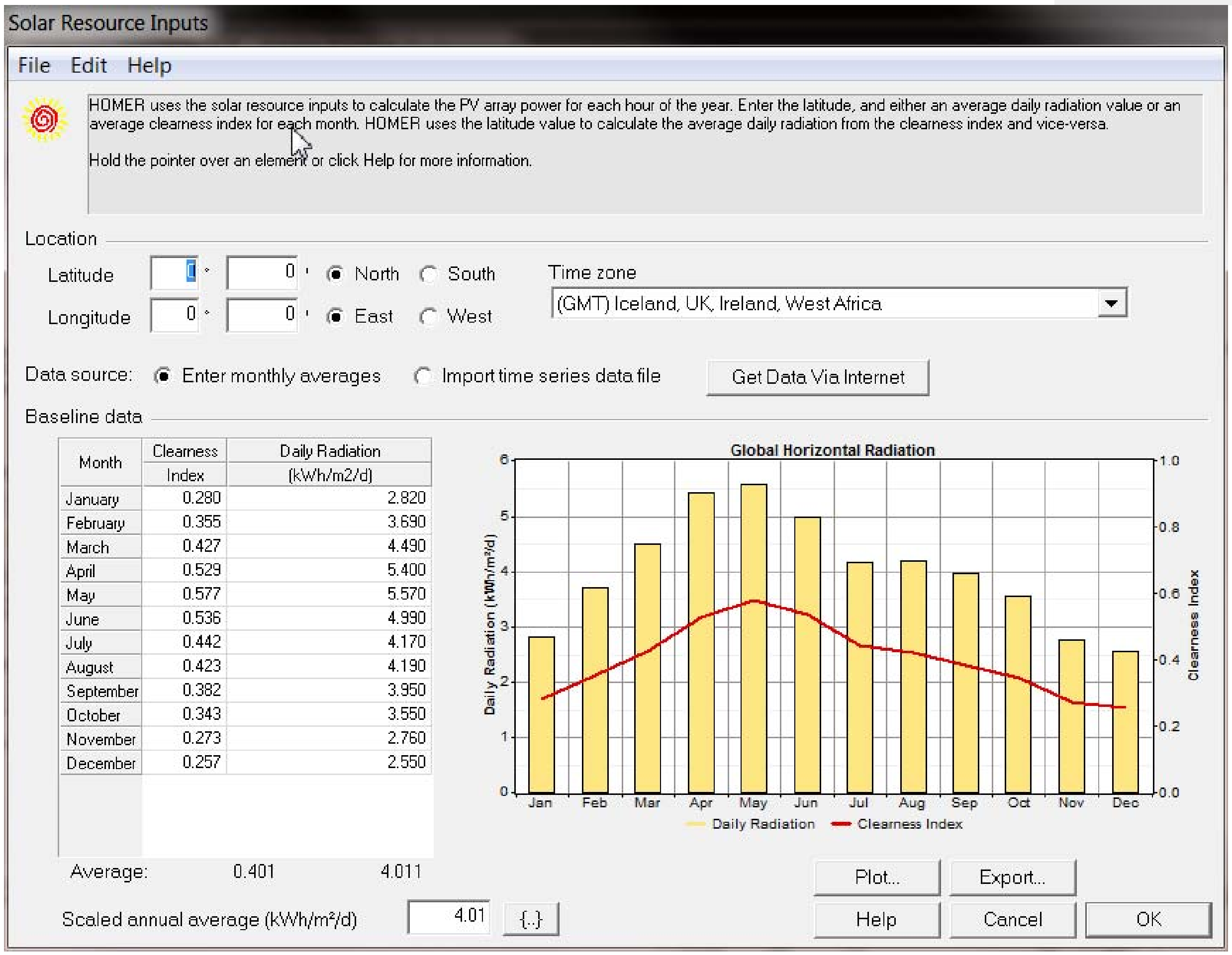
- Click “PV”
- Size: 2kW
- Capital: $7000
- Replacement: $7000
- O&M: $0/yr
- Sizes to consider: 0, 2kW, 4kW



Solar Resources Information

- Type in the solar radiation data obtained from SWERA

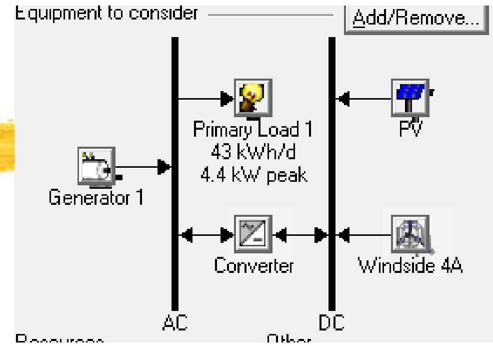


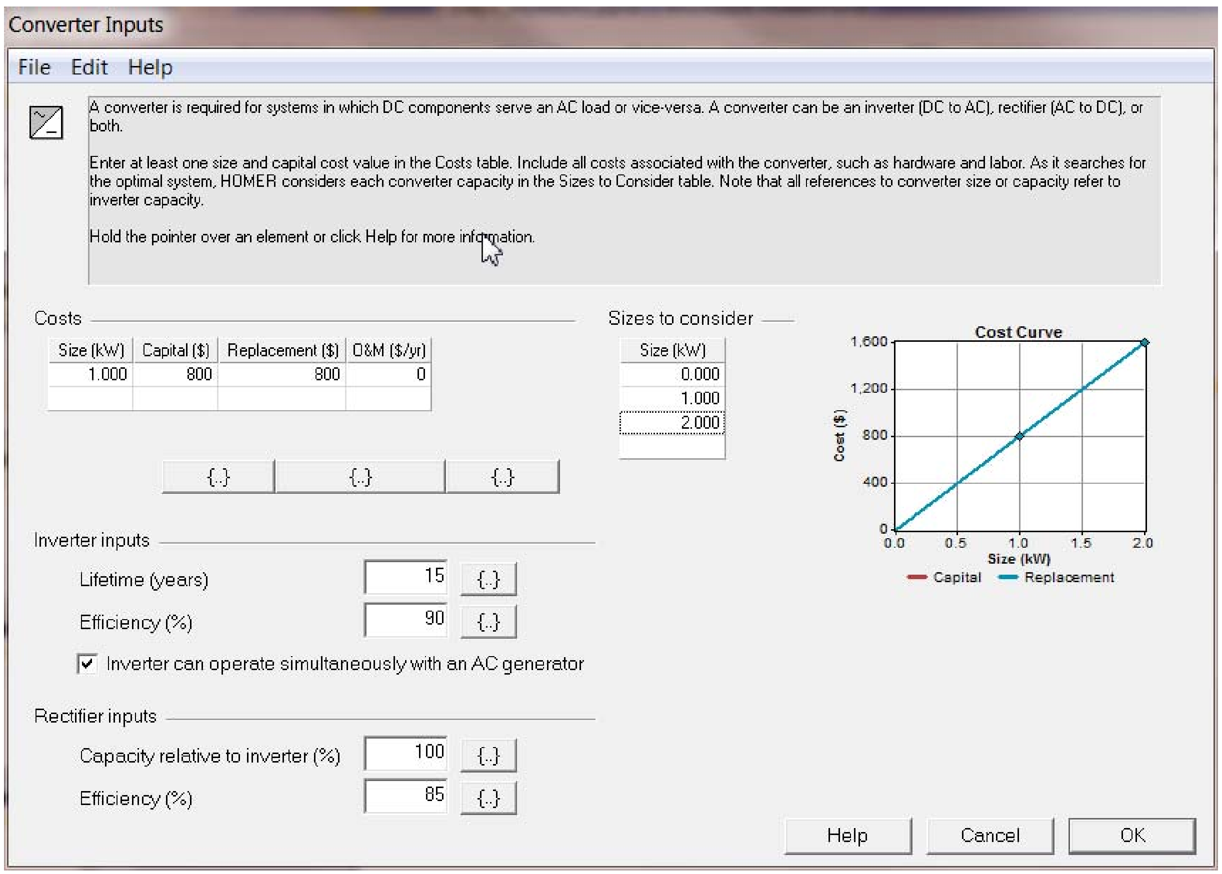


Month	Clearness Index	Daily Radiation (kWh/m2/d)
January	0.280	2.820
February	0.355	3.690
March	0.427	4.490
April	0.529	5.400
May	0.577	5.570
June	0.536	4.990
July	0.442	4.170
August	0.423	4.190
September	0.382	3.950
October	0.343	3.550
November	0.273	2.760
December	0.257	2.550

Converter Information

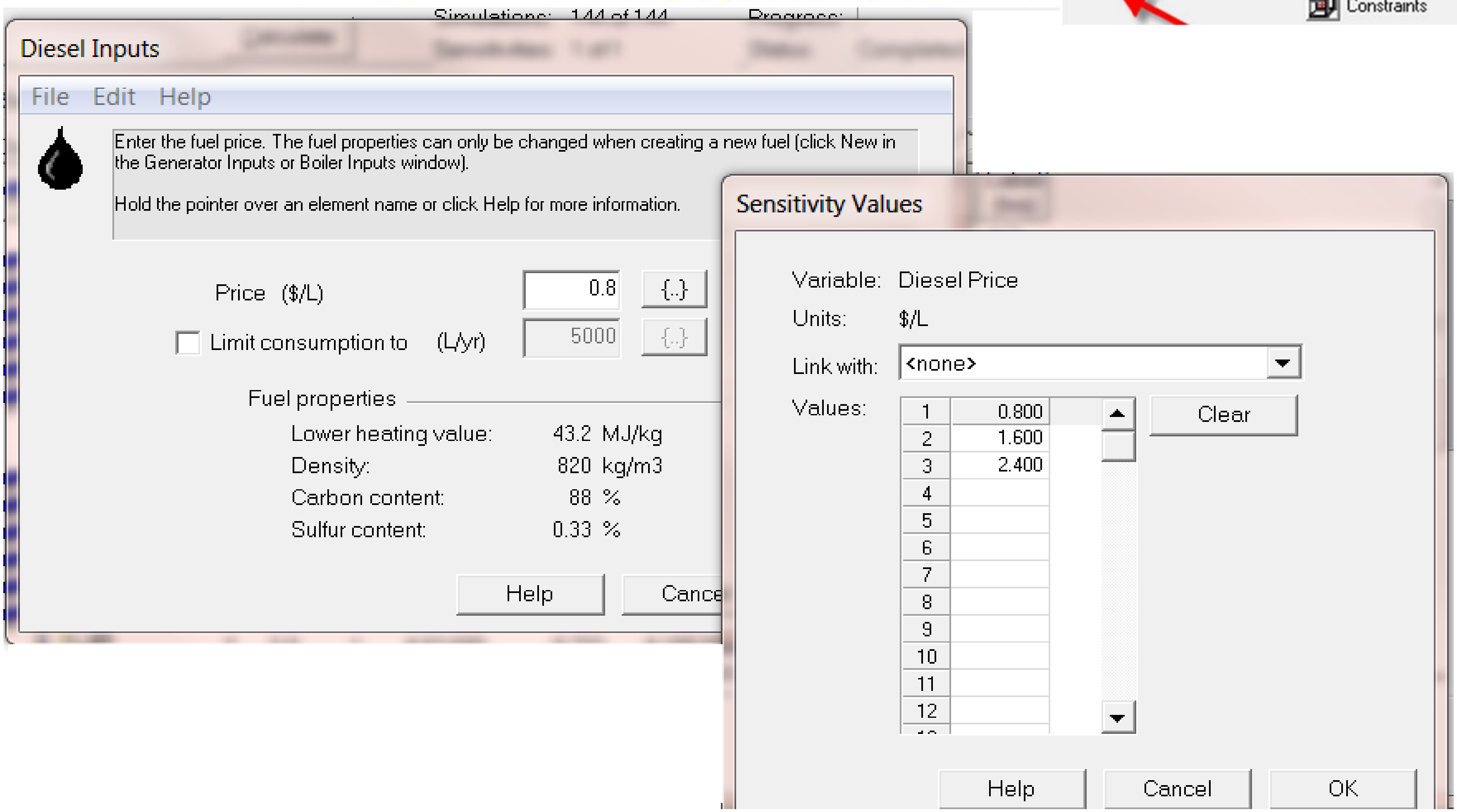
- Converter (DC→ AC)
- Size: 1kW
- Capital: $800
- O&M: $0
- Sizes to consider: 0, 1, 2 kW





Diesel Resources Information

- Fuel Price: \$0.8/L
- Sensitivity Price: \$0.8, 1.6, 2.4/L



Simulation

- ⌘ Optimization Result

Sensitivity Results | Optimization Results

Sensitivity variables

Diesel Price ($/L) 2.4

Double click on a system below for simulation results.

Categoriz · Ov

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

System Architecture: 2 kW PV; 5 kW Generator 1; 1 kW Inverter; 1 kW Rectifier

Total NPC: $ 253,996
Levelized COE: $ 1.254/kWh
Operating Cost: $ 19,040/yr

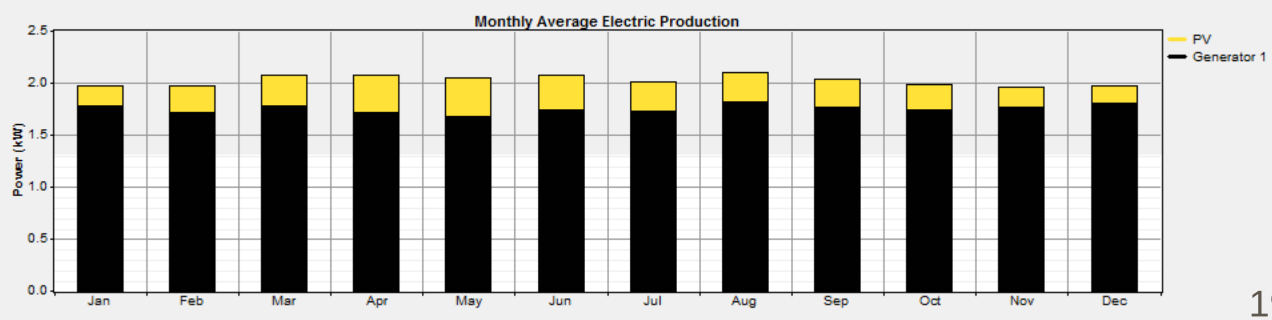
Cost Summary | Cash Flow | Electrical | PV | Label | Converter | Emissions | Hourly Data

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

Consumption	kWh/yr	%
AC primary load	15,841	100
Total	15,841	100

Quantity	kWh/yr	%
Excess electricity	1,737	9.79
Unmet electric load	0.0000340	0.00
Capacity shortage	0.00	0.00

Quantity	Value
Renewable fraction	0.132



XML Report | HTML Report | Help | Close

Sensitivity Analysis

Tabular Graphic

Export... Details...

Double click on a system below for optimization results

Diesel ($/L)	PV	Wind	Gen	Conv	PV (kW)	WS-...	Label (kW)	Conv. (kW)	Initial Capital	Operating Cost ($/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...

Tabular Graphic

Graph type: Spider graph

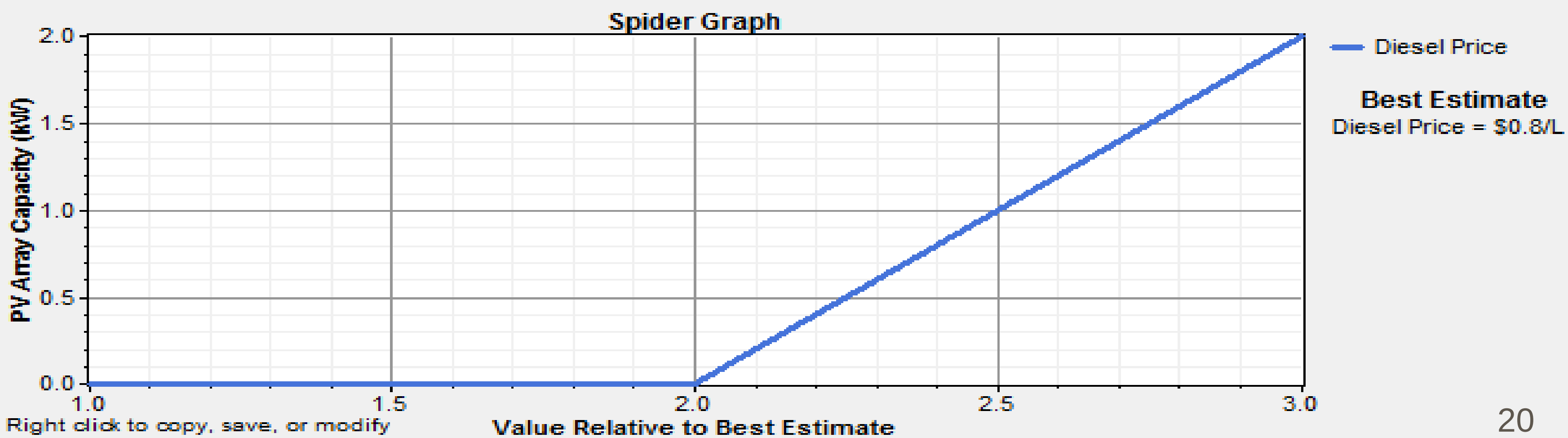
Sensitivity variables

Diesel Price ($/L): 0.8

Variables to plot

Primary: PV Array Capacity

New Window...



Right click to copy, save, or modify

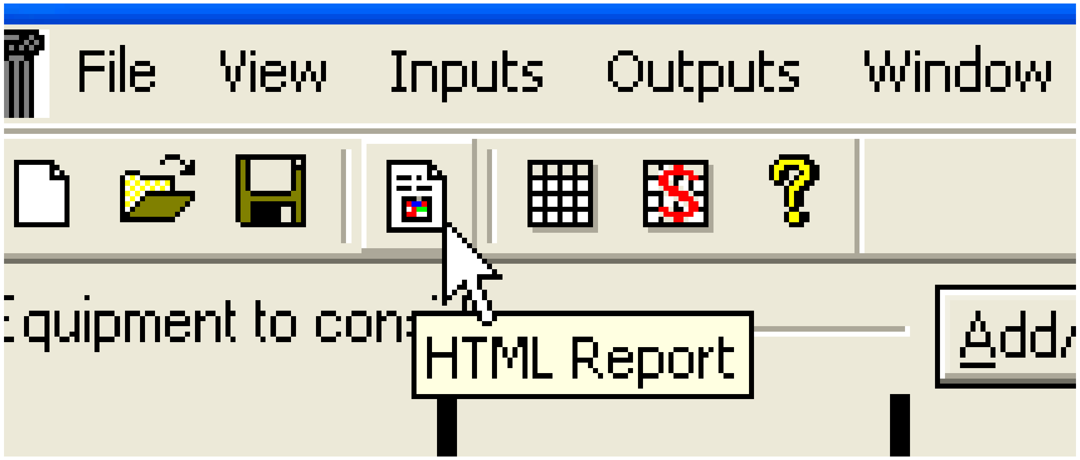
HOMER – Example Equipment Cost

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

Component	Size	Capital Cost($)	Replacement Cost	O&M Cost ($)	Lifetime
PV Panels	0.05 – 0.4 kW	$7,500/kW	$7,500kW	0.00	20 years
Vision6 FM200D Battery	200 Ah / 12 volt (bank size: 1-8 batteries)	$175/battery	$175/battery	$2.00/year	917 kWh of throughput per battery
FDseries Wind Turbine	0.4 kW DC	$2,500/kW	$2,500/kW	$10/year	15 years
Converter	0.1 – 1.5 kW	$200/kW	$200/kW	$20/year	15 years

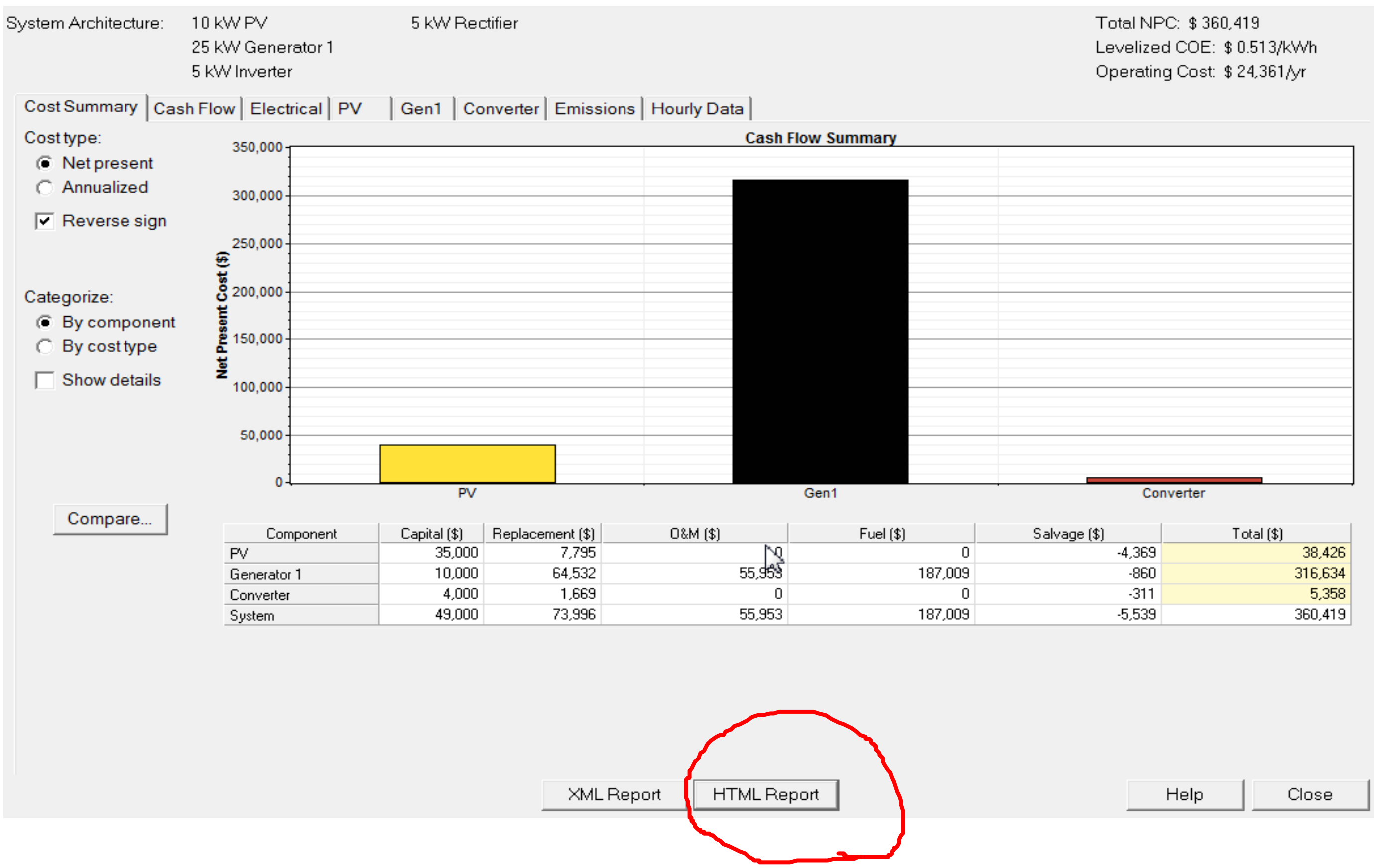
HOMER – Input Summary Report

- 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.



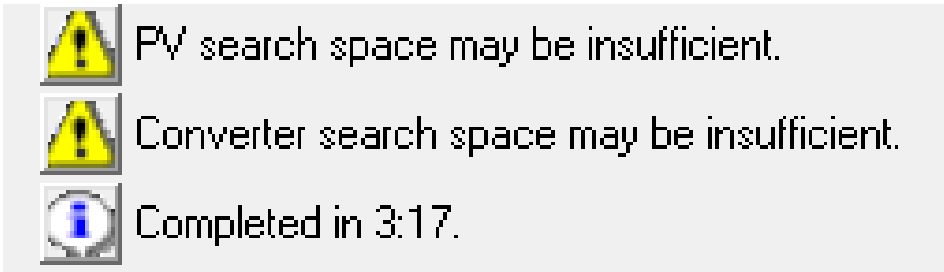
HOMER – Simulation Result Report

- HOMER Produces A Report Summarizing The Simulation Results
  - Just click the HTML Report button in the Simulation Results window:



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	35,000	7,795	0	0	-4,369	38,426
Generator 1	10,000	64,532	55,953	187,009	-860	316,634
Converter	4,000	1,669	0	0	-311	5,358
System	49,000	73,996	55,953	187,009	-5,539	360,419

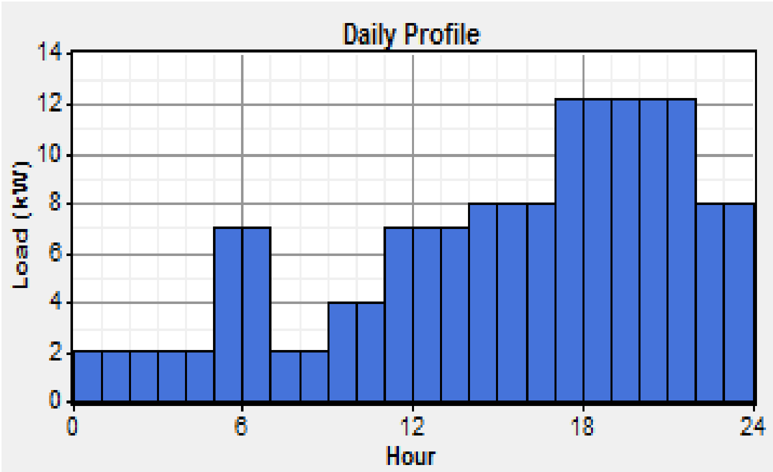
What is this message for?



- 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

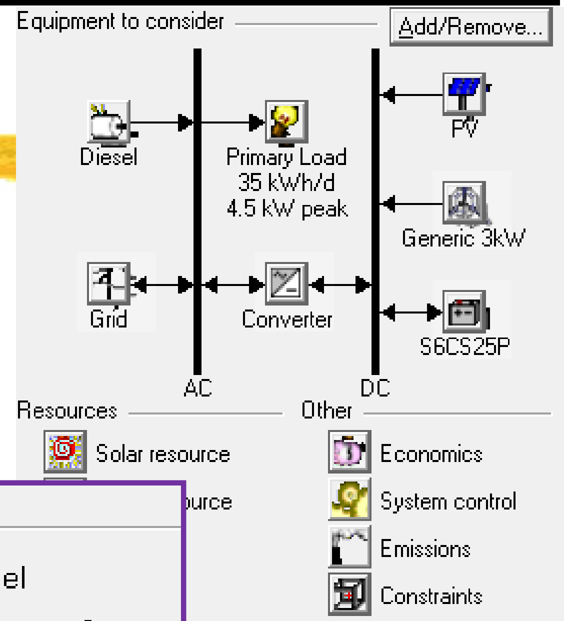


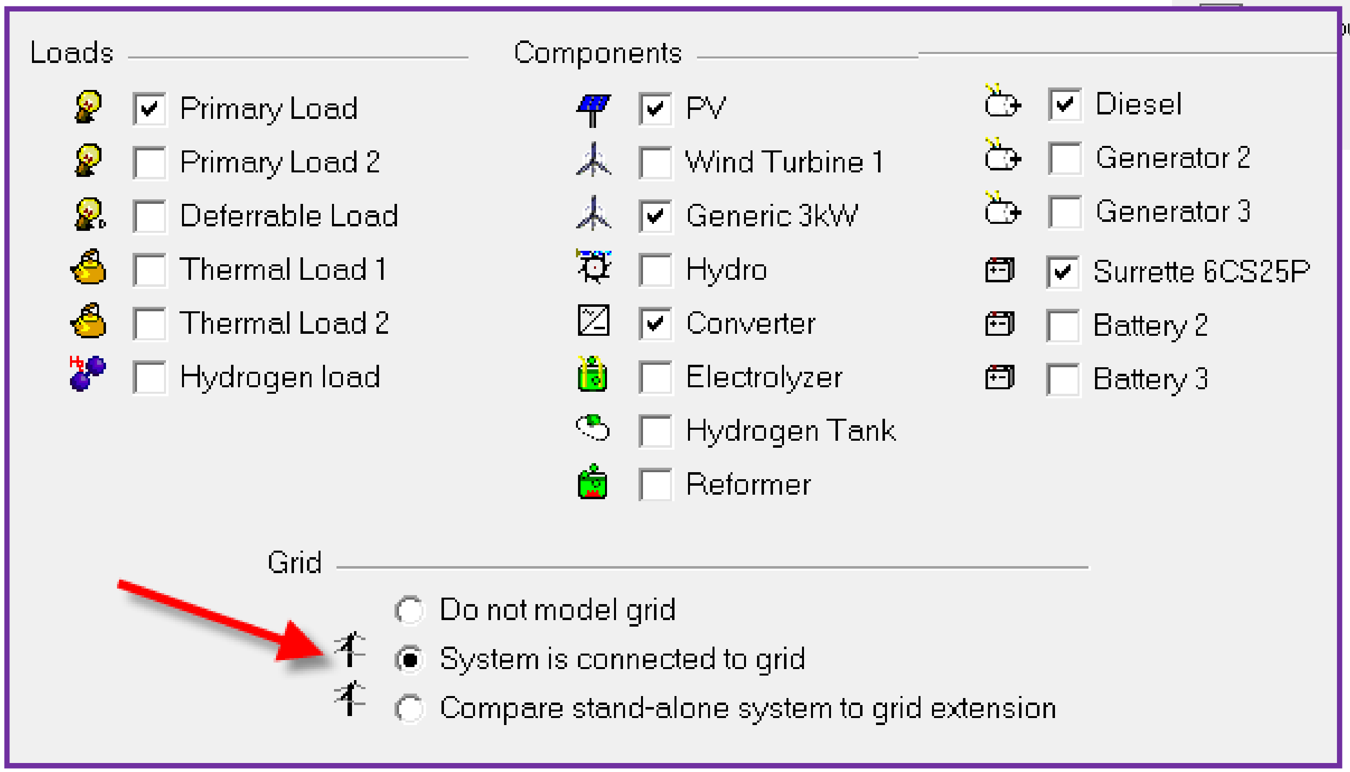
Components and Constraints

- 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”





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 37 ° 0 ' (•) North ( ) South

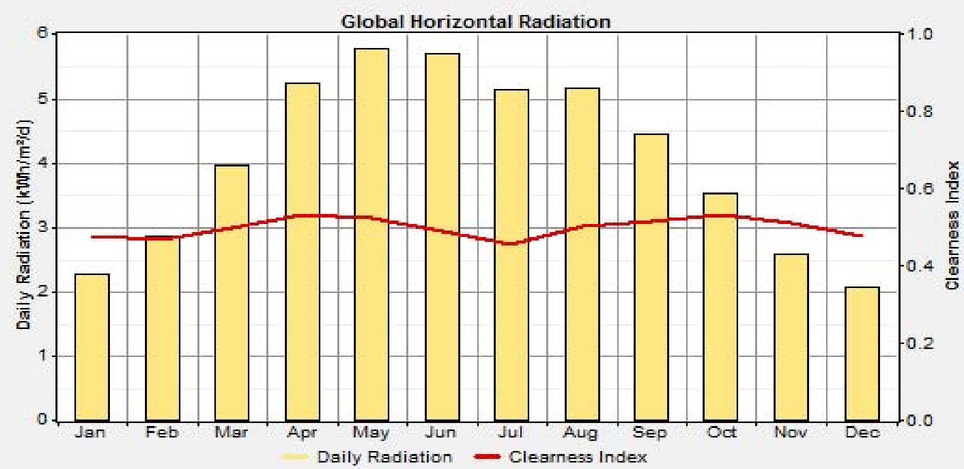
Longitude 127 ° 0 ' (•) East ( ) West

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

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

Baseline data

Month	Clearness Index	Daily Radiation (kWh/m2/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

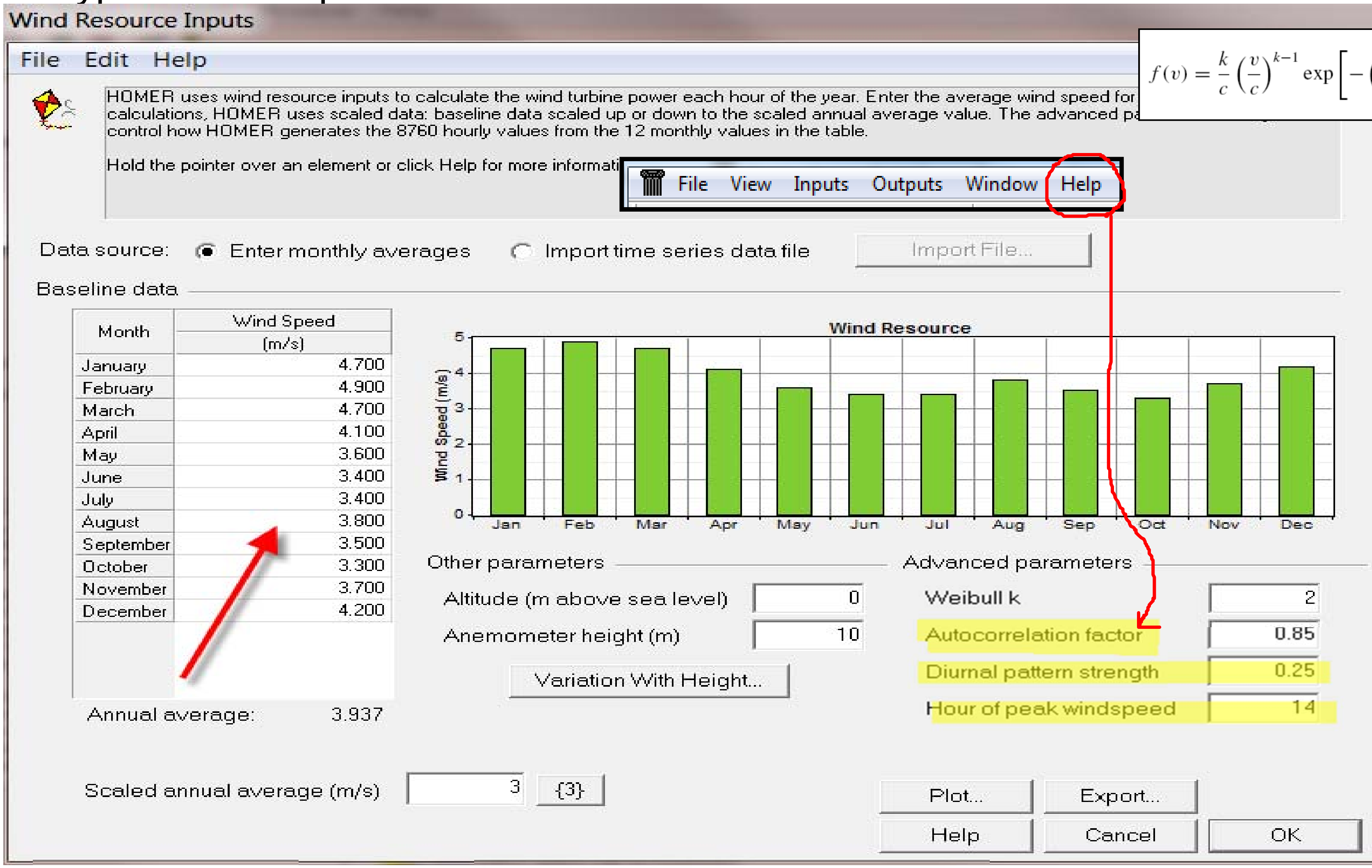


Scaled annual average (kWh/m²/d) 4.06 {..}

Plot... Export... Help Cancel OK

Wind Resources

⌘ Type in Wind Speed Data

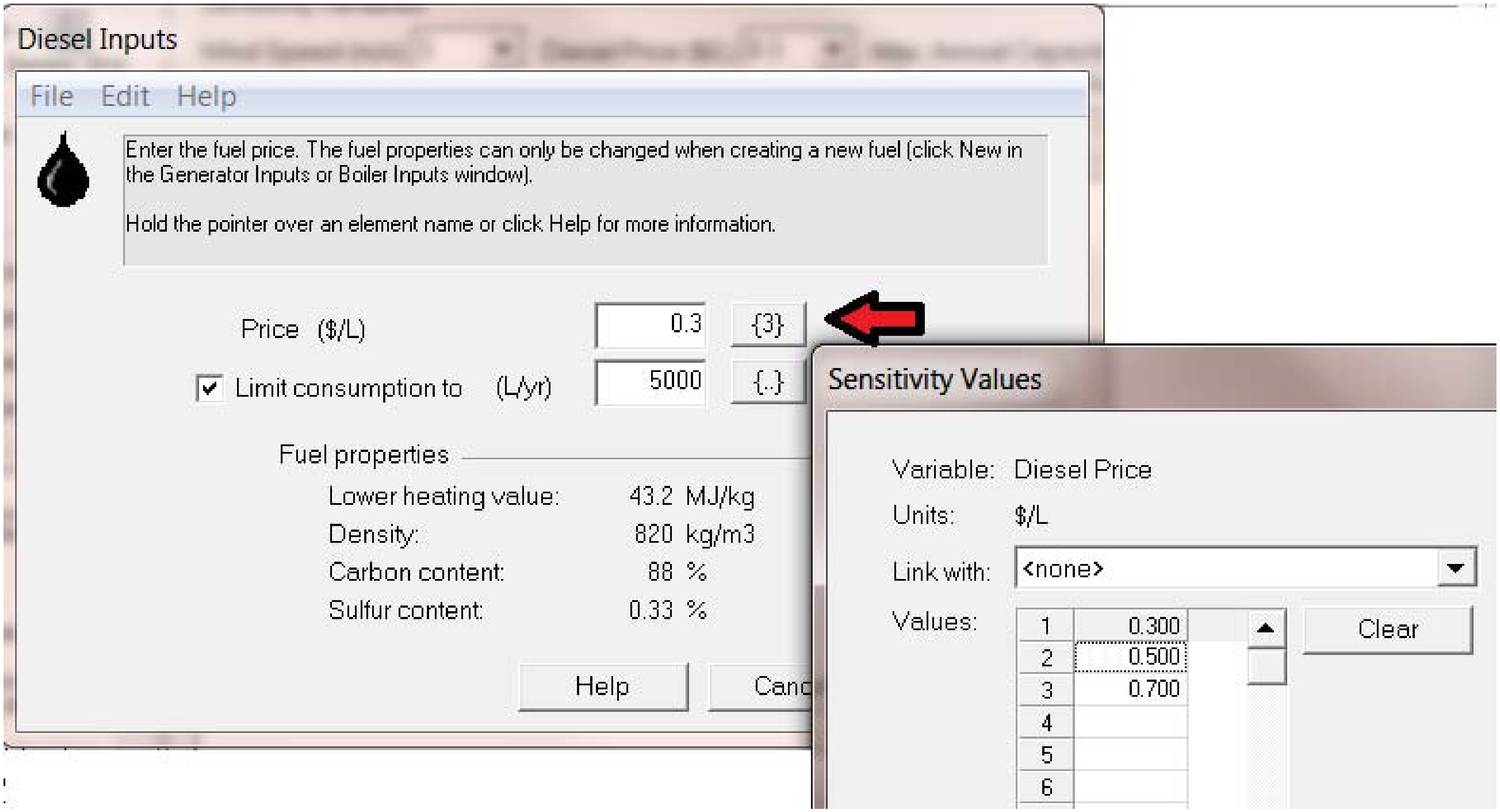


$$f(v) = \frac{k}{c}\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right]$$

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.

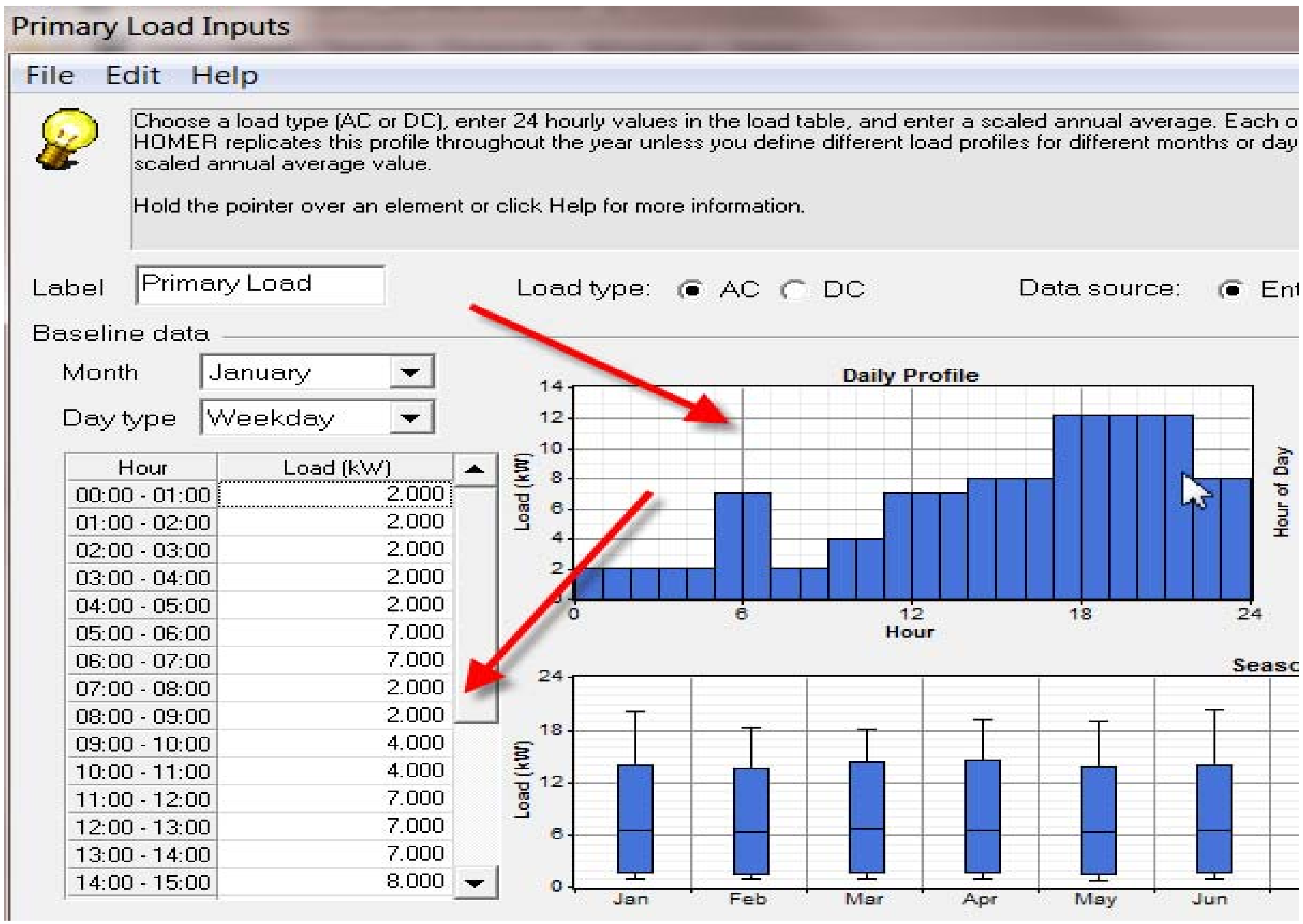
Diesel Resources

- $0.5/L
- Sensitivity: [$0.3, 0.5, 0.7]/L



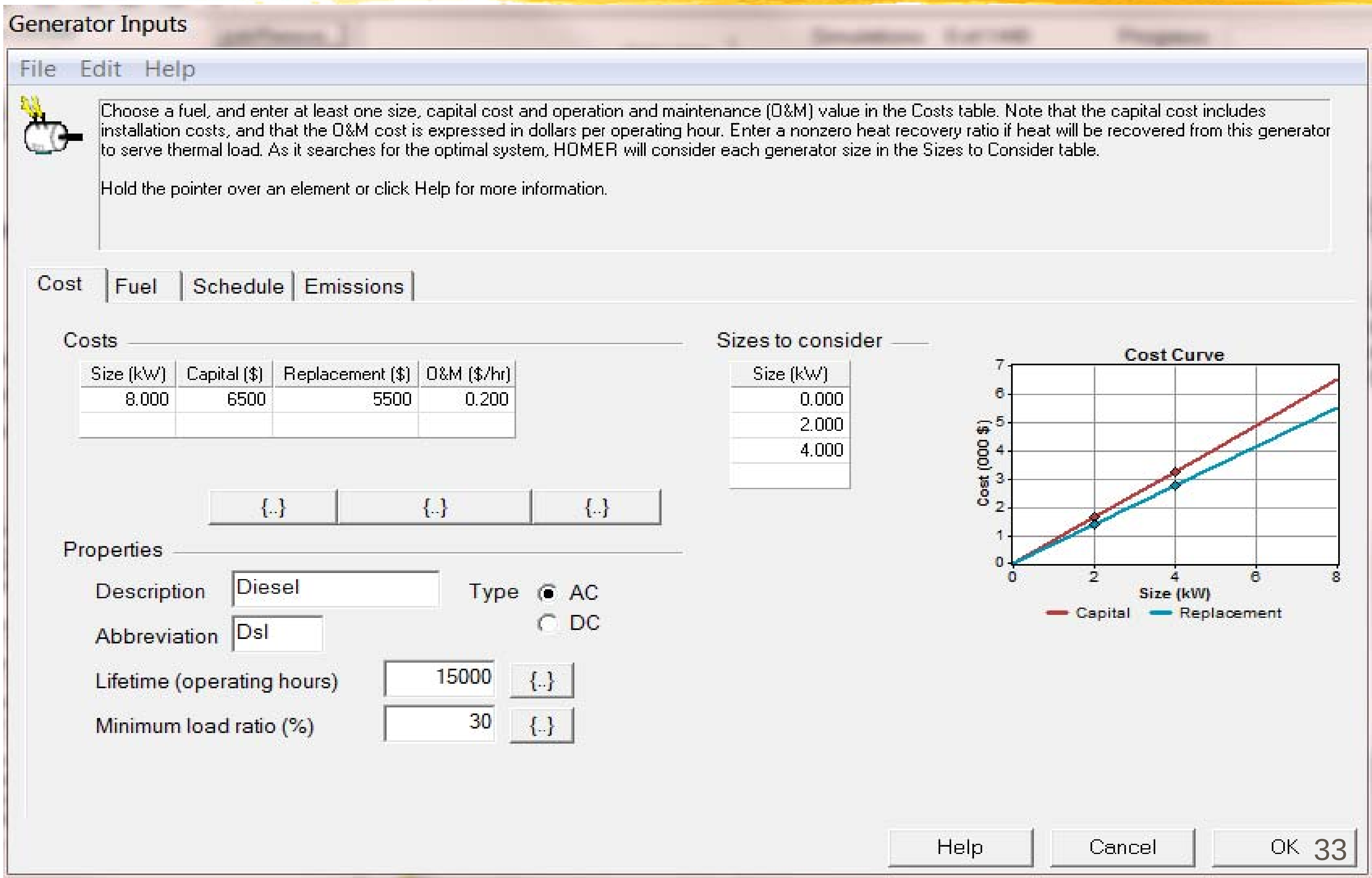
Component: Load Input

- 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

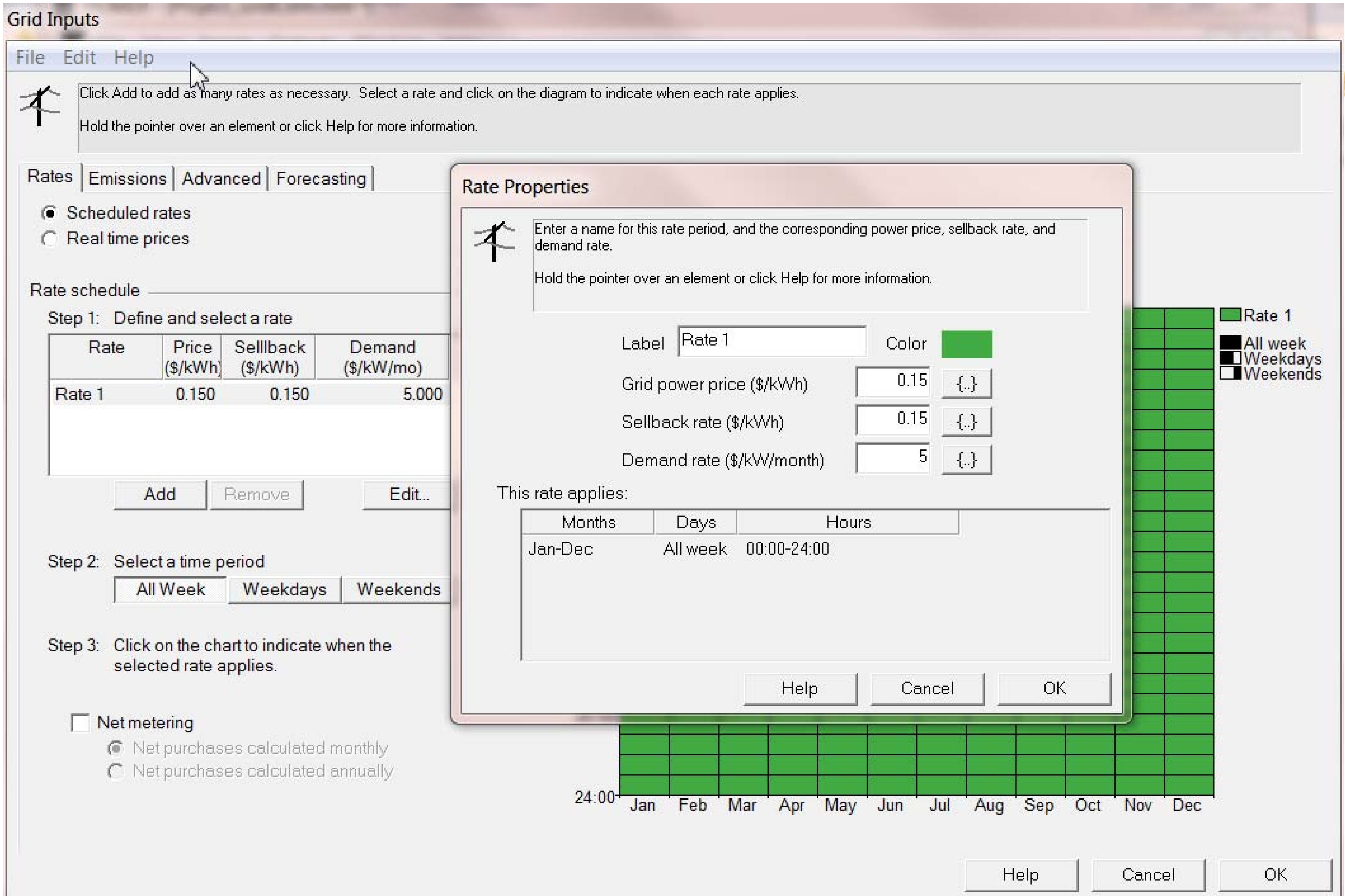


Component: Diesel Input

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

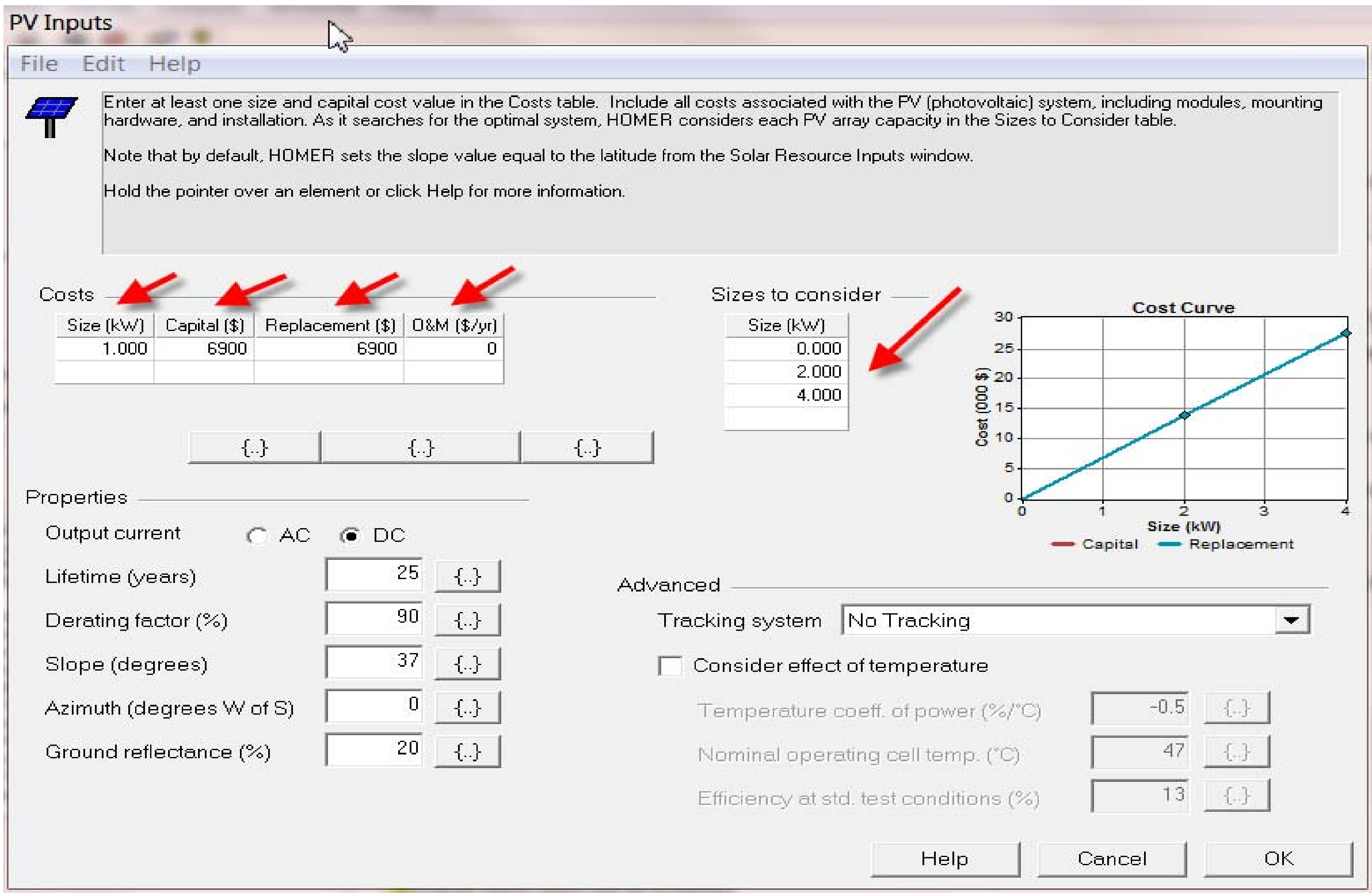


Component: Grid Input



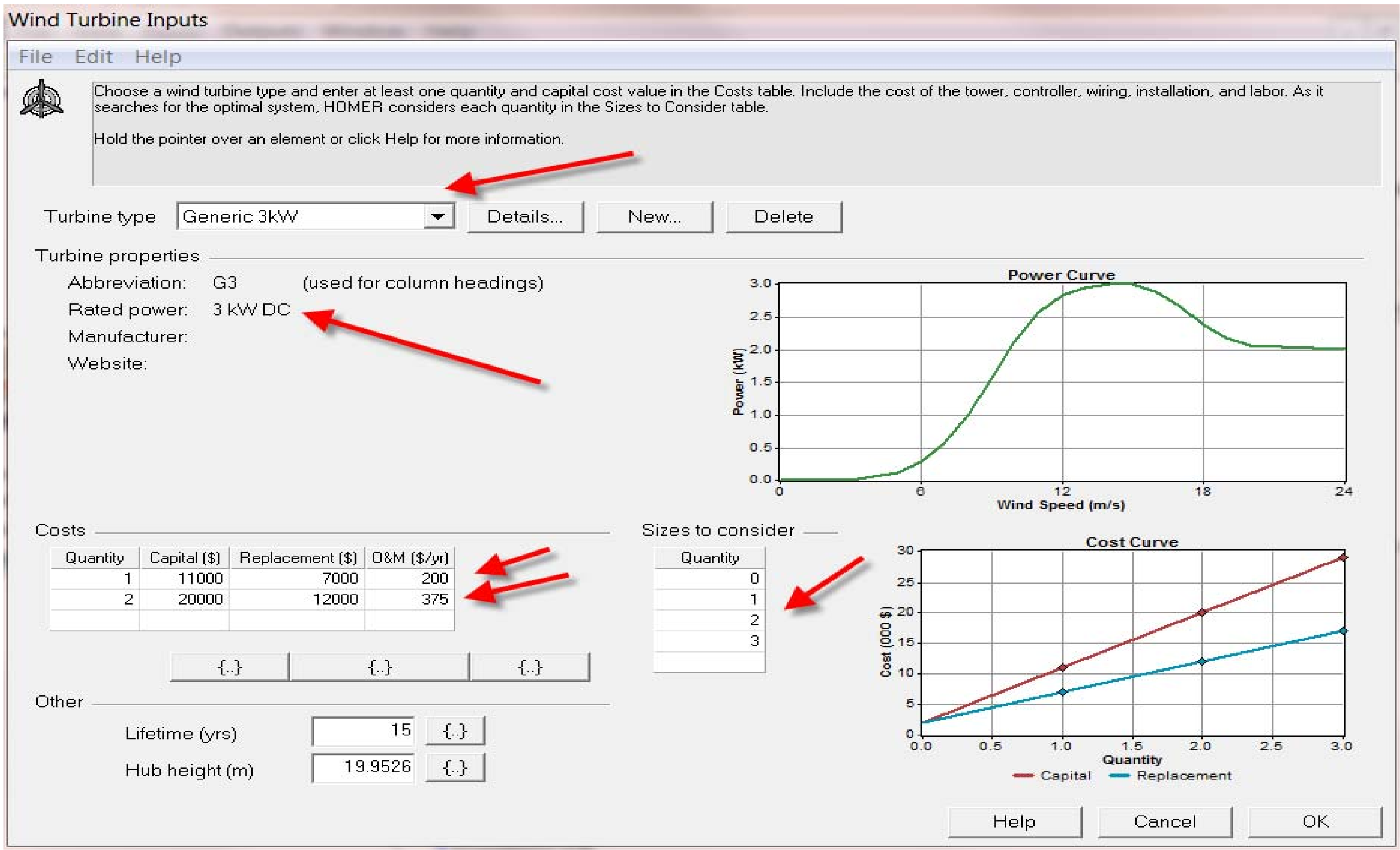
Component: PV Input

- 1kW, $6900, $6900, $0/yr
- [0, 2, 4] kW for sensitivity analysis



Component: Wind Turbine Input

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



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

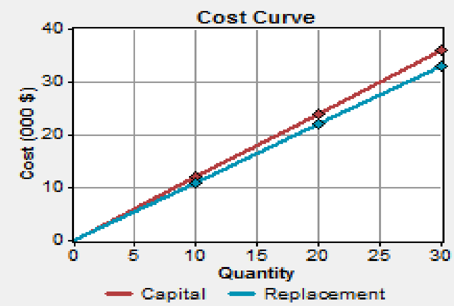
Costs

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

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

Sizes to consider

Batteries
0
10
20
30



Advanced

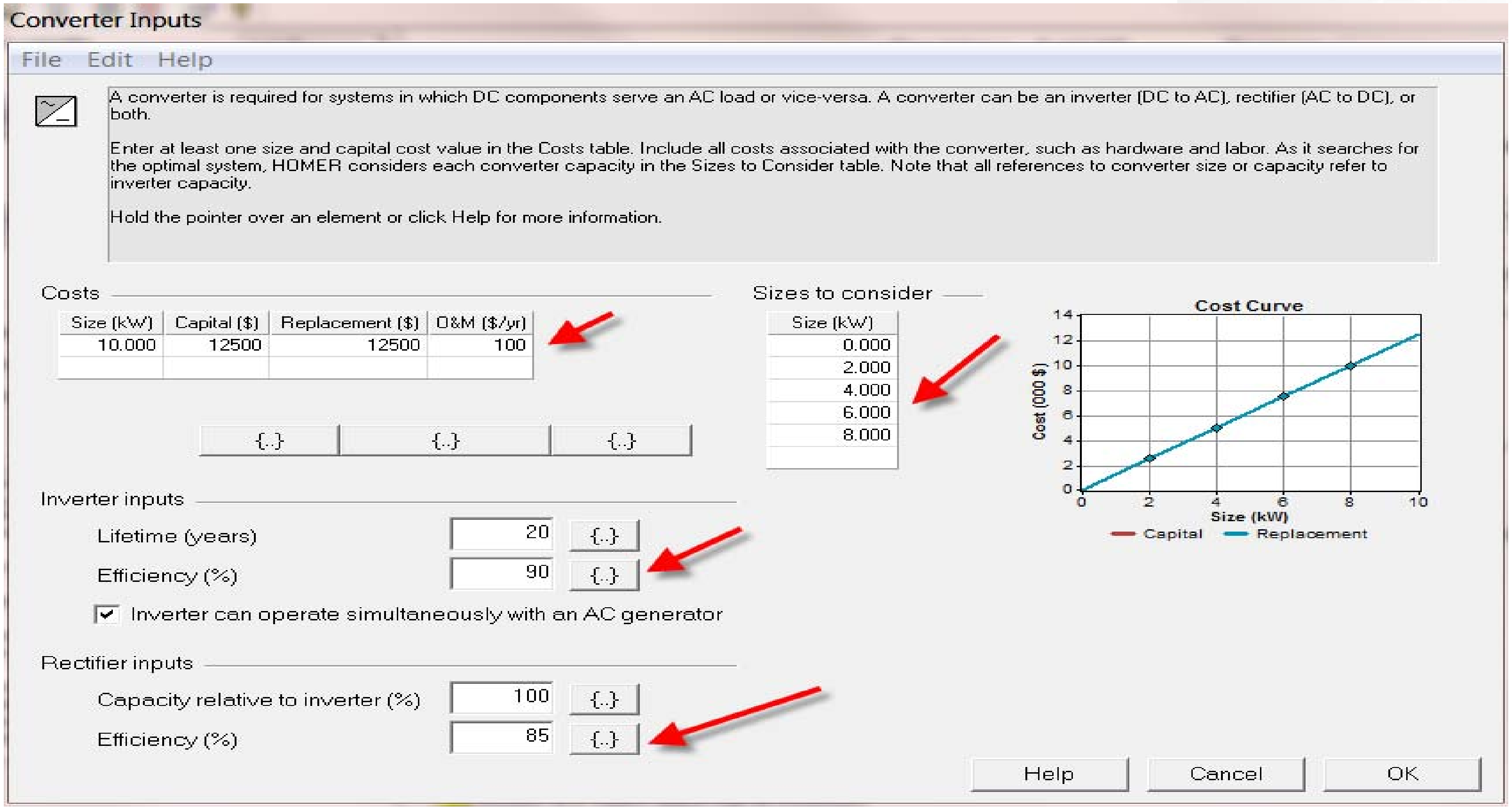
Batteries per string: 1 (6 V bus)

Minimum battery life (yr): 4 {..}

Help | Cancel | OK

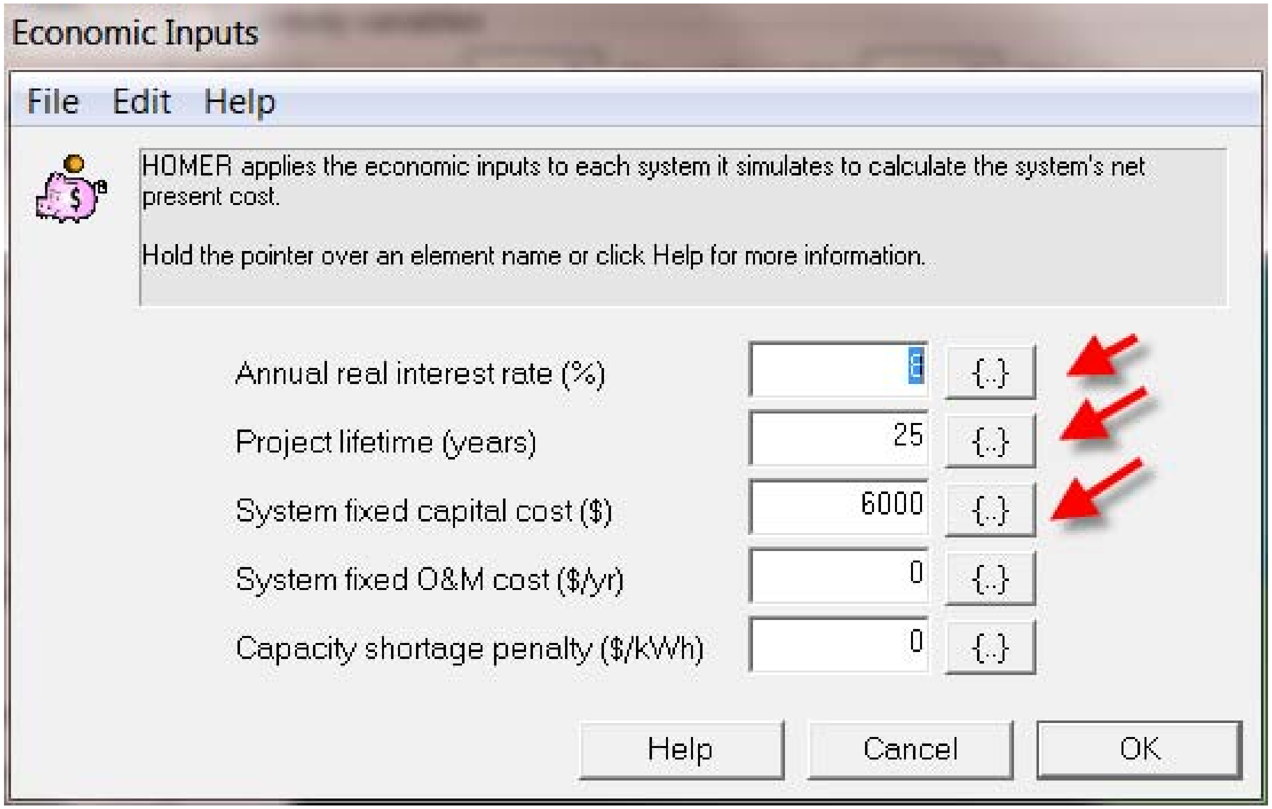
Component: Converter Input

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



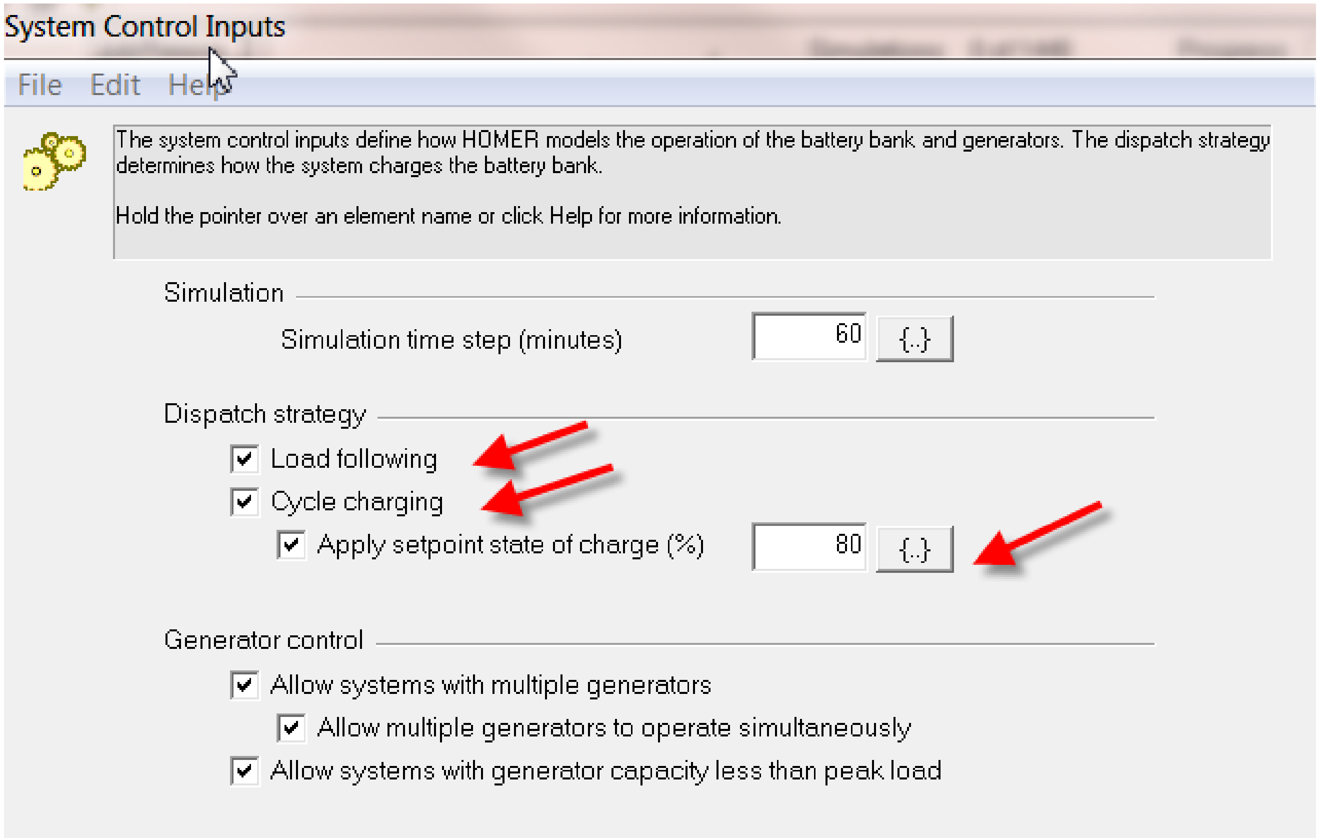
Other: Economics

- 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.



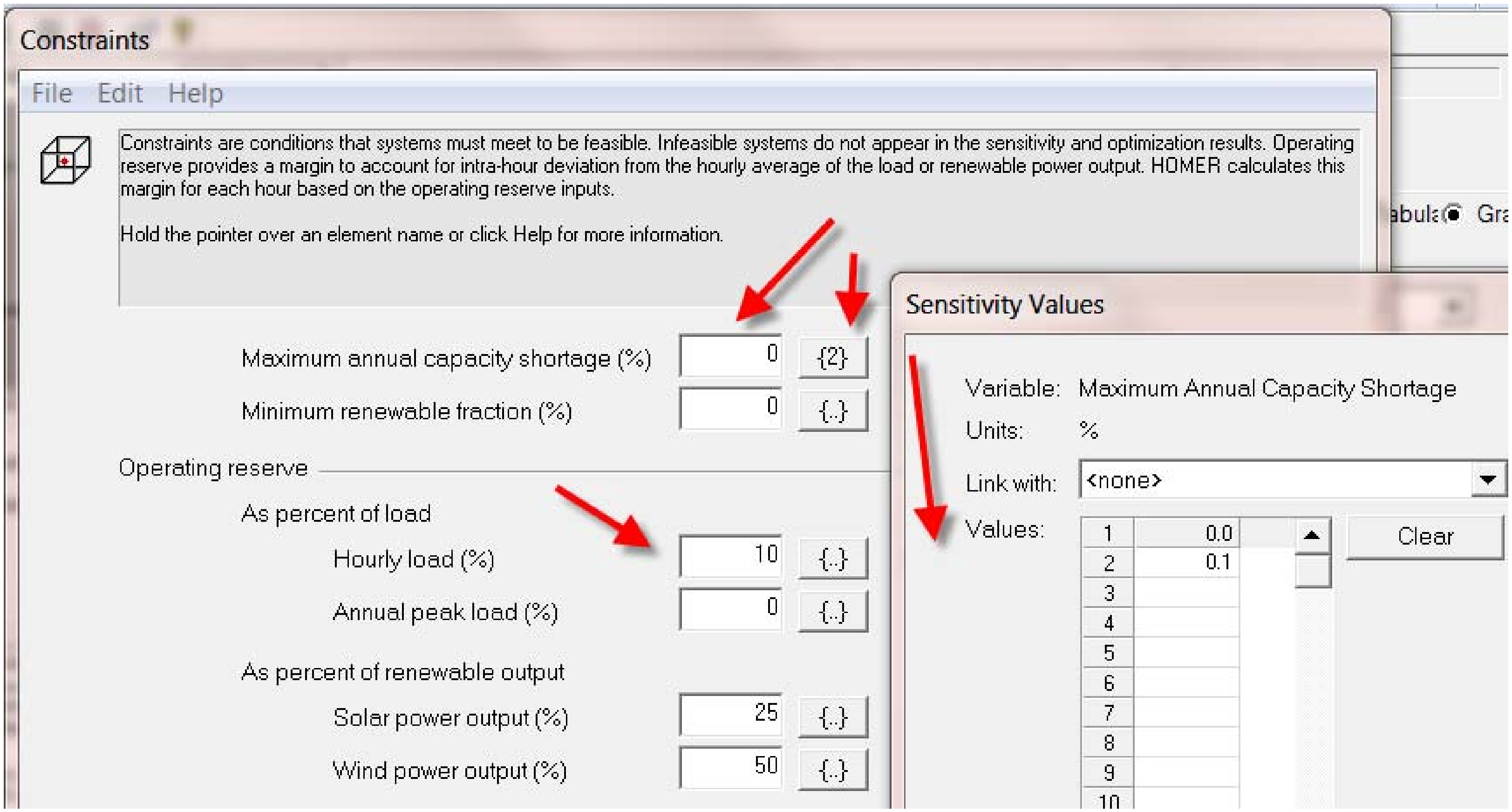
Other: System Control

- Simulation Time Step: 1 hr (60 min)
- Dispatch Strategies:
  - load following
  - cycle charging
    - Charge state set point: 80%



Other: Constraints Input

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



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 | Overal | 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 | Overal | 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

Simulation Results

System Architecture: 1 kW Grid, 2 kW Diesel, 10 Surrette 6CS25P, 2 kW Inverter, 2 kW Rectifier, Cycle Charging

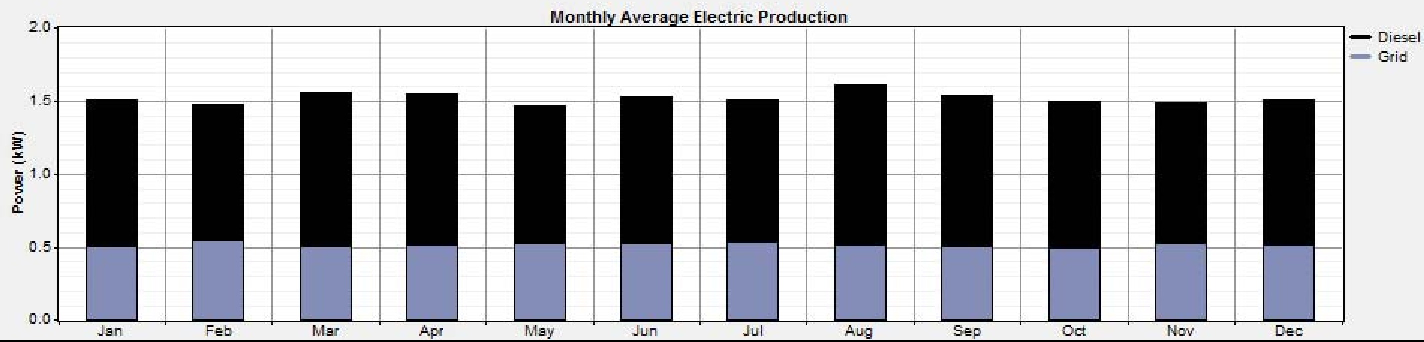
Total NPC: $ 55,776
Levelized COE: $ 0.409/kWh
Operating Cost: $ 3,152/yr

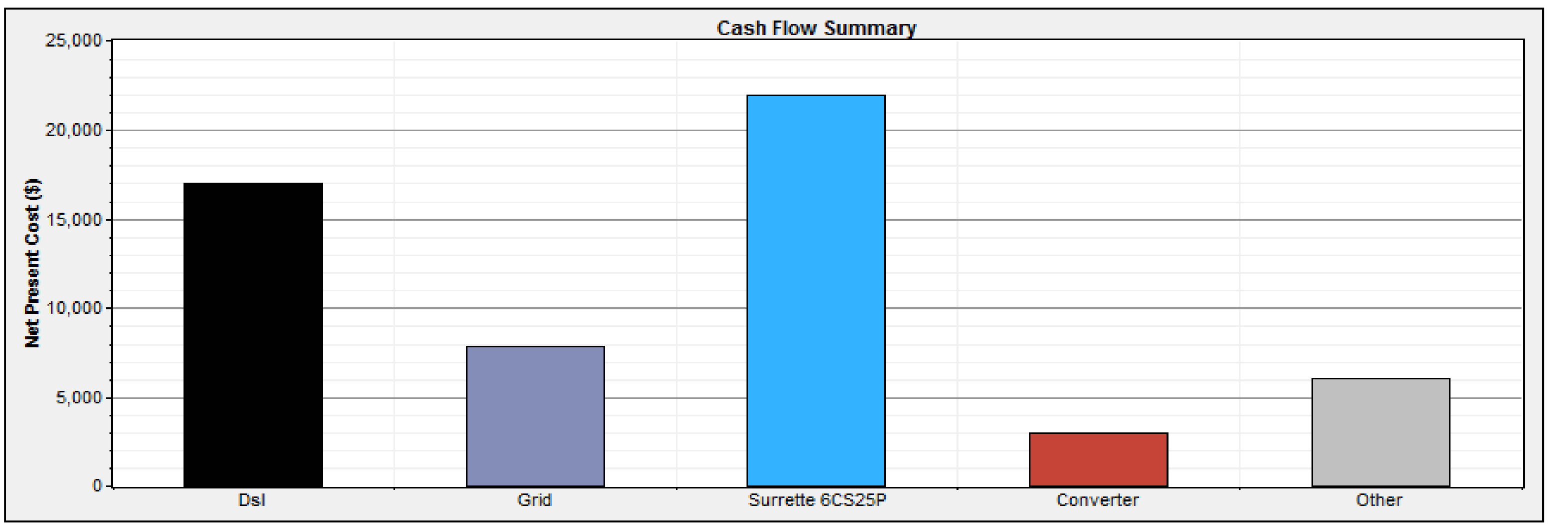
Cost Summary | Cash Flow | Electrical | Dsl | Battery | Converter | Grid | Emissions | Hourly Data

Production	kWh/yr	%
Diesel	8,800	66
Grid purchases	4,510	34
Total	13,310	100

Consumption	kWh/yr	%
AC primary load	12,775	100
Grid sales	14	0
Total	12,789	100

Quantity	kWh/yr	%
Excess electricity	0.0000127	0.00
Unmet electric load	0.00	0.00
Capacity shortage	0.00	0.00



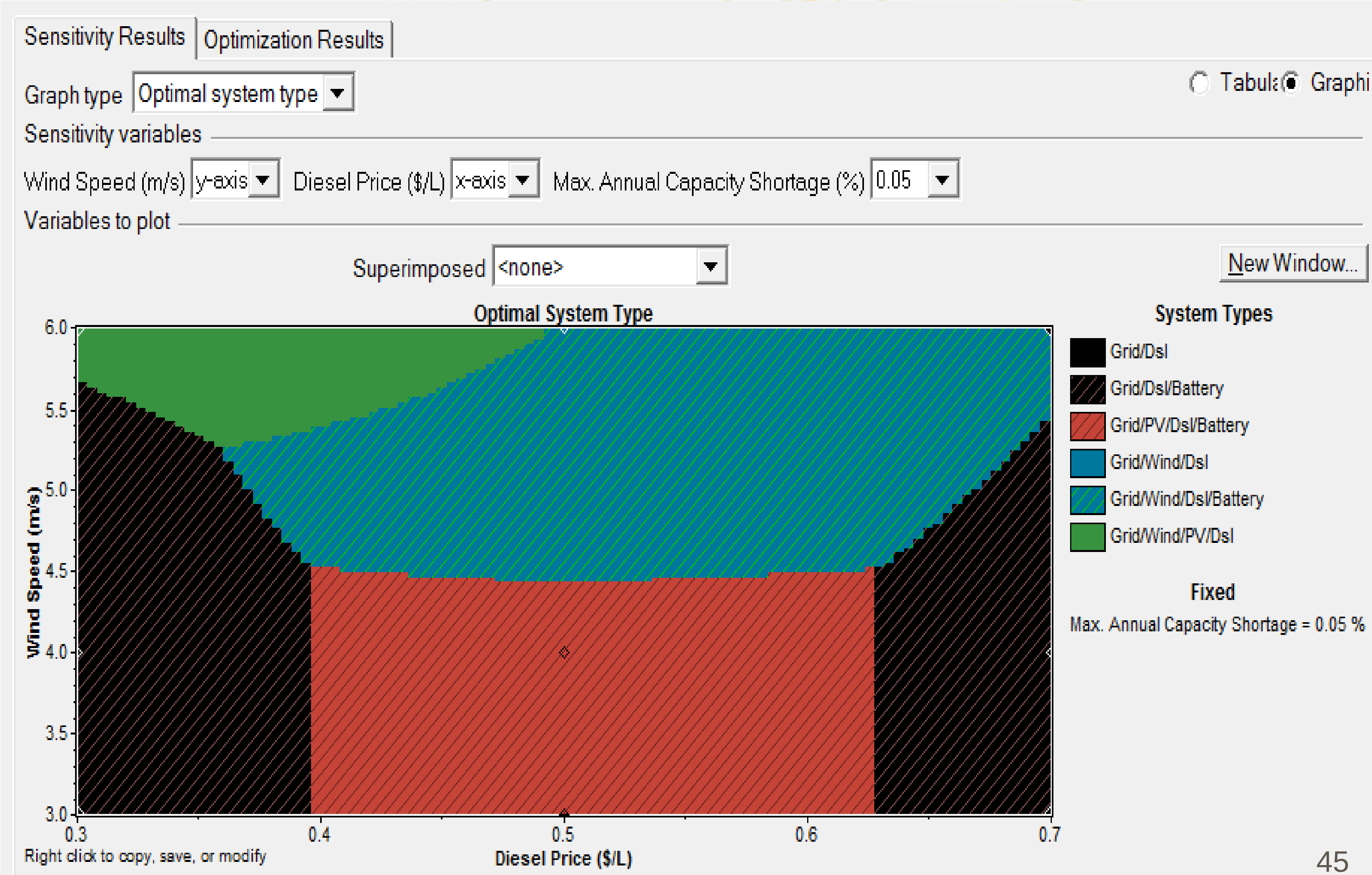


Sensitivity Analysis

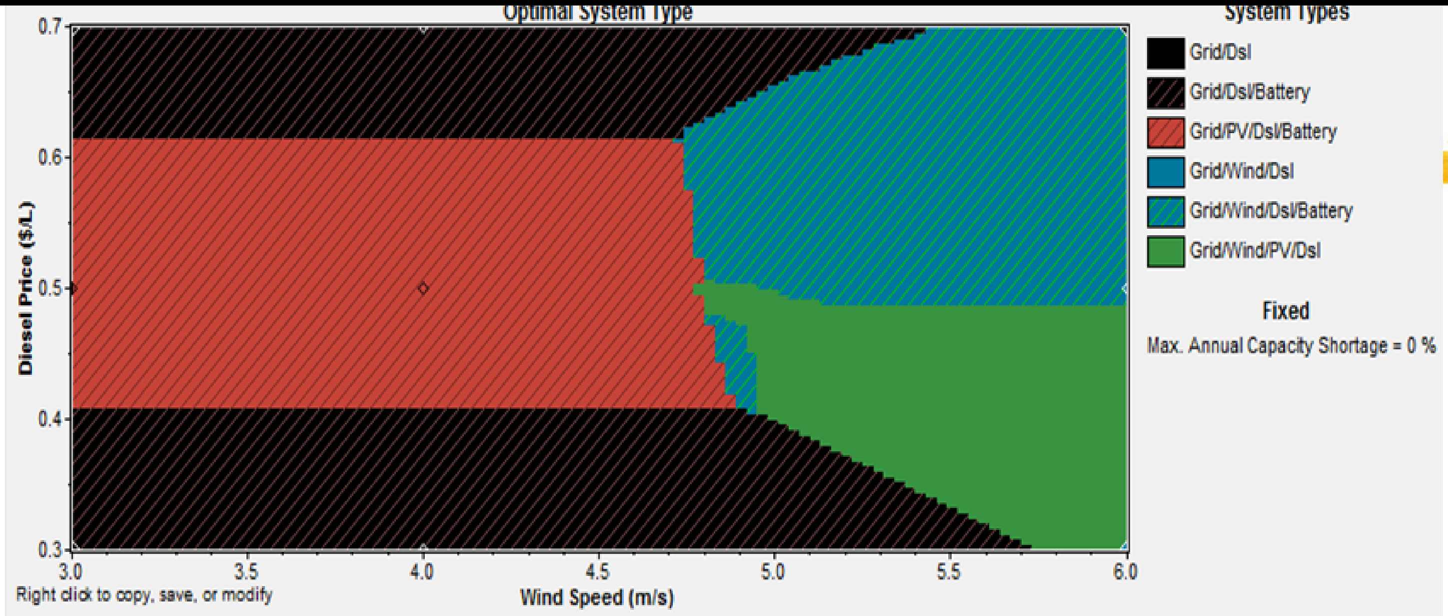
⌘ Wind Speed (x) vs. Diesel Price with 0% capacity shortage

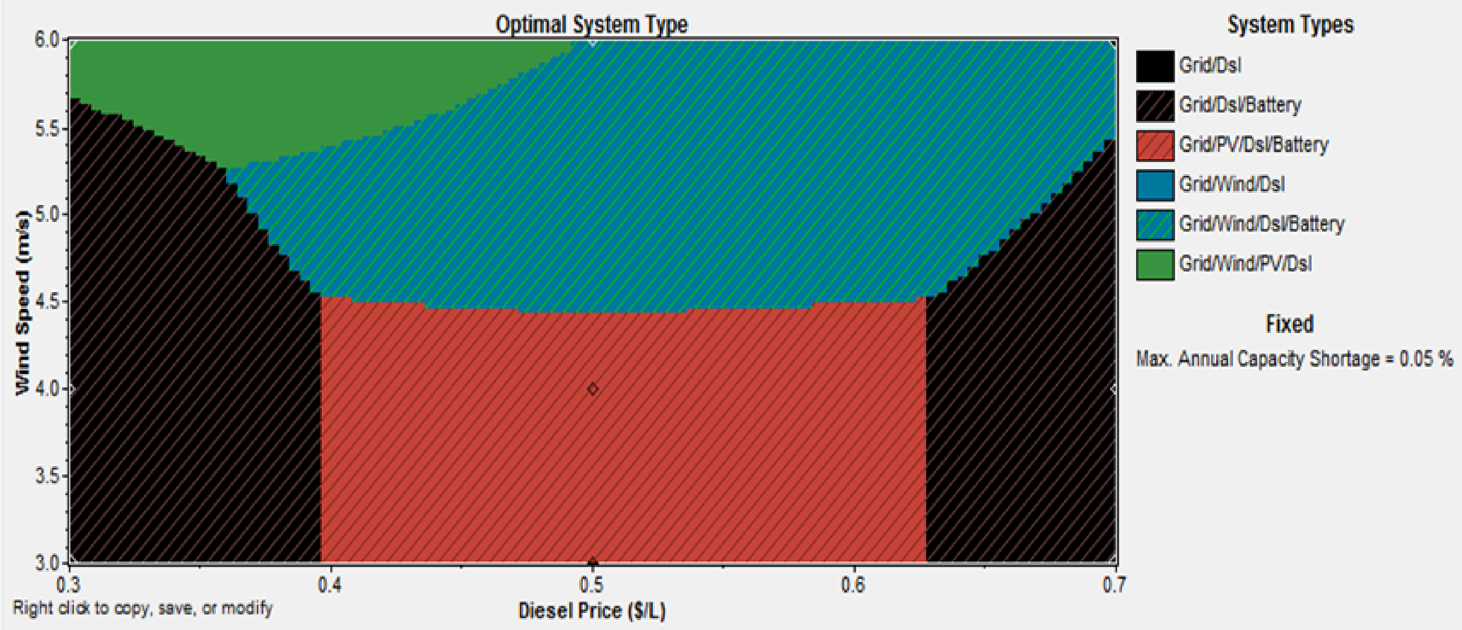
Sensitivity Analysis

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



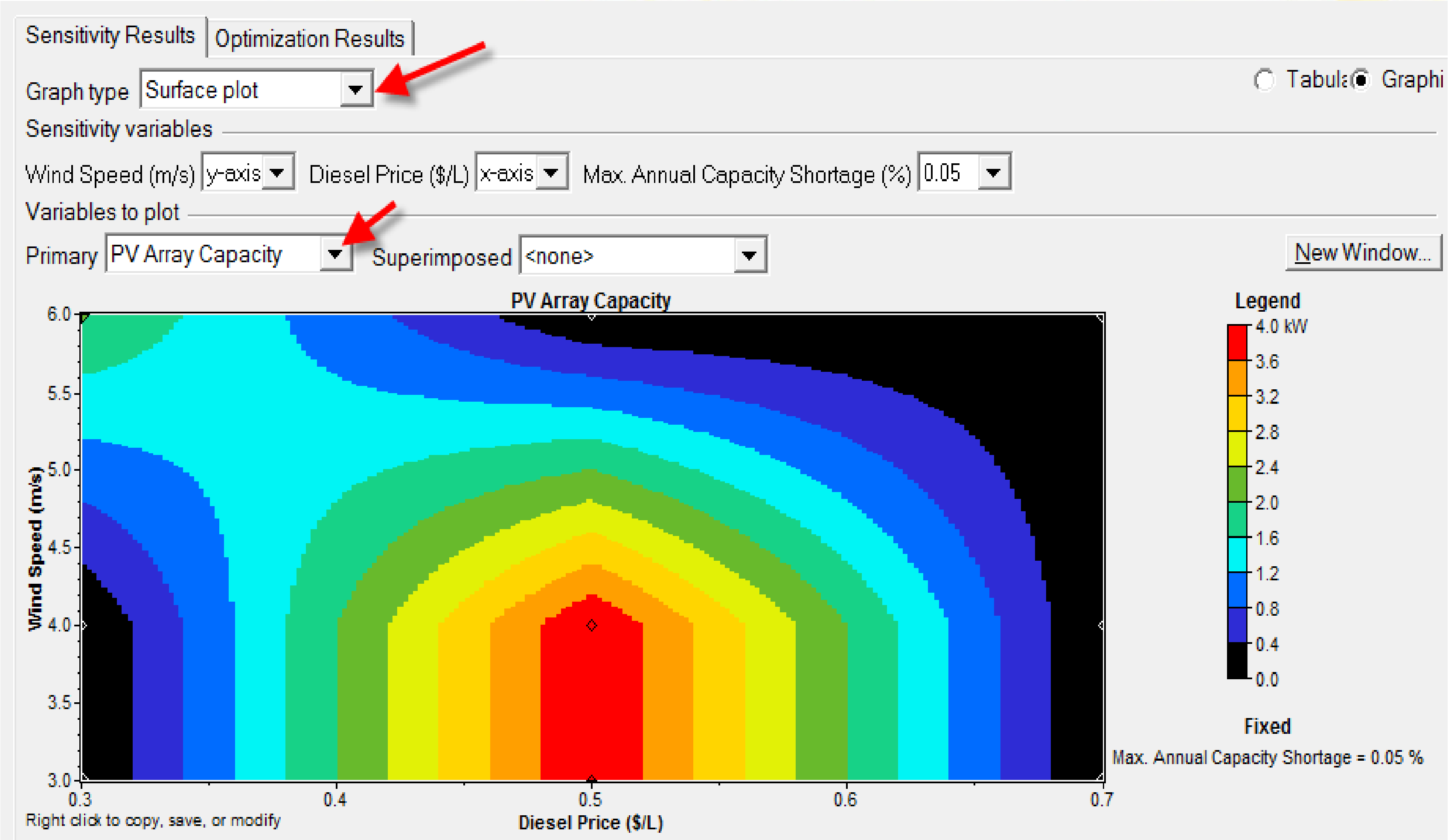
Capacity Shortage Impact





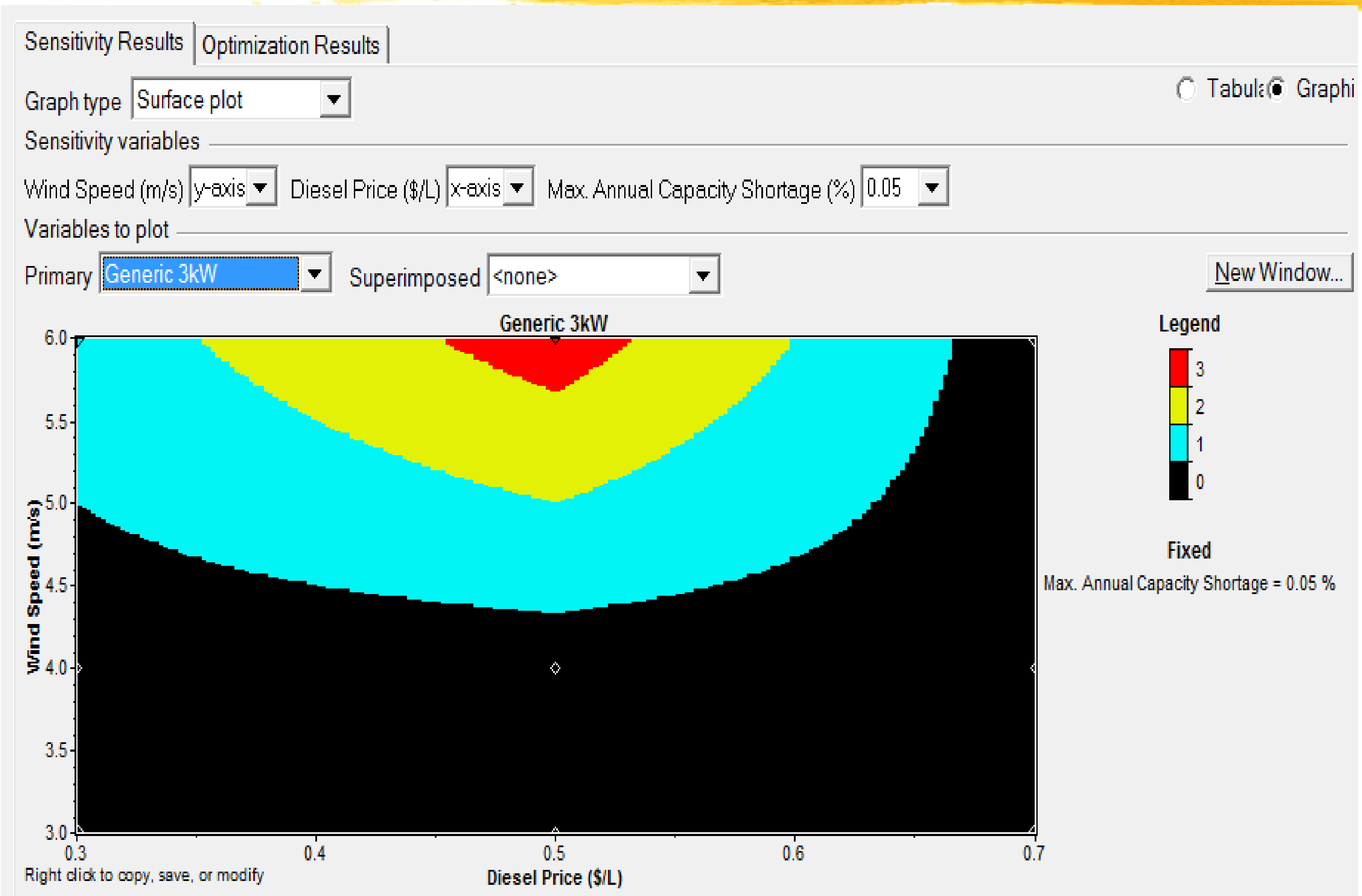
Surface Plot View

⌘ PV Array Capacity



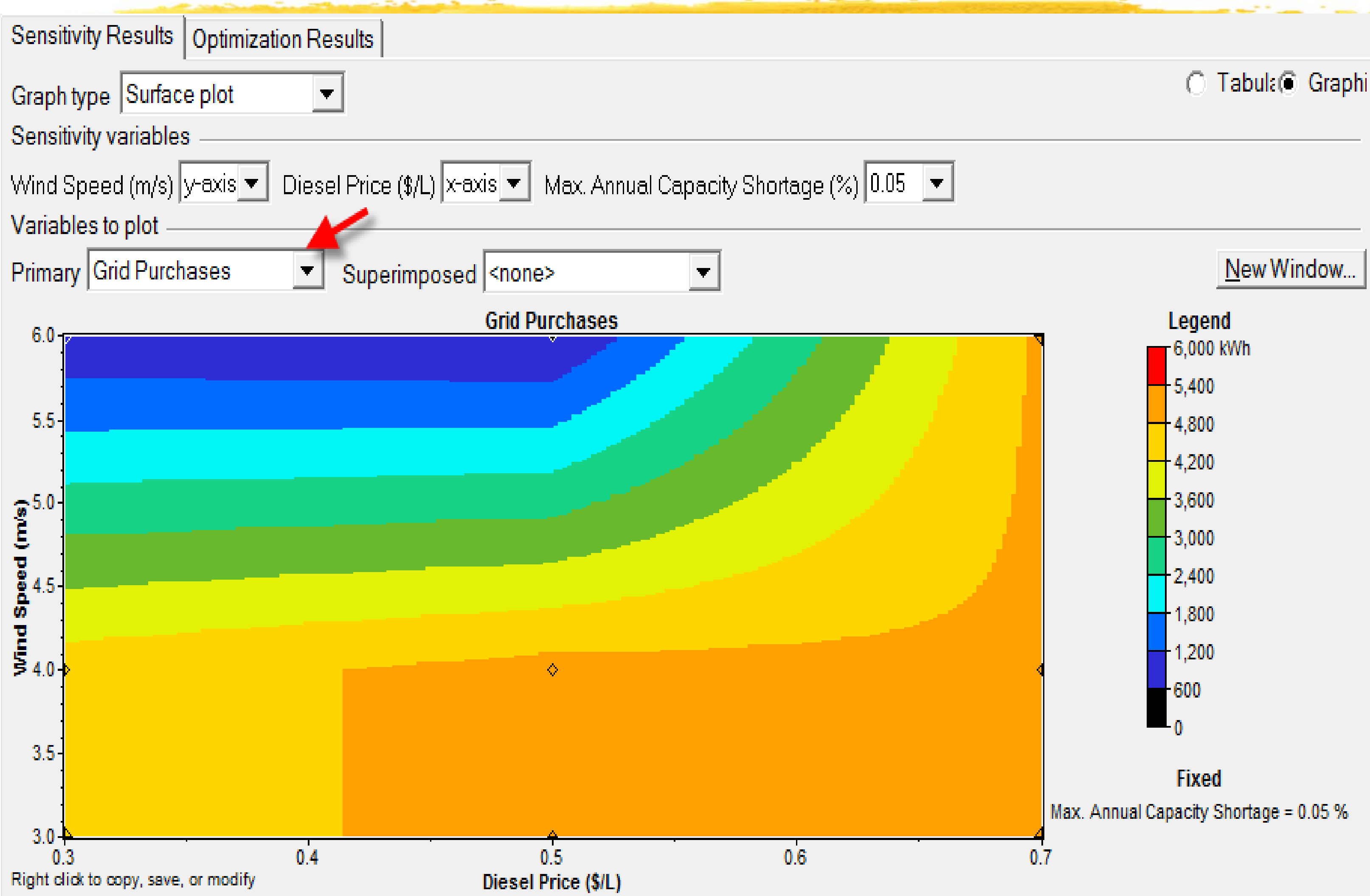
Surface Plot View

- 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
  - Team Project Demonstration/Presentation

Team Design Project

- Design a Hybrid Energy System (Grid may be connected)
- Site: **Work (School or Company or store) – team's consensus**
- Objective: **Find the optimum system** with sensitivity analysis
- Components: Grid (optional), Converter, Wind Turbine, PV panel, Fuel Cells, Electrolyzer, and Hydrogen Tank
- Project Lifetime: 20 years
- Fixed Cost: $10,000
- Load Profile →
  - You may use your **own load profile** obtained from your work
- You need to provide resource data on your work location
  - Solar Radiation {provide also sensitivity}
  - Wind Speed {sensitivity}

HOUR	[kW]
0000-0100	10
0100-0200	10
0200-0300	10
0300-0400	10
0400-0500	10
0500-0600	20
0600-0700	20
0700-0800	150
0800-0900	140
0900-1000	140
1000-1100	140
1100-1200	140
1200-1300	100
1300-1400	140
1400-1500	140
1500-1600	140
1600-1700	100
1700-1800	100
1800-1900	30
1900-2000	30
2000-2100	30
2100-2200	20
2200-2300	10
2300-2400	10

Suggested Component Data – Wind and PV

- Wind Turbine
  - Furhlander 30
    - Size: 30 kW
    - Lifetime: 20 years
    - Quantity: 10:   [0, 5, 10]
    - Capital Cost: $7,800 [for 1 unit]
    - Replacement Cost: 10% of the Capital Cost
    - O&M Cost/Year: 5% of the Capital cost
- PV Module
    - Size: 200kW: [0,100,200,300] kW
    - Derating Factor: 90%
    - Lifetime: 20 years
    - Capital Cost: $5000/kW
    - Replacement Cost: 10% of Capital Cost
    - O&M: 1% of Capital Cost

Suggested Component Data – Hydrogen

- Electrolyzer
  - Size: 100kW: [0, 50, 100] kW
  - Lifetime: 20 years
  - Capital Cost: $3000/kW
  - Replacement cost: 50% of Capital Cost
  - O&M Cost/Year: 5% of Capital cost
- Fuel Cell
  - Size: 200kW: [0, 100, 200, 300] kW
  - Lifetime: 30000 operating hours
  - Capital Cost: $5000/kW (or $500/kW)
  - Replacement Cost: $0
  - O&M cost: $0.1/hour
- Hydrogen Tank
  - Size: 2000 kg: [0, 1000, 2000, 3000]kg
  - Lifetime: 25 years
  - Capital Cost: $500/kg
  - Replacement Cost: 10% of Capital Cost
  - O&M Cost/year: 0.5% of the Capital Cost

Side Bar- Hydrogen Systems

- Electrolyzer system converts electricity into hydrogen by electrolyzing water
- Hydrogen is stored in steel tanks or geological cavern
- Reconverted to Electricity using 2 methods:
  - **Polymer Electrolyte Membrane (PEM) fuel cell**
  - Hydrogen Expansion Combustion Turbine

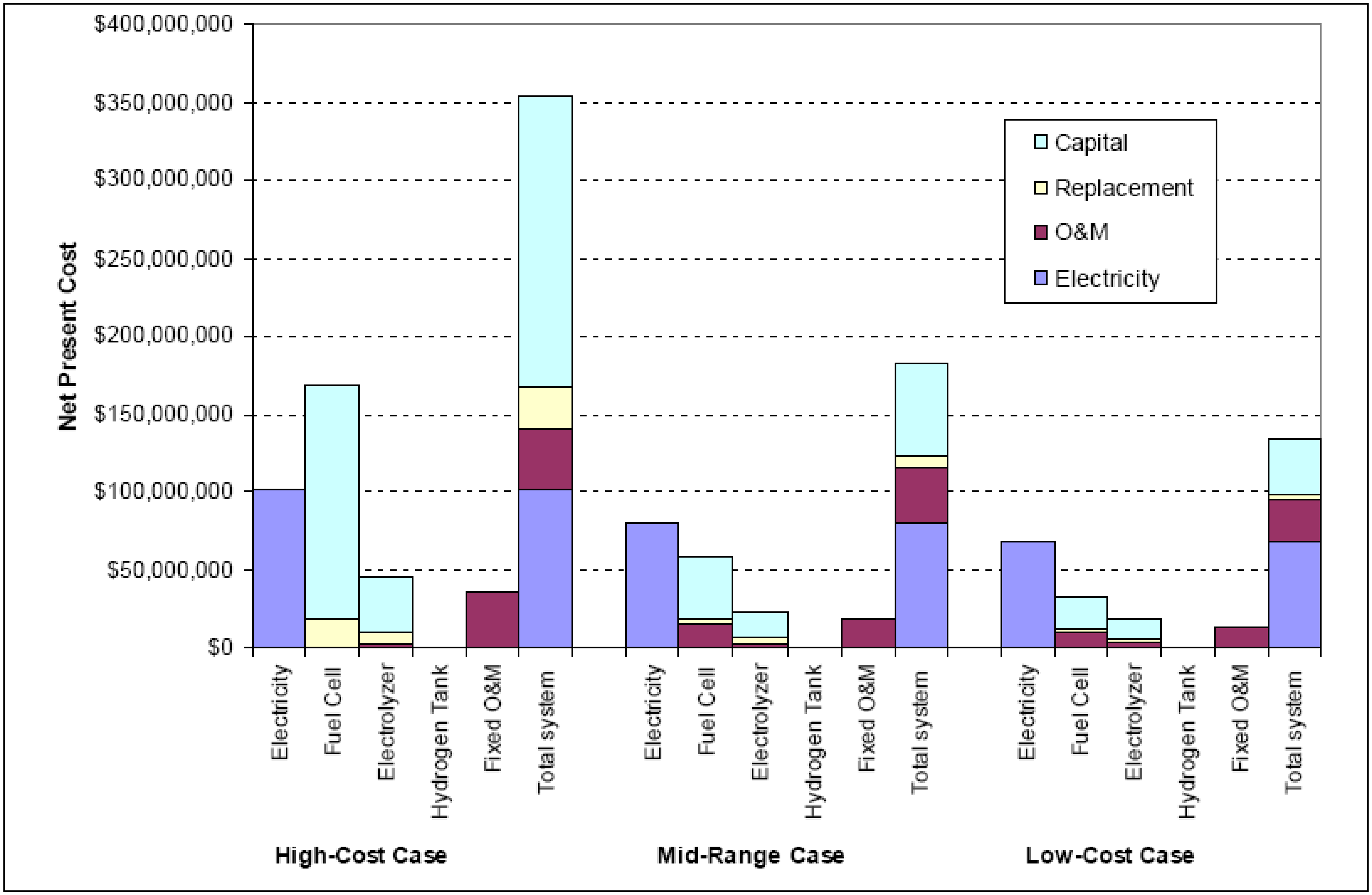
Side Bar – Fuel Cell

⌘Fuel Cell

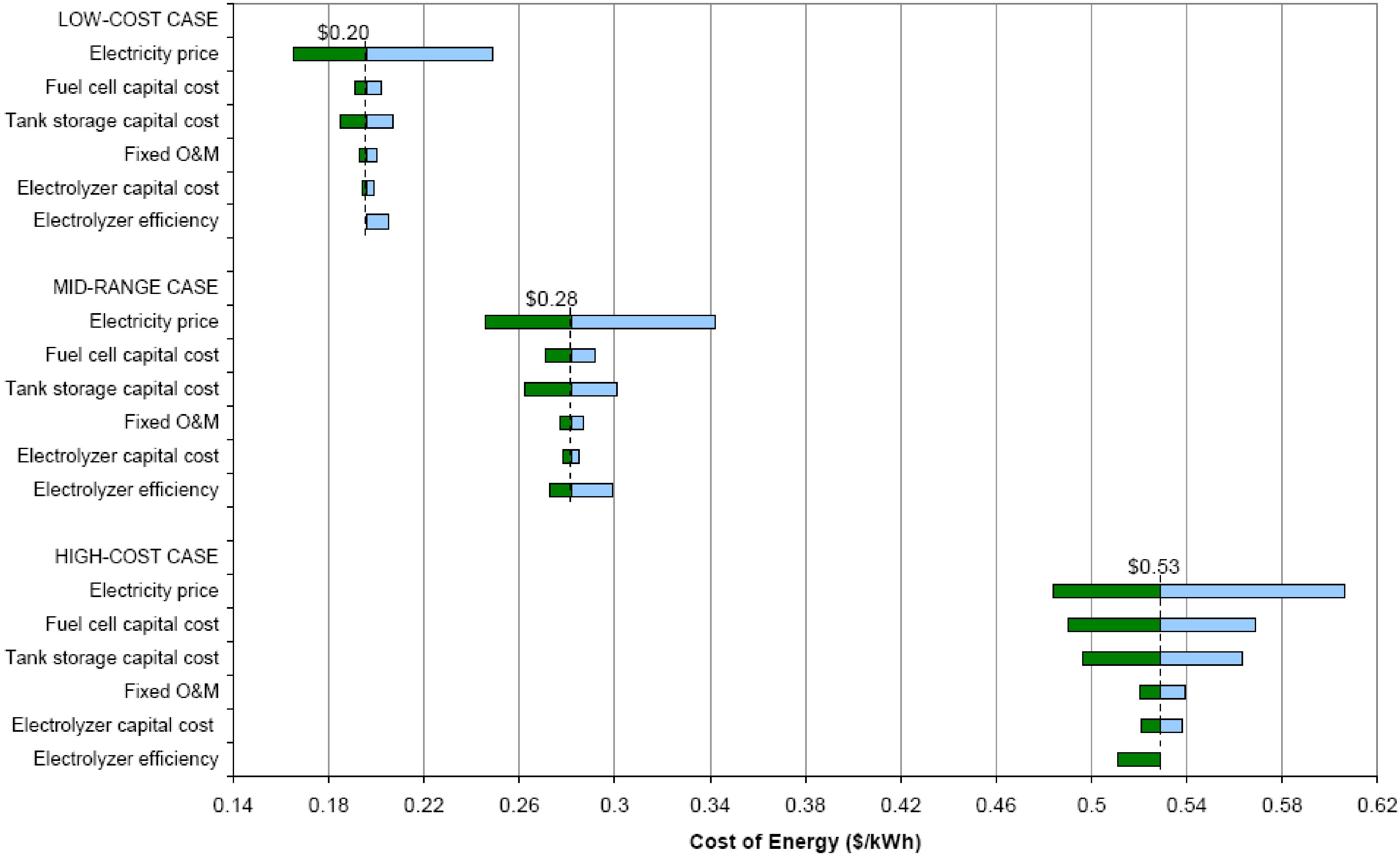
System Component	High-Cost Case Values	Mid-Range Case Values	Low-Cost Case Values
Fuel cell system installed capital cost ($2008)	$3,000/kW	$813/kW	$434/kW
Stack replacement frequency/cost	13 yr[1]/30% of initial capital cost	15 yr/30% of initial capital cost	26 yr[1]/30% of initial capital cost
O&M costs	$50/kW-yr[2]	$27/kW-yr	$20/kW-yr[2]
Fuel cell life	13 yr (20,000-hour operation)	15 yr (24,000-hour operation)	26 yr (40,000-hour operation)
Fuel cell system efficiency (LHV)	47%	53%[3]	58%[4]

[1]DOE (2007), Chapter 3.4; 20,000 hours for stationary PEM reformate system fuel cells 5–250 kW has been demonstrated. The goal for 2011 is, "By 2011, develop a distributed generation PEM fuel cell system operating on natural gas or LPG that achieves 40% electrical efficiency and 40,000 hours durability at $750/kW." Validated by 2014. Twenty thousand hours (13 years) was used for the high-cost value, and 40,000 hours (26 years) was used for the low-cost value.
[2]Values are from Lipman et al. (2004).
[3]Current technology value for stack efficiency is approximately 55% (O'Hayre et al. 2006). Value is mid-way between the high and low estimates.
[4]Assumed stack efficiency of 60% (MYPP 2010 target for direct hydrogen fuel cells for transportation) with 2% conversion losses for integrated system.

Side Bar - Hydrogen Fuel System Cost



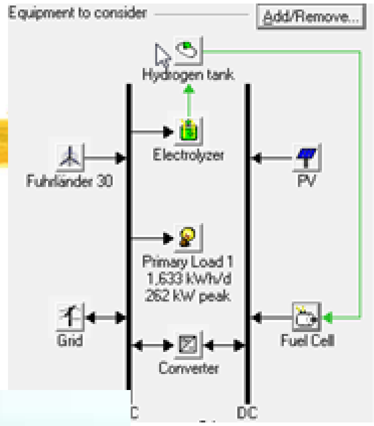
Side Bar - Nominal $/kWh Comparison

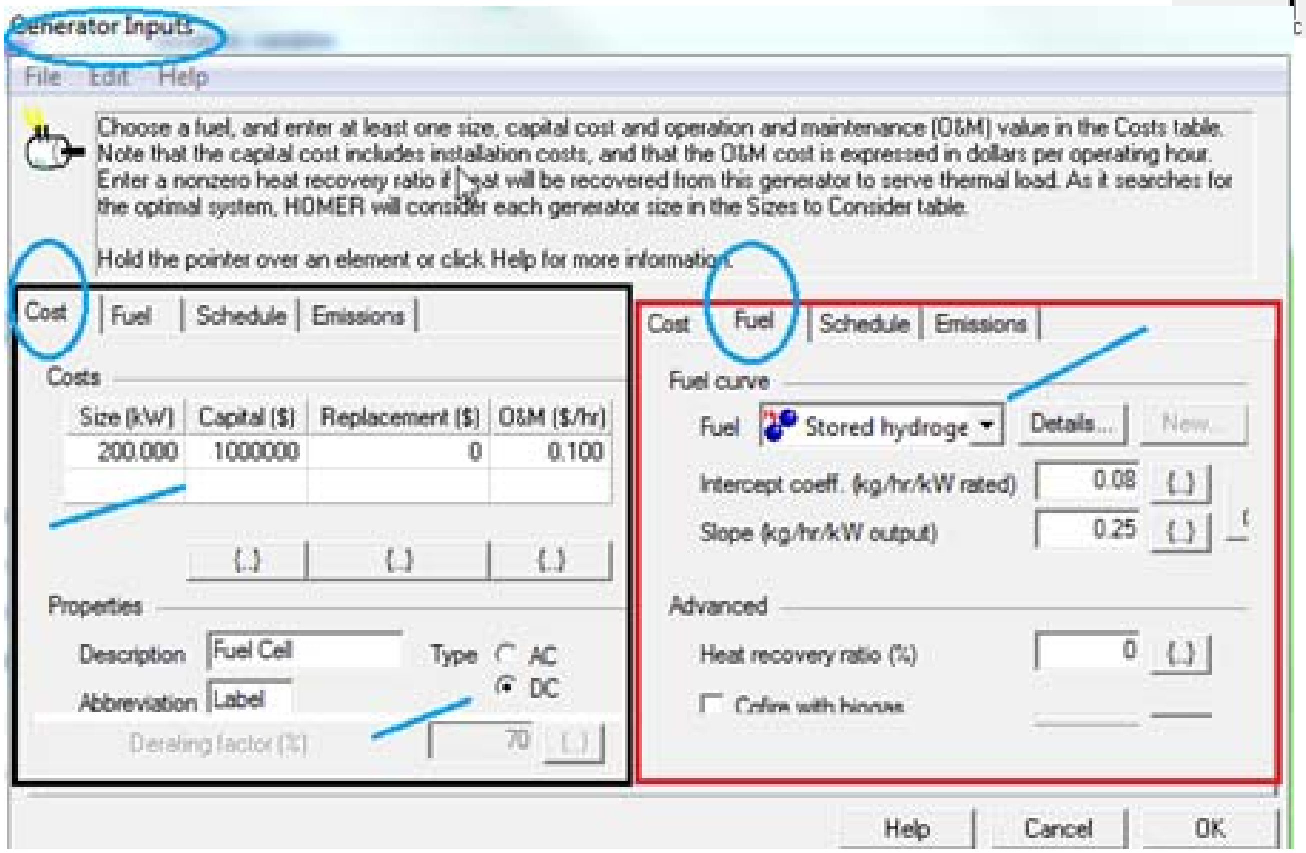


Nominal cost values shown may not line up precisely with x-axis values due to rounding.

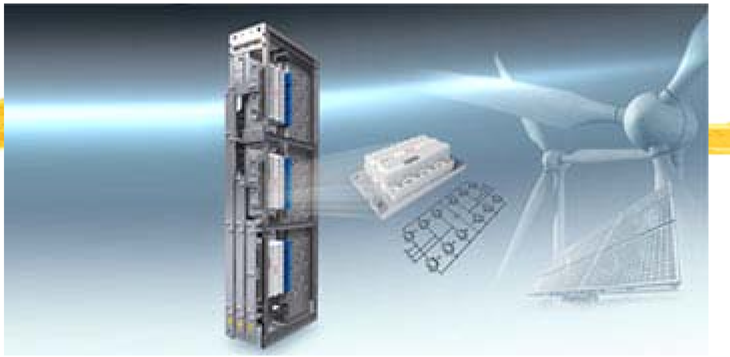
Fuel Cell Modeling

- Fuel Cell In HOMER modeling:
  - Pick a generator
  - Type: DC
  - Fuel: Stored Hydrogen





Suggested Component Data – Converter



- Converter
  - Size: 200kW: [0, 100, 200, 300]kW
  - Lifetime: 20 years
  - Efficiency: 90%
  - Capital Cost: $1000/kW
  - Replacement Cost: 30% of Capital Cost
  - O&M Cost/Year: 10% of Capital Cost
- Grid (Optional)
  - Single rate
  - Price ($/kWh): $0.15 :
    Sellback ($/kWh): $0.15
  - Demand: $0
  - **Purchase Capacity: 300kW**
  - Sellback Capacity: 200kW

Analysis Points and Team Presentation

Analysis Points:

- Find the Solar Radiation, and give Sensitivity values
- Find the Wind Speed, and give sensitivity values
- Calculate and Check the Optimization results
- Check the Sensitivity Results
- Find the optimum results
- Prepare Slides for team presentation (last day)
  - System Site, Location, etc (+ Real components and vendor info)
- Also run the HOMER in the presentation