

7. Micro-power System Modeling using HOMER - Part 1



Course Contents and Schedule

⌘ Day 3

⏏ HOMER Simulation 1

- ⊗ Input Requirements

- ⊗ Component Data Determination - – Diesel, Solar, Wind, and Battery

- ⊗ Simulation Details

⏏ Micro-Power System Design

- ⊗ Off-grid system design --- Isolated System

- ⊗ Combination of Renewable sources

⌘ Day 4

⏏ HOMER Simulation 2

- ⊗ Grid Data Details

- ⊗ Grid-Connected System Design

⏏ Team Practice

- ⊗ Isolated or Grid-Connected Power System Design

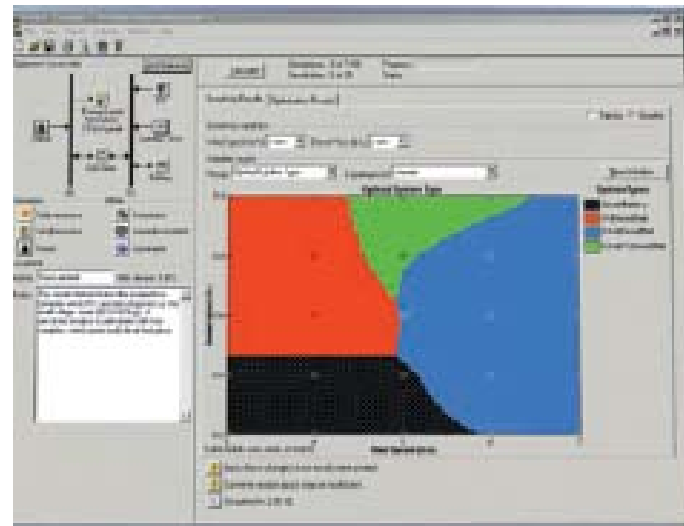
⌘ Day 5

- ⊗ Team Presentation

- ⊗ Summary and Conclusions

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

- ⌘ Simulation
- ⌘ Optimization
- ⌘ Sensitivity Analysis

Homer – a tool

⌘ A tool for designing micropower systems

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

- Wind turbines



- PV



- Batteries

- Diesels

- Microturbines



- Fuel cells



- Small hydro



- Small modular biomass



- Grid connection



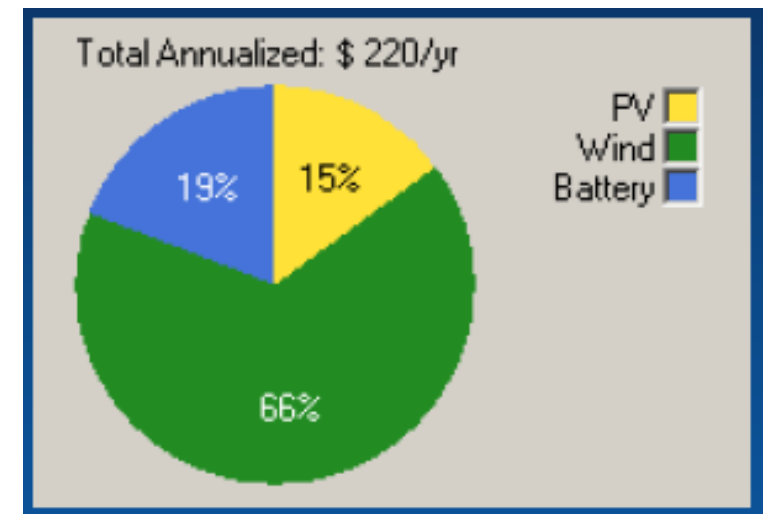
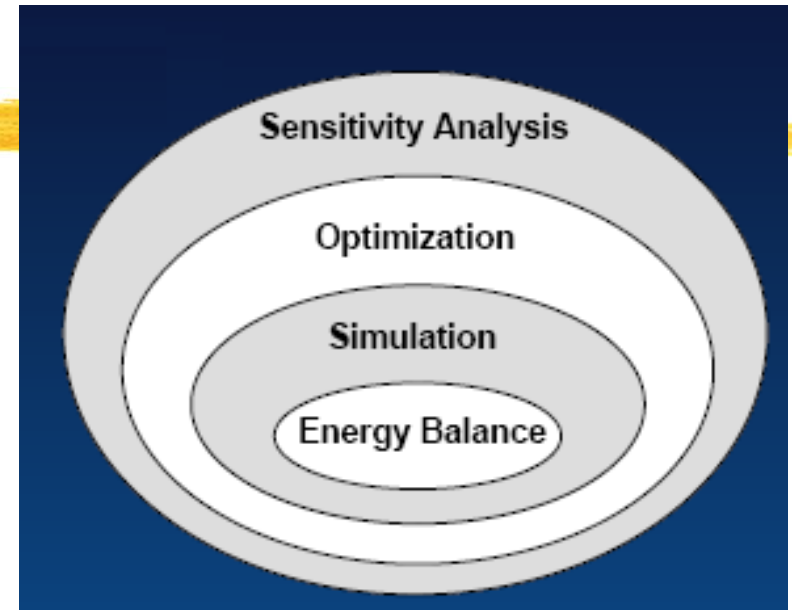
Homer - capabilities

⌘ Finds combination components that can service a load 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

⌘ Emerging Technologies

- ☑ Fuel Cells

- ☑ Microturbines

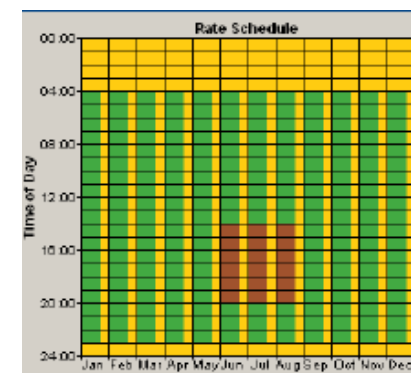
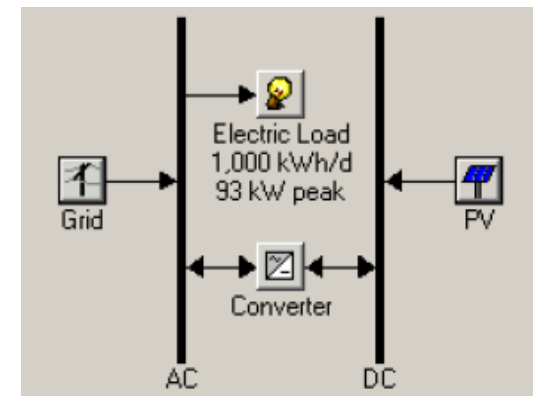
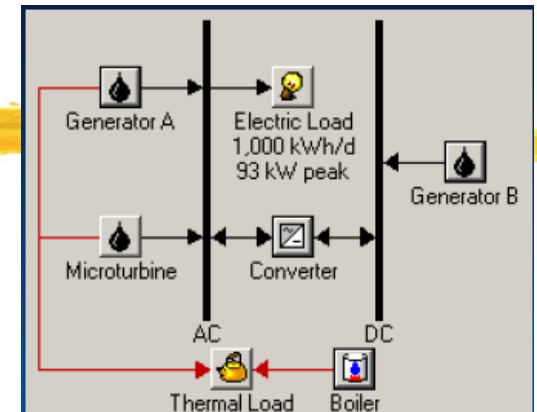
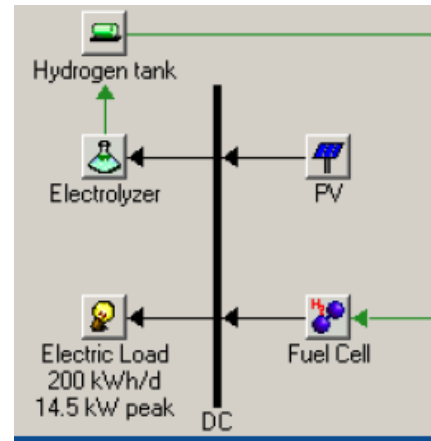
- ☑ Small Modular biomass

⌘ 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



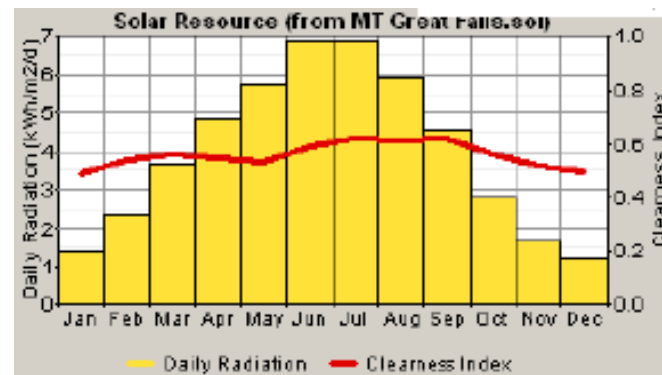
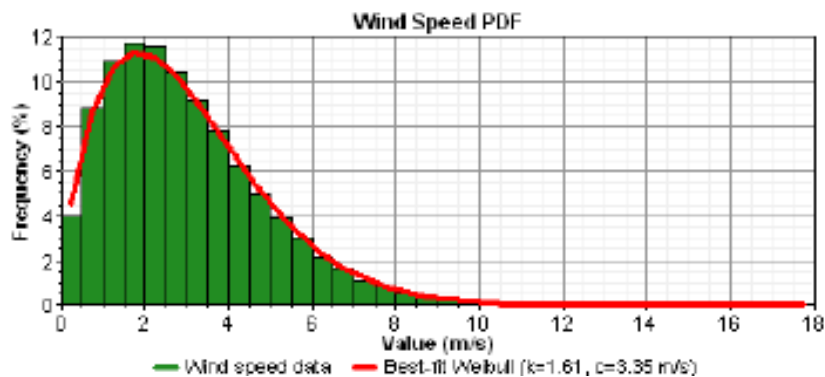
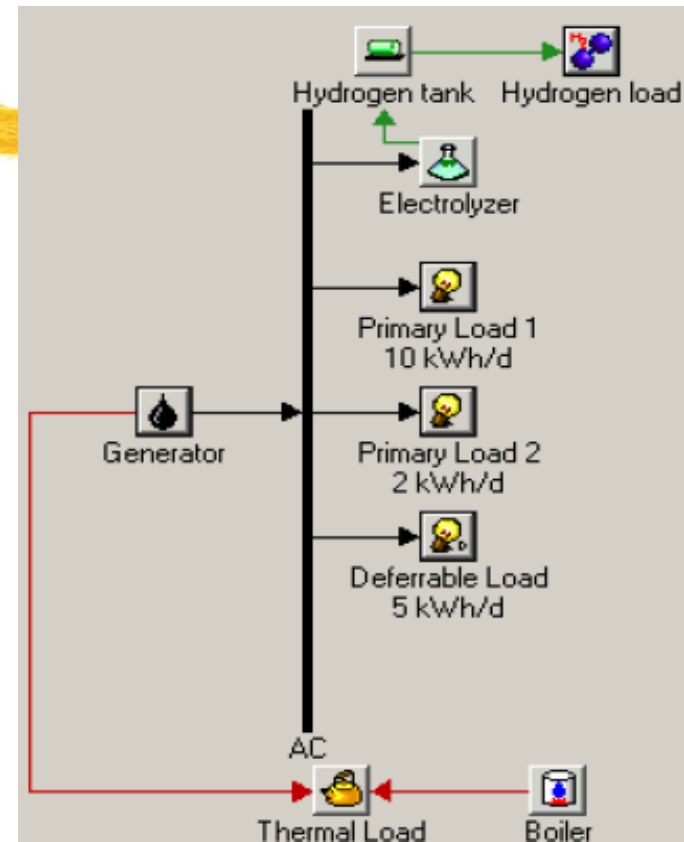
Features

⌘ Loads

- ⊞ Electrical
- ⊞ Thermal
- ⊞ Hydrogen

⌘ Resources

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



How to use HOMER

⌘ 1. Collect Information

⊞ Electric demand (load)

⊞ Energy resources

⌘ 2. Define Options (Gen, Grid, etc)

⌘ 3. Enter Load Data

⌘ 4. Enter Resource Data

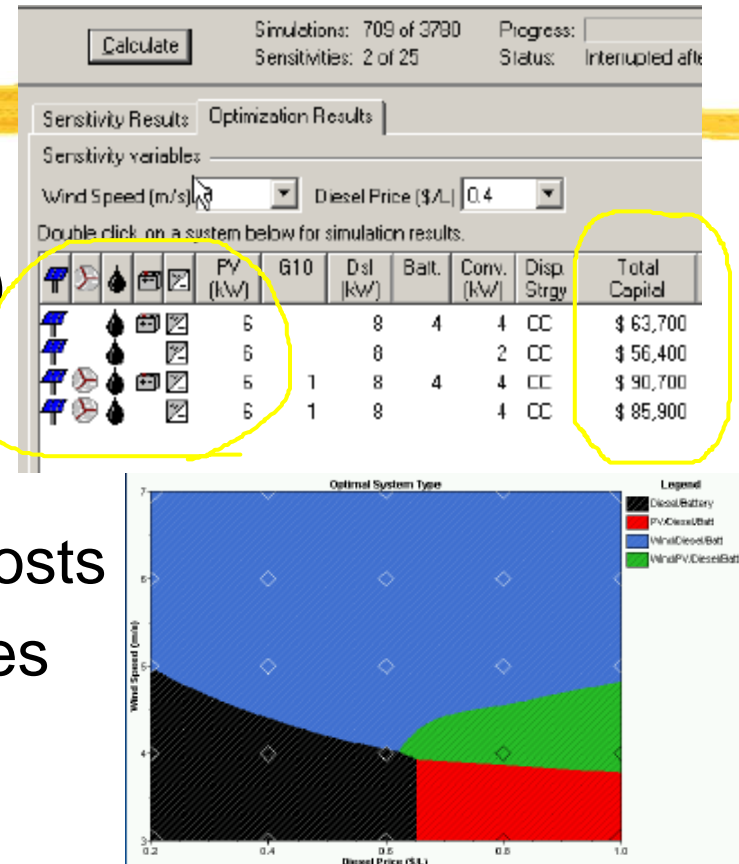
⌘ 5. Enter Component Sizes and Costs

⌘ 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.



HOMER Users

⌘ System designers:

- ☑ evaluate technology options

⌘ Project managers:

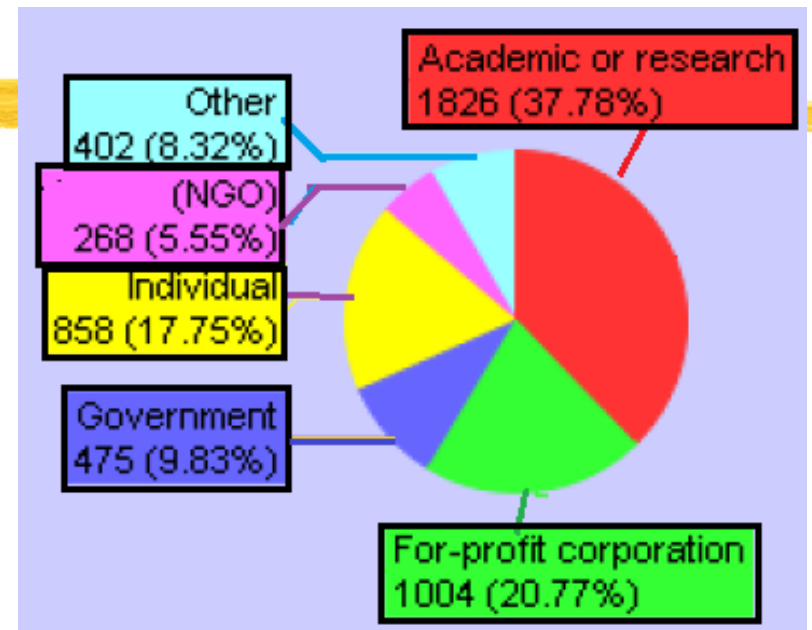
- ☑ evaluate costs of different options

⌘ Program managers:

- ☑ explore factors that affect system design (resource availability, fuel price, load size, carbon emissions, etc.)

⌘ Educators:

- ☑ teach and learn about renewable energy technologies

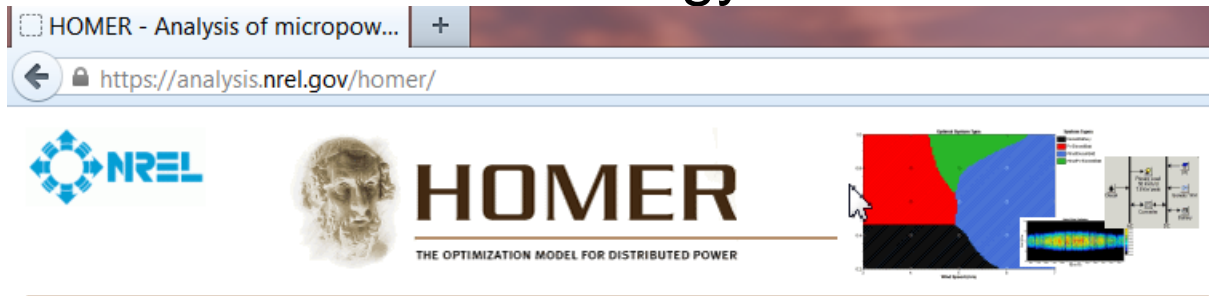


HOMER Users Worldwide

- ▶ Over 81,796 users
- ▶ 193 countries
- ▶ 1,500+ new users per month

HOMER software

⌘ NREL → Homer Energy



New Distribution Process for NREL's HOMER Model

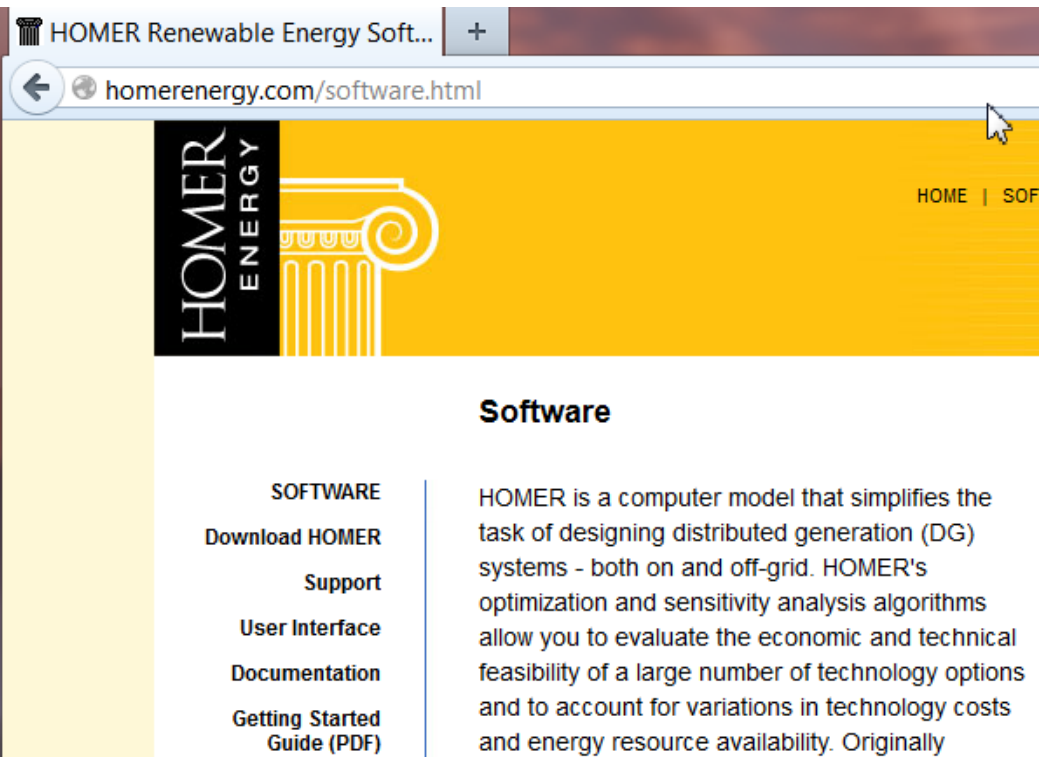
About HOMER
Overview
User Interface
Version History
User Testimonials
Ask Tom (FAQs)

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Software (Visit HOMER Energy)
Getting Started Guide (PDF File, 720 kB)
Brochure (English) (PDF File, 964 kB)
Brochure (Spanish) (PDF File, 1.3 MB)

Note! HOMER is now distributed and supported by [HOMER Energy](http://www.homerenergy.com) (www.homerenergy.com)

To meet the renewable energy industry's demand for a low-cost, easy-to-use software solution, NREL started developing HOMER in 1993. It has since been used by more than 30,000 individuals and universities worldwide.

HOMER is a computer model that simplifies the design of both off-grid and grid-connected power systems. Its optimization algorithms allow the user to evaluate the economic and technical feasibility of a large number of technology options and to account for variations in technology costs and energy resource availability, and other renewable energy technologies:



⌘ Download Sites

- 📄 [NREL.gov/homer](https://www.nrel.gov/homer)
- 📄 [Homerenergy.com](http://www.homerenergy.com)

HOMER download

- ⌘ Get the “LEGACY” version free
 - 📁 Registration required
- ⌘ Or, get the installation file from me.

Please log in to download or renew HOMER software, download files, or update !

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HOMER 2 is the supported version of the HOMER software for modeling and optimizing microgrids.

HOMER 2 is available at no cost and no obligation for a 2 week trial period. No credit card or payment information is required to try the software. The trial version is fully functional.

If you wish to license HOMER 2 for an **additional 6 months at the end of your trial, you may do so for \$99.99.**

(You will be asked to log in or create an **account** in order to download, but no payment information will be requested.)

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Are you looking for HOMER Legacy? HOMER Legacy is an **unsupported, never updated, no-cost version of HOMER.** You may obtain a 6-month license for HOMER Legacy, which is **renewable indefinitely.** We ask only that you share some basic information about how you are using the software. Download HOMER Legacy **here.** (You will be asked to log in or create an account in order to download HOMER Legacy.)

Optimizing Clean Power Everywhere

Energy Modeling Software for Hybrid Renewable Energy Systems

The HOMER energy modeling software is a powerful tool for designing and analyzing hybrid power systems, which contain a mix of conventional generators, combined heat and power, wind turbines, solar photovoltaics, batteries, fuel cells, hydropower, biomass and other inputs. It is currently used all over the world by tens of thousands of people.

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HOMER: The Hybrid Optimization Model for Electric Renewables

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*Download and install the trial before purchasing.

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Resource Files [Download](#)

Legacy Software

HOMER Legacy Free [Download](#)

Renew HOMER Legacy (was HOMER 2.68) Free [Renew](#)

VIPOR* Free [Download](#)

* VIPOR optimizes the layout of wires and transformers within a mini-grid. We offer it for free because it is not fully documented or supported but you are welcome to use it.



HOMER - Intro

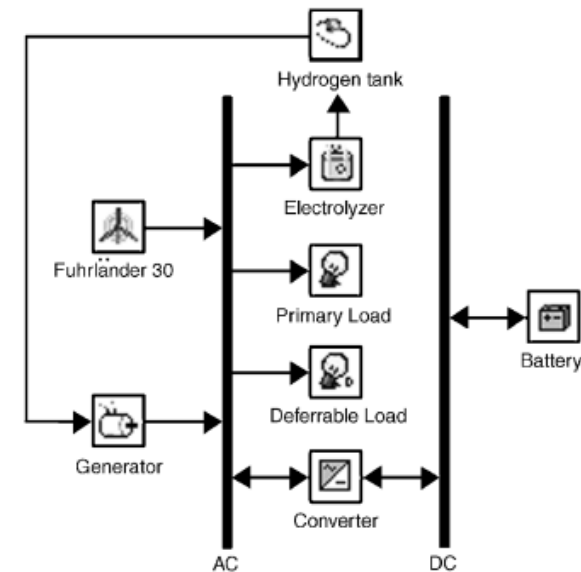
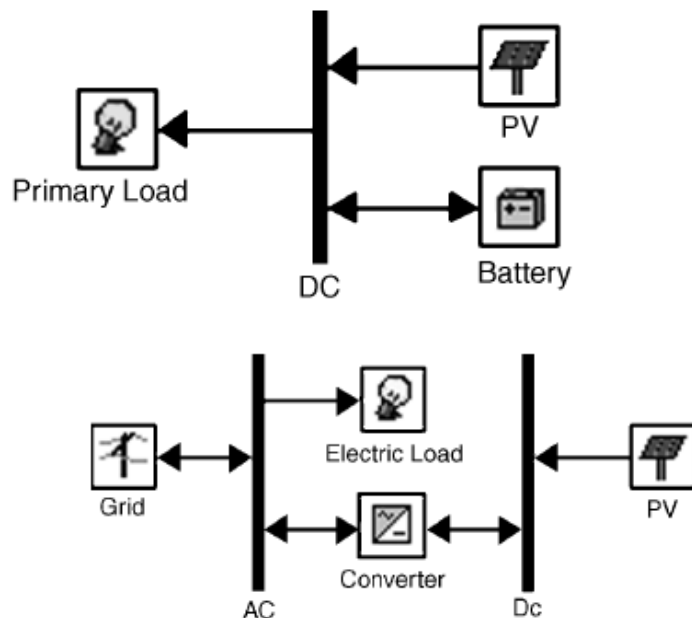
- ⌘ HOMER (Hybrid Optimization Model for Electric Renewables): Micropower Optimization computer model developed by NREL.
- ⌘ “Micropower system”: a system that generates electricity, and possibly heat, to serve a nearby load.→
Micro Grid
 - ☒ A solar–battery system serving a remote load
 - ☒ a wind–diesel system serving an isolated village
 - ☒ a grid-connected natural gas micro-turbine providing electricity and heat to a factory.
- ⌘ Models power system’s physical behavior and its life-cycle cost [installation cost + O&M cost]
- ⌘ Design options on technical and economic merit

HOMER – Principal 3 tasks

- ⌘ **Simulation:** HOMER models the performance of a particular micropower system configuration each hour of the year to determine
 - ☒ its technical feasibility (i.e., it can adequately serve the electric and thermal loads and satisfy other constraints) and
 - ☒ life-cycle cost.
- ⌘ **Optimization:** HOMER simulates many different system configurations in search of the one that satisfies the technical constraints at the lowest life-cycle cost.
 - ☒ Optimization determines the optimal value of the variables such as the mix of components that make up the system and the size or quantity of each.
- ⌘ **Sensitivity Analysis:** HOMER performs multiple optimizations under a range of input assumptions to gauge the effects of uncertainty or changes in the model inputs such as average wind speed or future fuel price

Simulation

- ⌘ The simulation process determines how a particular **system configuration** and an **operating strategy** that defines how those components work together, would behave in a given setting over a **long period of time**.
- ⌘ Home can simulate variety of micropower system configuration
- ⌘ **1-hour time step** to model the behavior of the sources involving intermittent renewable power sources with **acceptable accuracy**



Dispatch Strategies and NPC

- ⌘ A system with **battery bank** and **generator** requires dispatch strategy
- ⌘ Dispatch strategy: A set of rules governing how the system **charges** the battery bank
 - ⊞ **(LF) Load-following dispatch:** Renewable power sources charge the battery but the generators do not
 - ⊞ **(CC) Cycle-charging dispatch:** Whenever the generators operate, they produce more power than required to serve the load with surplus electricity going to charge the battery bank.
- ⌘ Life Cycle Cost of the system is represented by total net present cost (NPC):
 - ⊞ NPC includes all costs and revenues that occur within the project lifetime, with future cash flows discounted to the present.
 - ⊞ Any revenue from the sale of power to the grid reduces the total NPC
 - ⊞ NPC is the negative of NPV (Net Present Value)

NPV & “Time value of money”

- ⌘ Compare money today with money in the future
- ⌘ Relationship between \$1 today and \$1 tomorrow
- ⌘ \$1 (time t) → \$? (time t+1)
- ⌘ Case: Invest in a piece of land that costs \$85,000 with certainty that the next year the land will be worth \$91,000 [a sure \$6,000 gain], given that the guaranteed interest in the bank is 10%?

⊞ Future Value (If invested in the bank) perspective

$$FV = C_0 \times (1 + r) \quad \$85,000 \times (1 + 0.1) = \$93,500$$

future value \$93,500 > \$91,000

⊞ Present Value (PV) perspective

$$PV \times (1 + 0.1) = \$91,000 \quad PV = \frac{\$91,000}{1.1} = \$82,727.27$$

present value \$82,727.27 < \$85,000

$$PV = \frac{C_1}{1 + r}, \text{ where } C_1 \text{ is cash flow at date 1}$$

Do not to buy the land.

NPV (Net Present Value)

⌘ Net Present Value(NPV):

⊞ Present value of future cash flows minus the present value of the cost

$$NPV = PV - Cost.$$

$$NPV = \frac{\$91,000}{1.1} - \$85,000 = -\$2,273$$

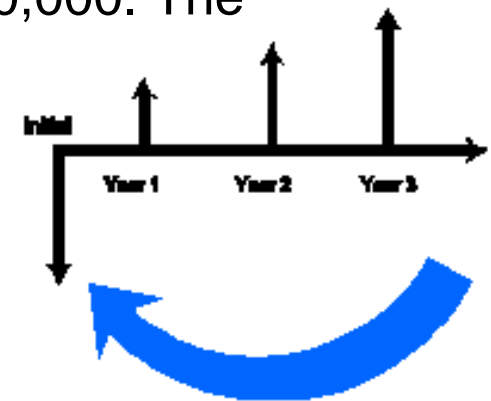
⊞ Formula:

$$NPV = -C_0 + \frac{C_1}{1+r} + \frac{C_2}{(1+r)^2} + \dots + \frac{C_T}{(1+r)^T}$$

$$NPV = -C_0 + \sum_{i=1}^T \frac{C_i}{(1+r)^i}$$

NPV Example

⌘ A company is determining whether they should invest in a new project. The company will expect to invest \$500,000 for the development of their new product. The company estimates that the first year cash flow will be \$200,000, the second year cash flow will be \$300,000, and the third year cash flow to be \$200,000. The expected return of 10% is used as the discount rate.



Year	Cash Flow	Present Value
0	-\$500,000	-\$500,000
1	\$200,000	\$181,818.18
2	\$300,000	\$247,933.88
3	\$200,000	\$150,262.96

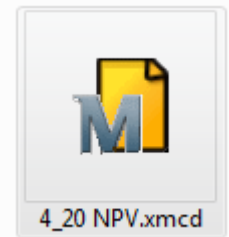
Net Present Value = \$80,015.02

$$NPV = -\$500,000 + \frac{\$200,000}{1.10} + \frac{\$300,000}{1.10^2} + \frac{\$200,000}{1.10^3}$$

$$NPV = -C_0 + \sum_{i=1}^T \frac{C_i}{(1+r)^i}$$

Year	Interest	Cash Flow	PV	NPV
0	0.1	-500000	-500000.00	-500000.00
1	0.1	200000	181818.18	-318181.82
2	0.1	300000	247933.88	-70247.93
3	0.1	200000	150262.96	80015.03
4	0.1	100000	90909.09	216617.72
5	0.1	100000	82644.63	340801.98
6	0.1	100000	75131.48	453696.77
7	0.1	100000	68301.35	556328.39
8	0.1	100000	62092.13	649629.87
9	0.1	100000	56447.39	734449.39
10	0.1	100000	51315.81	811558.05
	0.1	100000	46650.74	80015.03
	0.1	100000	42409.76	216617.72
	0.1	100000	38554.33	340801.98
	0.1	100000	35049.39	453696.77
	0.1	100000	31772.17	556328.39
	0.1	100000	28702.88	649629.87
	0.1	100000	25820.79	734449.39
	0.1	100000	23109.81	811558.05
	0.1	100000	20554.37	80015.03
	0.1	100000	18140.34	216617.72
	0.1	100000	15854.81	340801.98
	0.1	100000	13686.19	453696.77
	0.1	100000	11624.72	556328.39
	0.1	100000	9660.66	649629.87
	0.1	100000	7884.24	734449.39
	0.1	100000	6276.62	811558.05
	0.1	100000	4818.78	80015.03
	0.1	100000	3490.71	216617.72
	0.1	100000	2274.28	340801.98
	0.1	100000	1157.43	453696.77
	0.1	100000	14.00	556328.39

NPV in MathCad



NPV Example.xmcd Charles Kim 2013

A company is determining whether they should invest in a new project. The company will expect to invest \$500,000 for the development of their new product. The company estimates that the first year cash flow will be \$200,000, the second year cash flow will be \$300,000, and the third year cash flow to be \$200,000. The expected return of 10% is used as the discount rate.

(Q) Calculate NPV at each year

Cash Flow (C)

$$C := \begin{pmatrix} -500000 \\ 200000 \\ 300000 \\ 200000 \end{pmatrix}$$

$$C_0 = -5.0000 \times 10^5$$

$$C_1 = 2.0000 \times 10^5$$

Discount Rate (r) $r := 0.1$

Function in MathCad (for Present value)

Net Present Value (NPV)

$$PV(\text{Cash}, \text{Discount}, n) := \begin{cases} \text{Sum} \leftarrow 0 \\ \text{for } i \in 1..n \\ \text{Sum} \leftarrow \text{Sum} + \frac{\text{Cash}_i}{(1 + \text{Discount})^i} \\ \text{return Sum} \end{cases}$$

$$NPV := C_0 + PV(C, r, 3) = 8.0015 \times 10^4$$

At the end of the 3rd year

MathCad

Generation of Graphs

$$C_0 := -500000 \quad C_1 := 200000 \quad C_2 := 300000$$

$$m := 3..9$$

$$C_m := 200000$$

$$npv1_0 := C_0$$

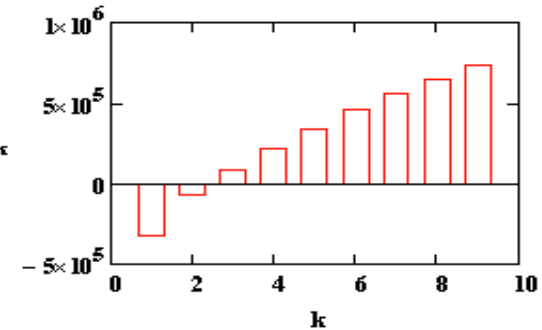
$$k := 1..9$$

$$npv1_k := C_0 + PV(C, r, k)$$

npv1 =

	0
0	$-5.0000 \cdot 10^5$
1	$-3.1818 \cdot 10^5$
2	$-7.0248 \cdot 10^4$
3	$8.0015 \cdot 10^4$
4	$2.1662 \cdot 10^5$
5	$3.4080 \cdot 10^5$
6	$4.5370 \cdot 10^5$
7	$5.5633 \cdot 10^5$
8	$6.4963 \cdot 10^5$
9	$7.3445 \cdot 10^5$

npv1_k



Cash Flow of 100000/year case

$$m := 1..9$$

$$C_m := 100000$$

$$npv2_0 := C_0$$

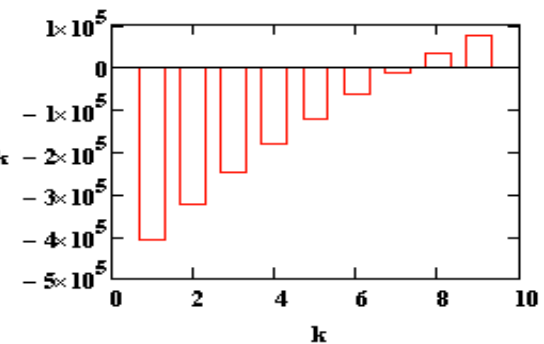
$$k := 1..9$$

$$npv2_k := C_0 + PV(C, r, k)$$

npv2 =

	0
0	$-5.0000 \cdot 10^5$
1	$-4.0909 \cdot 10^5$
2	$-3.2645 \cdot 10^5$
3	$-2.5131 \cdot 10^5$
4	$-1.8301 \cdot 10^5$
5	$-1.2092 \cdot 10^5$
6	$-6.4474 \cdot 10^4$
7	$-1.3158 \cdot 10^4$
8	$3.3493 \cdot 10^4$
9	$7.5902 \cdot 10^4$

npv2_k

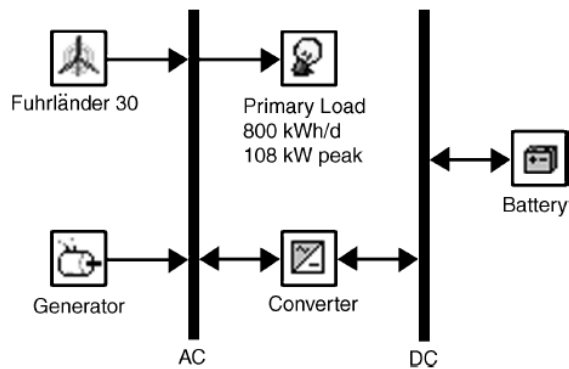


Optimization

- ⌘ Best possible system configuration that satisfies the user-specified constraints at the **lowest total net present cost**.
- ⌘ Decide on the mix of components that the system should contain, the **size** or **quantity** of each component, and the **dispatch strategy (LF or CC)** the system should use.
- ⌘ Ranks the feasible ones according to total net present cost
- ⌘ Presents the feasible one with the lowest total net present cost as the optimal system configuration.

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

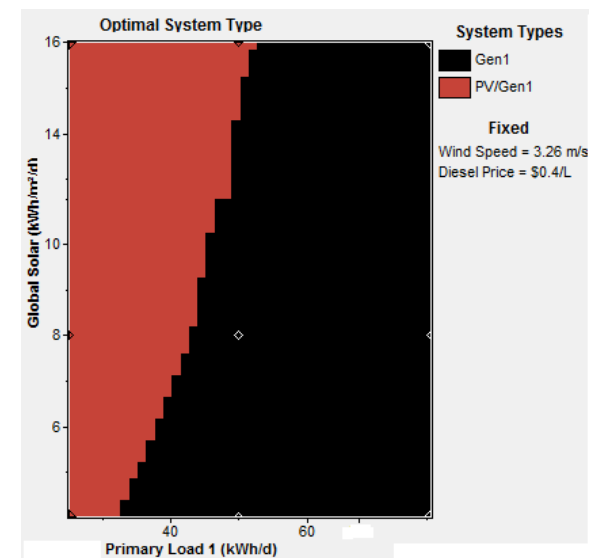
Sensitivity Values

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

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

Clear

Help Cancel OK

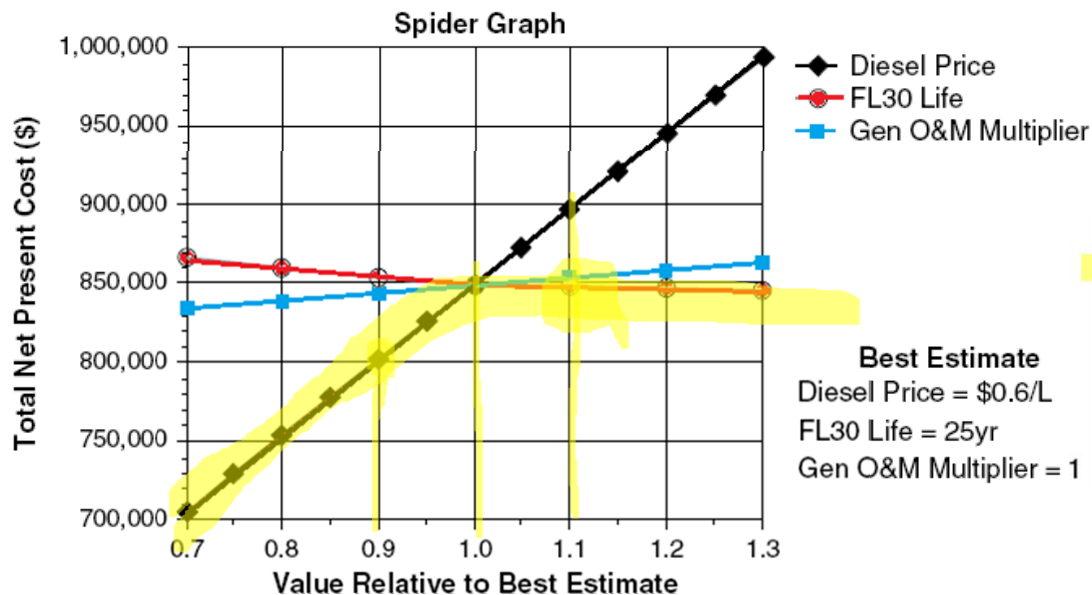


Why Sensitivity Analysis? Uncertainty!

- ⌘ 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

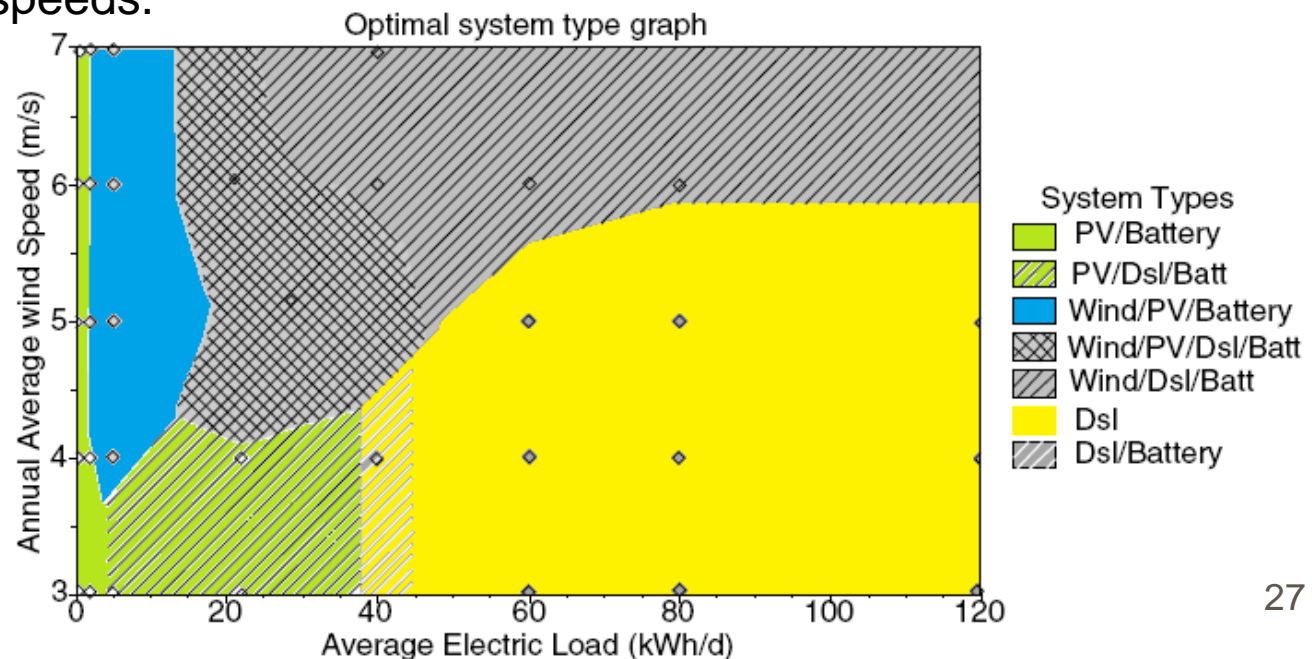
Tabular Format



Diesel (\$/L)	Wind	Gen	Batt.	Conv.	FL30	Gen (kW)	Batt. (kW)	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.



Physical Modeling - Loads

⌘ 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/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

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

Components- PV, Wind, and Hydro

⌘ PV Array

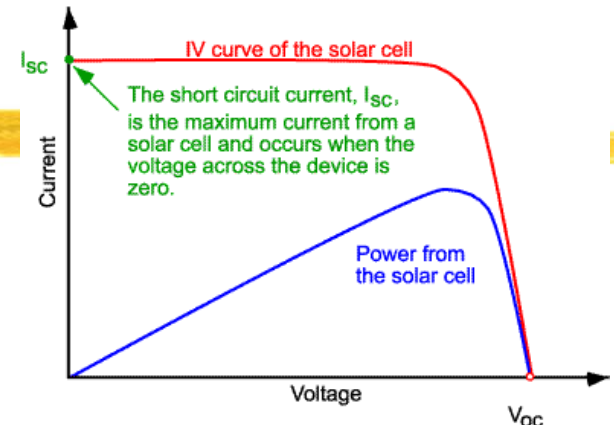
☒ f_{PV} : PV derating factor

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

☒ Y_{PV} : Rated Capacity [kW]

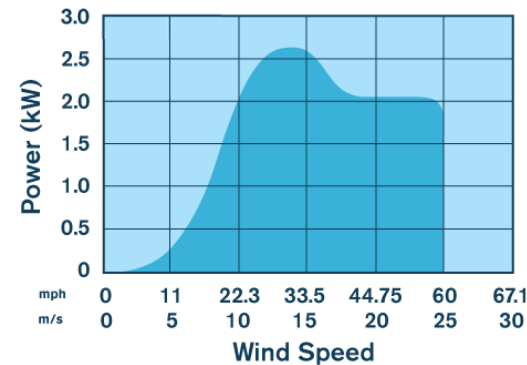
☒ I_T : Global Solar Radiation incidence on the surface of the PV array [kW/m²]

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



⌘ Wind Turbine

☒ Wind turbine power curve



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

⌘ Hydro Turbine

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

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

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]

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

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 33

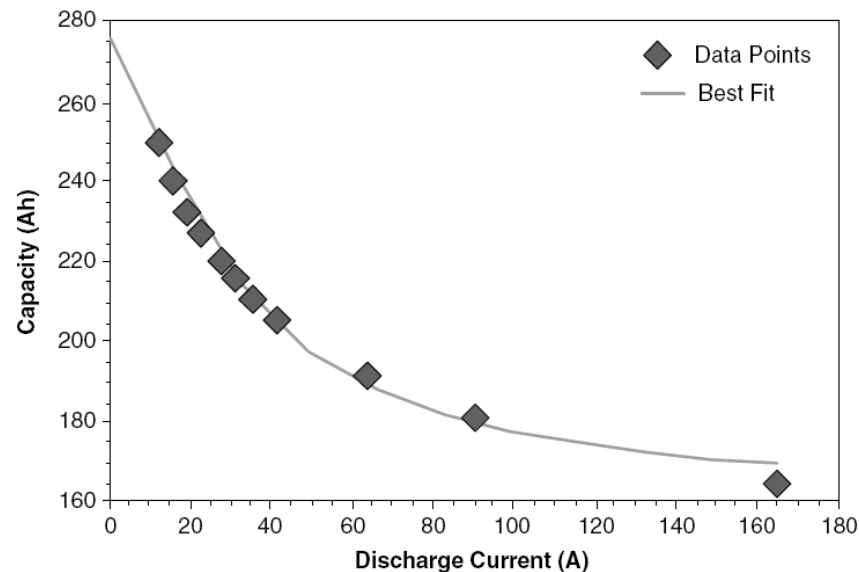
Components – Battery Bank

⌘ 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)



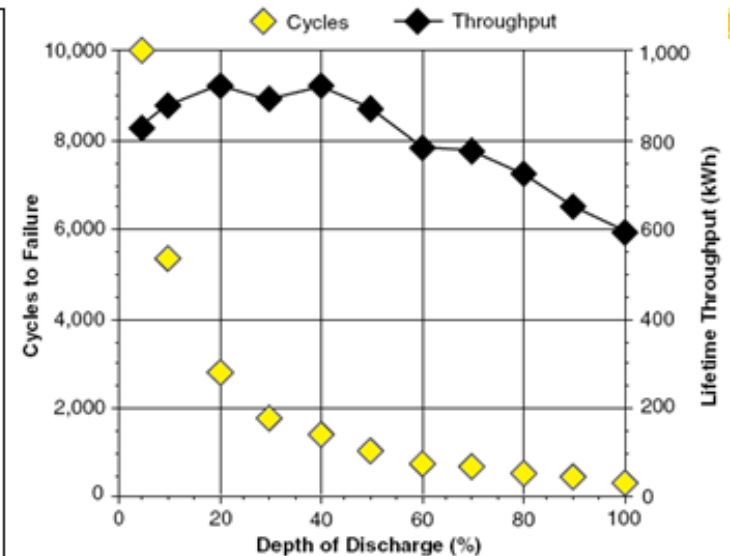
Components - Battery

⌘ Battery Lifetime Curve and Example for US-250

R_{batt} life of the battery bank

$$R_{\text{batt}} = \min\left(\frac{N_{\text{batt}} Q_{\text{lifetime}}}{Q_{\text{thrpt}}}, R_{\text{batt},f}\right)$$

N_{batt} is the number of batteries in the battery bank,
 Q_{lifetime} the lifetime throughput of a single battery,
 Q_{thrpt} the annual throughput (the total amount of energy that cycles through the battery bank in one year)
 $R_{\text{batt},f}$ the float life of the battery (the maximum life regardless of throughput).



⌘ Battery Fixed cost = \$0

⌘ Battery Marginal Cost = Battery Wear Cost + Battery Energy Cost

⊞ **Battery Wear Cost:** the cost per kWh of cycling energy through the battery bank

⊞ **Battery energy cost:** the average cost of the energy stored in the battery bank

Components - Battery

- ⌘ **Battery energy cost** each hour: dividing the **total year-to-date cost of charging the battery bank** by the **total year-to-date amount of energy put into the battery bank**
 - ⊞ Load-following dispatch strategy: since charged only by surplus electricity, charging cost of battery is always zero
 - ⊞ Cycle-charging strategy: charging cost is not zero.
- ⌘ **Battery wear cost**:

$$c_{bw} = \frac{C_{rep,batt}}{N_{batt} Q_{lifetime} \sqrt{\eta_{rt}}}$$

$C_{rep,batt}$ is the replacement cost of the battery bank (dollars)

N_{batt} is the number of batteries in the battery bank,

$Q_{lifetime}$ is the lifetime throughput of a single battery (kWh)

η_{rt} is the round-trip efficiency.

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.

Emission Trading (“Cap and Trade”)

- ⌘ Market based approach for controlling pollution by providing economic incentives for achieving reductions in the emissions of pollutants.
- ⌘ Carbon credits for emission
- ⌘ Firms that need to increase their emissions must buy permits from those who require fewer permits
- ⌘ Buyer is paying a charge for pollution while seller is rewarded for reduction of it.
- ⌘ Difference from Carbon Tax: Responsive to inflation

Carbon Tax

- ⌘ A carbon tax is a direct tax on the carbon content of fossil fuels (coal, oil and natural gas).
- ⌘ A carbon tax is the most economically efficient means to convey crucial price signals that spur carbon-reducing investment.
- ⌘ Carbon taxes should be phased in so businesses and households have time to adapt.
- ⌘ A carbon tax can be structured to soften the impacts of added costs by distributing tax revenues to households (“dividends”) or reducing other taxes (“tax-shifting”).
- ⌘ Support for a carbon tax is growing steadily among public officials; economists; scientists; policy experts; business, religious, and environmental leaders; and ordinary citizens.

Carbon Tax Implementation – US and Canada

⌘ California

- ☒ In 2008, 9 counties around the San Francisco Bay area --- 4.4 cents per ton of CO₂

⌘ Maryland

- ☒ In 2001, \$5 per ton of CO₂ from any stationary source emitting more than a million tons of CO₂ during a calendar year

⌘ Quebec

- ☒ \$3.50 per ton of CO₂ (equivalent)

⌘ British Columbia

- ☒ \$10.00 per ton of CO₂ (equivalent)

⌘ Alberta

- ☒ \$15 per ton of CO₂ for companies emitting more than 100,000 tons annually.

Carbon Tax Implementation - Korea

- ⌘ In February 2010, a deputy finance minister confirmed that South Korea is considering a carbon tax to help reduce emissions 4% from 2005 levels by 2020.
- ⌘ This would be in conjunction with a cap-and-trade program to be implemented later this year.
- ⌘ With a tax rate of **31,828 won** (25 Euros) **per ton of CO₂**, the South Korean government would collect 9.1 trillion won (\$7.9 billion) in tax revenue based on 2007 emissions.
- ⌘ Income from the carbon tax would be used to reduce corporate and income taxes. On July 22, 2010 Chairman of the Korea Chamber of Commerce and Industry asked for the South Korean government to delay the implementation of the carbon tax: "If the government applies much stricter guidelines over carbon emissions, then companies might be burdened."

Example of Grid Rate for Medium General Service

⌘ Year 2007 example

⌘ Medium General Service:

☒ Monthly Use: > 3500kWh

☒ Summer Peak: <300kW

⌘ Rate:

☒ Customer charge: \$25.42/month

☒ Energy Charge: \$0.062533/kWh [summer],
\$0.069533/kWh [winter]

☒ Demand charge: \$22.69535/kW [summer],
\$14.7419/kW [winter]

⌘ A Restaurant (a summer month: Jun - Sep) 24000 kWh,
150kW demand

☒ Customer charge: \$25.42

☒ Energy charge: \$1500.79

☒ Demand charge: \$3404.02

Example of a residential customer

Welcome to Manage Your Account

Last Payment Received On

December 17, 2012 \$51.82

Current Charges Billed On

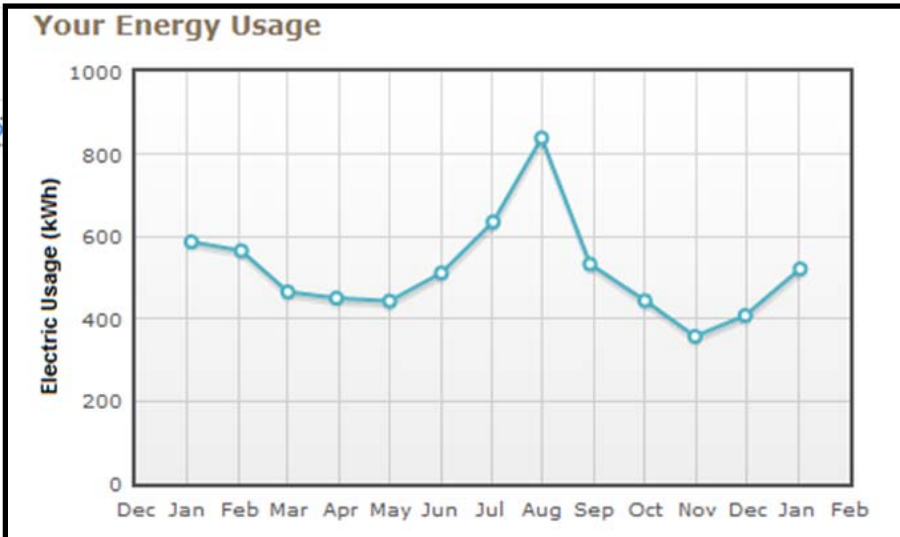
January 04, 2013 \$64.12 [View Bill](#)

Total Amount Due Will Be Drafted On Or After

January 15, 2013 \$64.12

Next Bill Date

February 04, 2013 [View P](#)



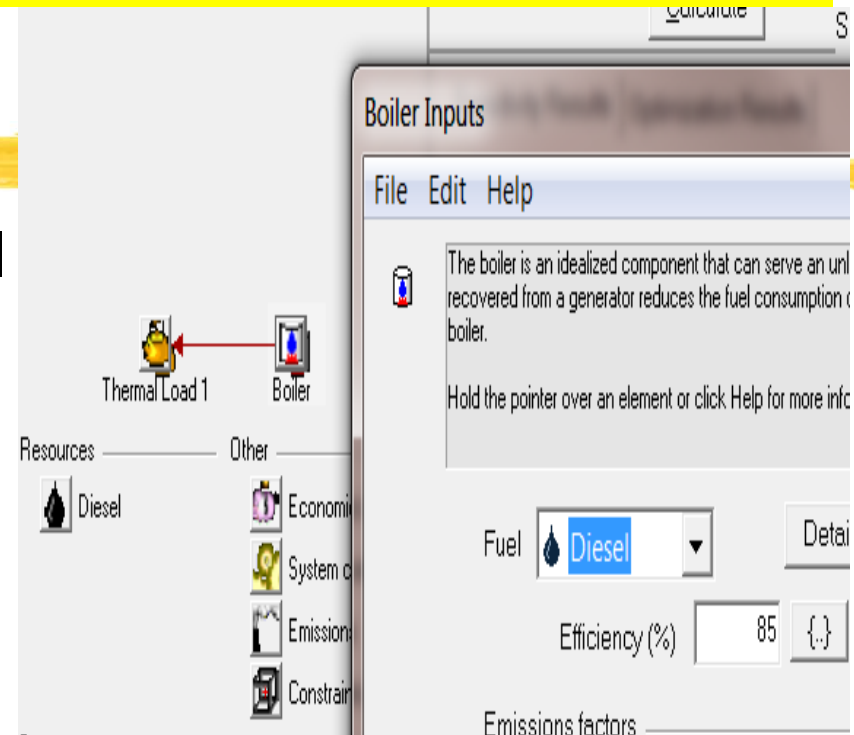
South Korea

Energy Efficiency/CO2 ¹ Indicators	Units	1980	1990	2000	2007
Residential, service and agriculture sectors					
Average electricity consumption of households per capita	kWh/cap	139	414	789	1130
Average electricity consumption per household	kWh/hh	728	1716	2412	3822
Average electricity consumption of electrified households	kWh/hh	728	1716	2412	3822
Households consumption for electrical appliances and lighting	kWh/hh	0	1541	1980	n.a.

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

Heating Value of Fuel

⌘ Higher Heating Value (HHV)

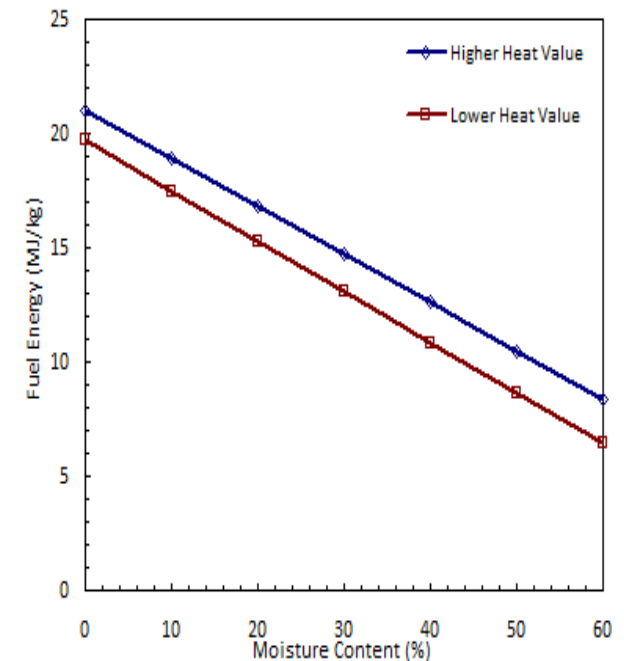
⏏ The Higher Heating Value (HHV) is the total amount of heat in a sample of fuel - including the energy in the water vapor that is created during the combustion process.

⌘ Lower Heating Value (LHV)

⏏ The Lower Heating Value (LHV) is the amount of heat in a sample of fuel **minus** the energy in the combustion water vapor. The Lower Heating Value is always **less** than the Higher Heating Value for a fuel.

Typical Higher and Lower Heat Values for Fuels

Fuel Type	Higher Heat Value (kJ/kg)	Lower Heat Value (kJ/kg)
Wood, Dry	21	19.7
Grass, Dry	18.5	17.4
Dairy Manure, Dry	20.5	19.3
Coal, Bituminous	28	26
Natural Gas	42.5	38.1
Fuel Oil	45.9	43
Gasoline	47.9	43.8
Ethanol	29.8	26.9



Components – Converter & Fuel Cell

⌘ Converter

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

⌘ 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



Operating Reserve

⌘ Operating Reserve

⊞ Safety margin for reliable electricity supply despite variability in load and renewable power supply

⊞ Required amount of reserve: Fraction of load at an hour + fraction of the annual peak primary load + fraction of PV power output at that hour + fraction of the wind power output at that hour.

⊞ **Example** for a wind-diesel system

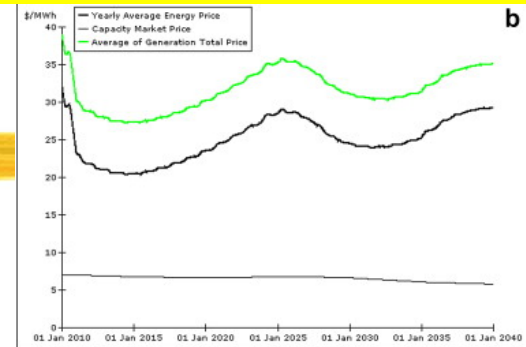
⊞ User defines operating reserve as 10% of the hourly load + 50% of the wind power output

⊞ Load = 140kW; Wind power output = 80kW

⊞ Required Operating Reserve = $140\text{kW} \cdot 0.1 + 80\text{kW} \cdot 0.5 = 54 \text{ kW}$

⊞ Diesel Generator should provide 60 kW ($140 - 80$) + 54 = 114 kW

⊞ So, the capacity of the diesel gen must be at least 114 kW



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**.

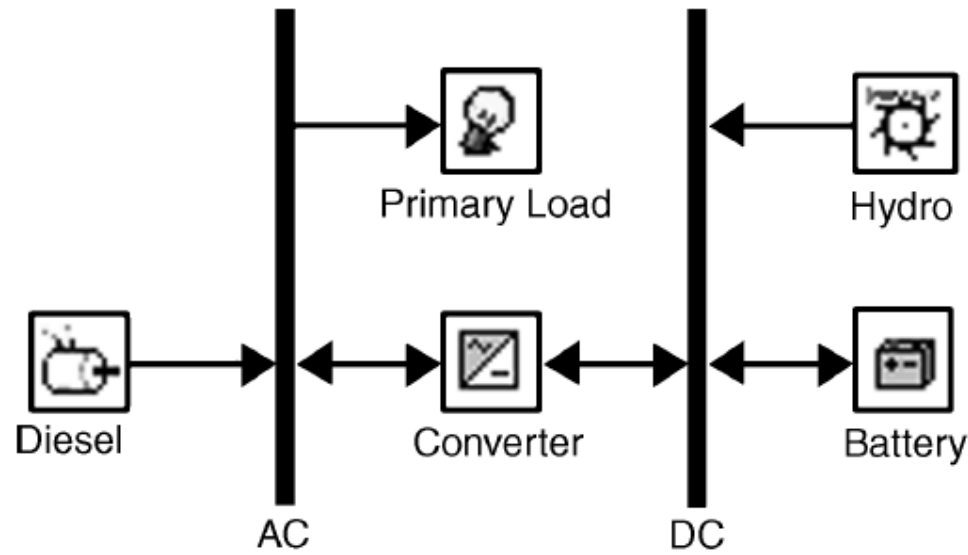
Dispatch Strategy for a system with Gen and Battery

⌘ Dispatch Strategy

- ⊞ Whether and how the generator should charge the battery bank?
- ⊞ There is no deterministic way to calculate the value of charging the battery bank – the value of charging in one hour depends on what happens in future hours. [enter Wind power which can provide enough power the next hour – then the diesel power into battery would be wasted]
- ⊞ 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

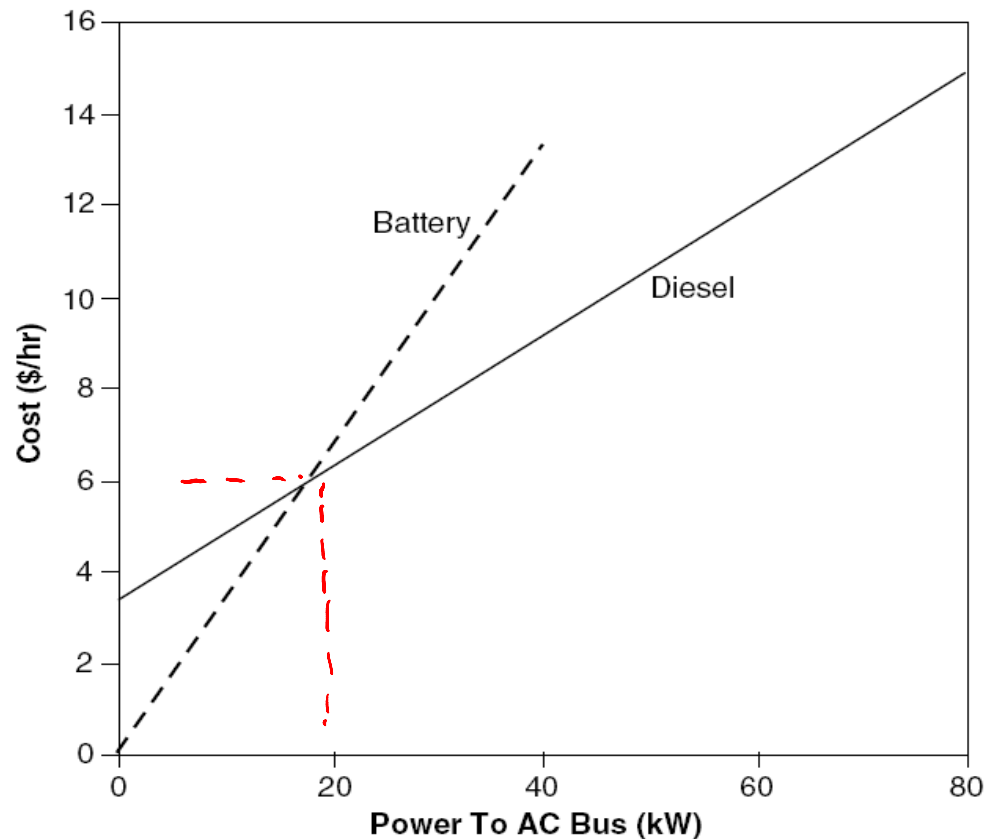
- ⌘ Fundamental principle: cost minimization – fixed cost and marginal cost
- ⌘ Example: Hydro-Diesel-Battery System



- ⌘ 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.

<p>300 Watt Dump Load for 12 Volt Systems</p>  <p>\$21.98</p> <p>Add to cart</p>	<p>300 Watt Dump Load for 24 Volt Systems</p>  <p>\$21.98</p> <p>Add to cart</p>
--	--

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

What HOMER includes in NPC

Knowledgebase: Economics

10303 - Total net present cost in HOMER

Posted by on 21 December 2010 11:45 AM



What is meant by life cycle cost and how it is determined?

HOMER uses the total net present cost (NPC) to represent the life-cycle cost of a system. The total NPC condenses all the costs and revenues that occur within the project lifetime into a single lump sum in year-zero dollars, with future cash flows discounted back to year zero using the discount rate. Costs may include **capital costs, replacement costs, operating and maintenance costs, fuel costs, the cost of buying electricity from the grid, and miscellaneous costs such as penalties resulting from pollutant emissions.** Revenues may include income from selling power to the grid, plus any salvage value that occurs at the end of the project lifetime.

With the NPC, costs are positive and revenues are negative. This is the opposite of the net present value (NPV). As a result, the NPC differs from NPV only in sign.

To see a detailed breakdown of the how HOMER calculates the total NPC for any system in the Optimization Results list, double click on that system to see the Simulation Results window, switch to the Cash Flow tab, and click the Details button in the top right corner. HOMER will display a spreadsheet showing the cash flows that occur in every year of the project lifetime, broken down by component and type. If you choose to display the discounted cash flows, the total net present cost will appear in the bottom right cell.

Example Case – Micro Grid in Sri Lanka

⌘ Load profile:

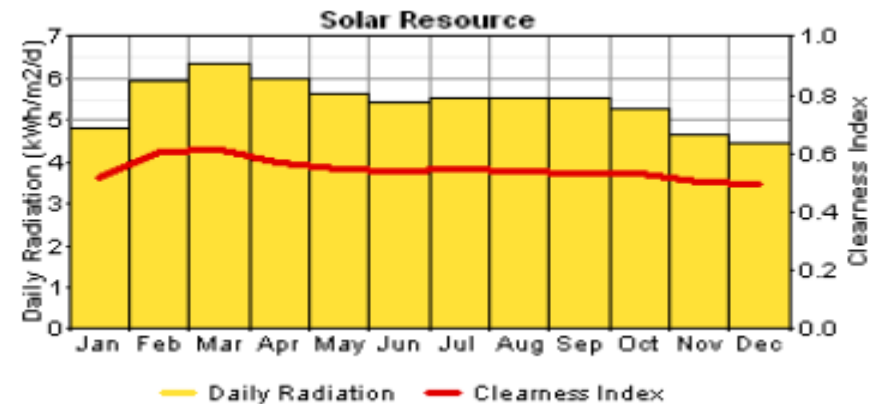
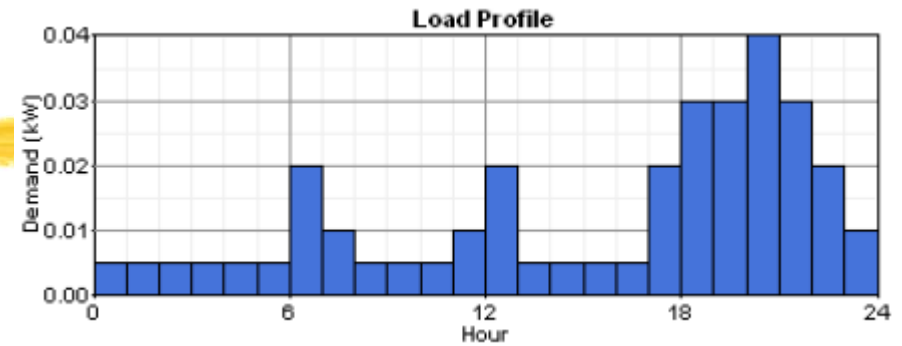
- ⌘ base load of 5W, small peaks of 20 W, peak load of 40W; total daily average load = 350 Wh
- ⌘ Sensitivity analysis range: [0.3kW/h, 16kWh/d]

⌘ 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

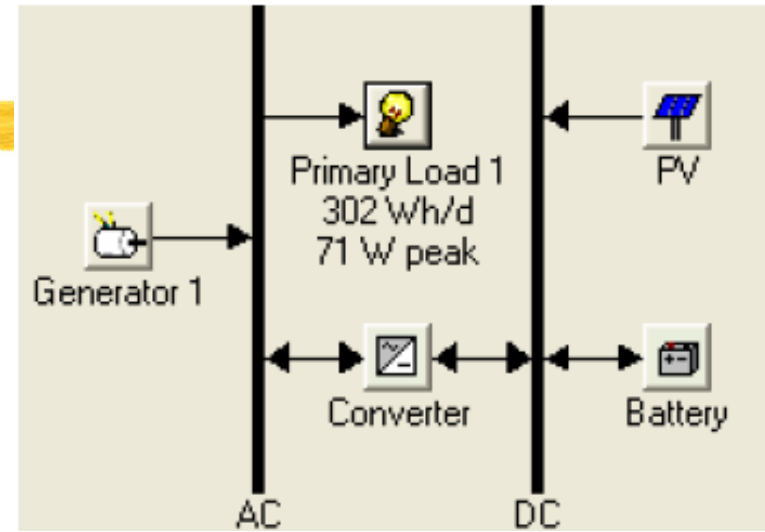
- ⌘ \$0.4/L – \$0.7/L
- ⌘ Sensitivity analysis range: [\$0.3, 0.8] with increment of \$0.1/L



- **Economics:**
 - Real annual interest rate at 6%
 - **Reliability Constraints**
 - 0% annual capacity shortage
- Sensitivity Analysis range: [0.5 – 5]%

Example Case – Micro Grid in Sri Lanka

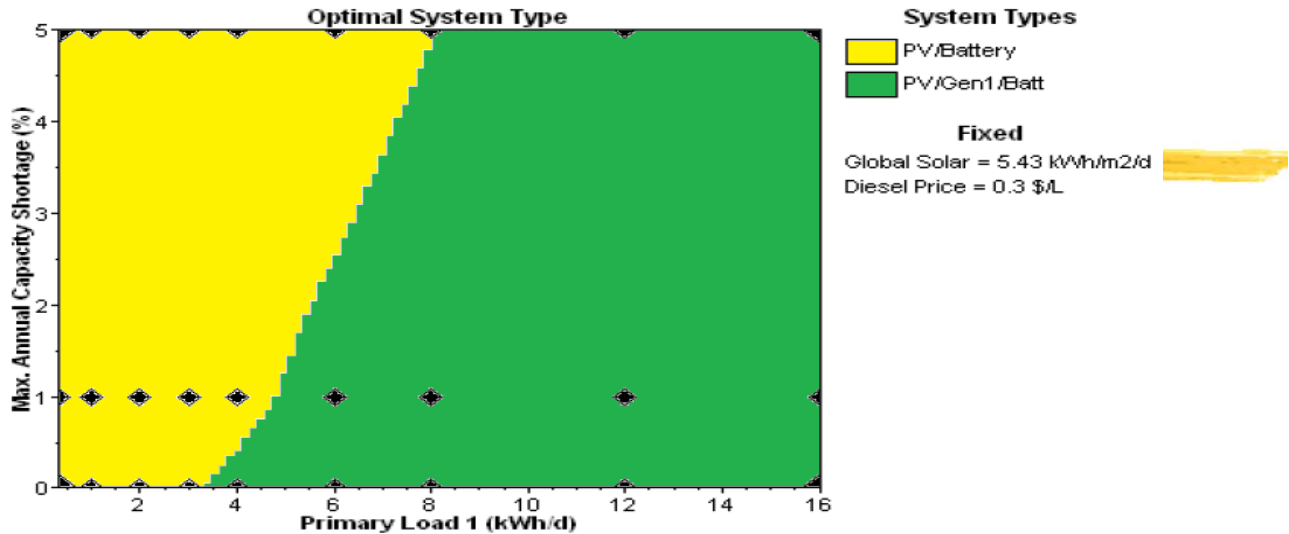
- ⌘ PV: de-rating factor at 90%
- ⌘ Battery: T-105 or L-16
- ⌘ Converters: efficiency at 90% for inversion and 85% for rectification
- ⌘ Generator: not allowed to operate at less than 30% capacity



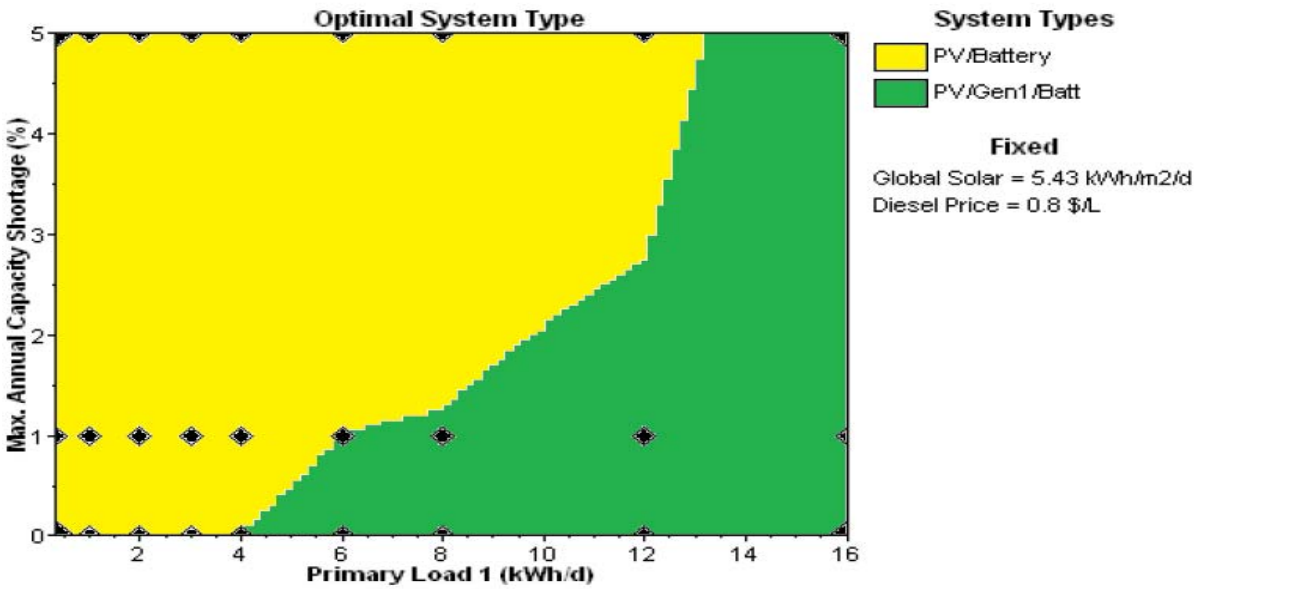
Component	Size	Capital Cost (\$)	Replacement Cost	O&M Cost (\$)	Lifetime
PV Panels	0.05 – 5.0 kW	\$7,500/kW	\$7,500/kW	0.00	20 years
Trojan T-105 Batteries	225 Ah / 6 volt (bank size: 1 – 54 batteries)	\$75/battery	\$75/battery	\$2.00/year	845 kWh of throughput per battery
Converter	0.1 – 4.0 kW	\$1,000/kW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

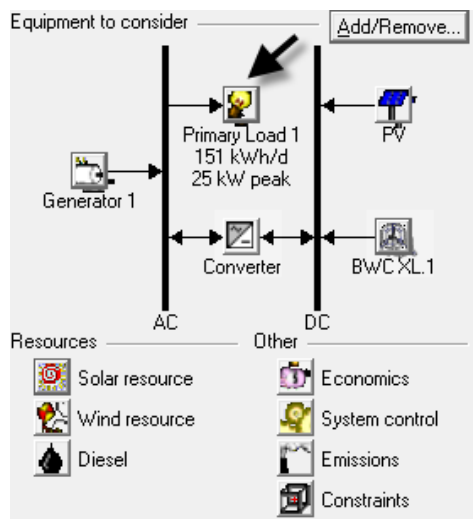
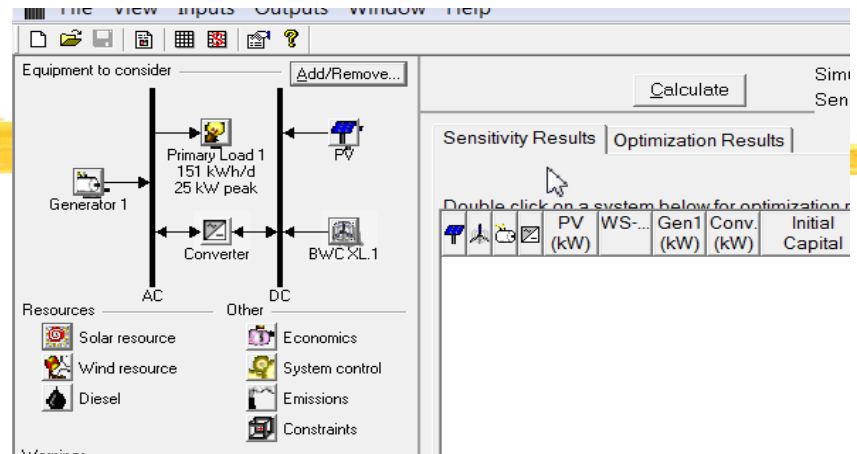


⌘ Diesel Price \$0.8/L

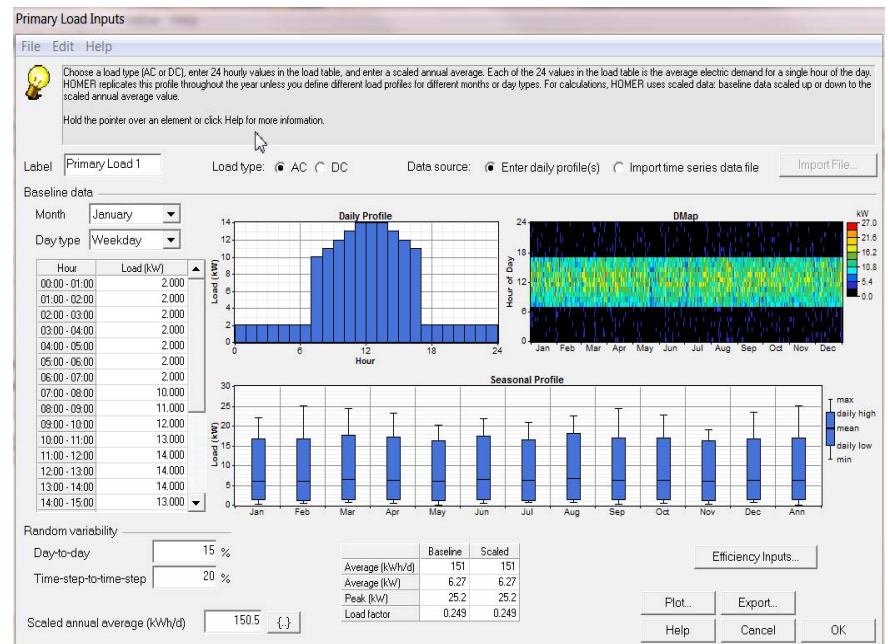


HOMER: Getting Started – with existing file

- ⌘ 1. www.mwftr.com/kt2013.html
- ⌘ 2. Download {save as }
“ExampleProject.hmr”
- ⌘ 3. Open the Example Project File:
ExampleProject.hmr
- ⌘ 4. Click the Primary Load



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



Find the Site [Location]

⌘ Latitude and Longitude

⌘ 36.76 & 127.28 ??



Latitude and Longitude of a Point

Get the Latitude and Longitude of a Point

When you click on the map, move the marker or enter an address the latitude and longitude coordinates of the point are inserted in the boxes below.

Latitude:
Longitude:



LatLong.net Lat&Long Finder

Find

Search place name or
Click on map to get lat long coordinates.

Latitude:
Longitude:

Map Mouse Over Lat & Long

Lat:
Long:

LAT and LONG --- Conversion

Convert Latitude / Longitude in Degrees... +

transition.fcc.gov/mb/audio/bickel/DDDMSS-decimal.html

Most Visited Getting Started New Tab

Go to FCC.gov

Degrees Minutes Seconds to Decimal Degrees

Enter Degrees Minutes Seconds latitude: 32 7 22.799

Enter Degrees Minutes Seconds longitude: 125 12 56.64

Convert to Decimal Clear Values

Results: Latitude: 32.123 Longitude: 125.215733

Decimal Degrees to Degrees Minutes Seconds

Enter Decimal Latitude: 32.1230

Enter Decimal Longitude: 125.1824

Convert to Degrees Minutes Seconds Clear Values

Results: Latitude: 32° 7' 22.7994" Longitude: 125° 10' 56.64"

Solar and Wind Data

- ⌘ <http://en.openei.org/apps/SWERA/>
- ⌘ Click “Homer”, input latitude and longitude, then click “Get Homer Data”

The screenshot displays the Solar and Wind Energy Resource Assessment (SWERA) web application. The main interface features a world map with a data overlay, navigation controls, and a data entry form. The data entry form includes fields for Latitude (36.76) and Longitude (127.28), a "Get HOMER Data" button, and a "Homer XML" link. Below the map, there are buttons for "Solar", "Wind", "Climate", and "Homer". The application is powered by OpenEI and is a UNEP facilitated effort administered by NREL.

Solar and Wind Energy Resource Assessment
A United Nations Environment Programme facilitated effort.

Getting Started Data Sets Analysis Tools About SWERA

Latitude: 36.76 Longitude: 127.28
Get HOMER Data Homer XML

Solar Wind Climate Homer

POWERED BY Google

SWERA is a UNEP facilitated effort administered by NREL and powered by OpenEI.

Solar Radiation and Wind Speed Data

⌘ Monthly Solar Radiation [kW/m²-day] and Wind Speed [m/s]

```

-<data>
  -<monthly>
    -<monthly_average_radiation>
      <float> 2.82 </float> Jan
      <float> 3.69 </float> Feb
      <float> 4.49 </float> Mar
      <float> 5.40 </float> Apr
      <float> 5.57 </float> May
      <float> 4.99 </float> Jun
      <float> 4.17 </float> Jul
      <float> 4.19 </float> Aug
      <float> 3.95 </float> Sep
      <float> 3.55 </float> Oct
      <float> 2.76 </float> Nov
      <float> 2.55 </float> Dec
    </monthly_average_radiation>
  </monthly>
</data>
-<scaled_annual_average>
  -<values>
    <float> 4.01 </float> Annual
  </values>

```

Annual
Average

```

<data>
  -<monthly>
    -<monthly_average_wind_speed>
      <float> 3.46 </float>
      <float> 3.66 </float>
      <float> 3.81 </float>
      <float> 3.91 </float>
      <float> 3.43 </float>
      <float> 3.03 </float>
      <float> 3.02 </float>
      <float> 2.88 </float>
      <float> 2.68 </float>
      <float> 2.73 </float>
      <float> 3.25 </float>
      <float> 3.34 </float>
    </monthly_average_wind_speed>
  </monthly>
</data>
<scaled_annual_average>
  -<values>
    <float> 3.27 </float>

```

```

-<anemometer_height>
  -<values>
    <float> 50 </float>
  </values>
</anemometer_height>

```


Import XLM File from SWERA

⌘ SWERA

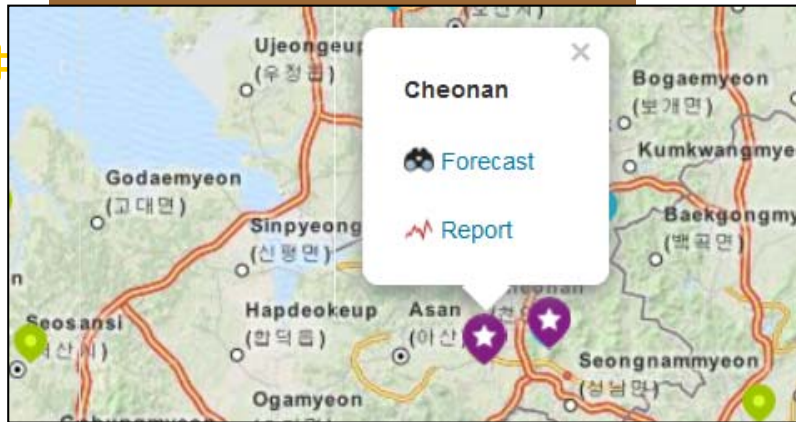
- ☑ Lat & Longs → Get Homer
- ☑ From the XLM data screen
 - ☒ CTRL+S (save to a xlm file)

⌘ 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.

Wind Finder

www.windfinder.com



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

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

Windfinder - Wind & weather statistic Cheonan

Wind statistic | Wind report | Forecast | Nearby

Cheonan (CHEONAN)

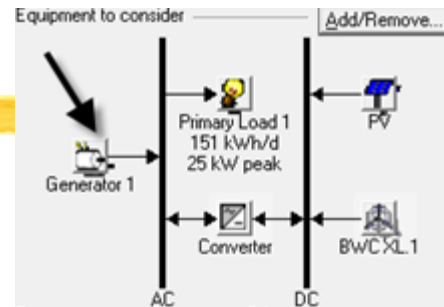
Statistics based on observations taken between 8/2011 - 12/2012 daily from 7am to 7pm local time.

Month of year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	SUM
	01	02	03	04	05	06	07	08	09	10	11	12	1-12
Dominant Wind dir.	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘	↘
Wind probability > = 4 Beaufort (%)	27	28	37	44	17	20	10	15	16	18	26	20	23
Average Wind speed (Knots)	7	9	10	11	7	8	6	7	7	7	9	7	7
Average air temp. (°C)	0	0	7	14	22	26	27	27	23	16	10	0	14
Select month (Help)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year

Wind dir. distribution Cheonan December

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

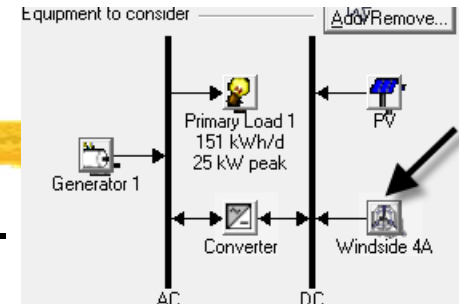
Cost Curve

Size (kW)	Capital Cost (000 \$)	Replacement Cost (000 \$)
0	0	0
10	4	3.5
20	8	7
30	12	10.5
40	16	14

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 kWDC
- Manufacturer:
- Website: www.windside.com

Costs

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

Sizes to consider

Quantity
0
1
2
3

Other

- Lifetime (yrs): 15 [{}]
- Hub height (m): 25 [{}]

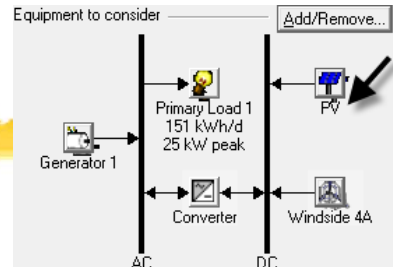
Power Curve

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

Sizes to consider

Size (kW)
0.000
10.000
15.000
20.000
25.000

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 (%)

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

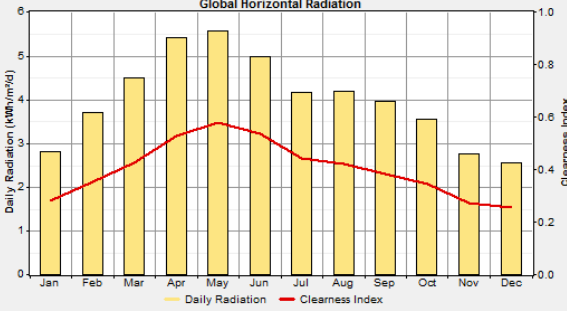
Data source: Enter monthly averages Import time series data file

Baseline data

Month	Clearness Index	Daily Radiation (kWh/m ² /d)
January	0.280	2.820
February	0.395	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)



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 or a clearness index for each month. HOMER uses the scaled data control to control how HOMER generates the 8760 hours of wind speed data.

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)

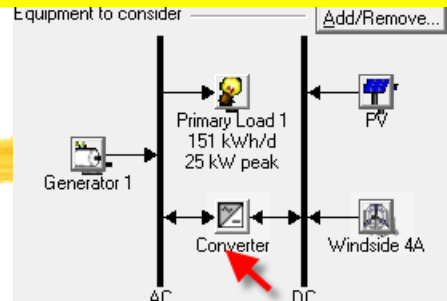
Fuel properties

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.

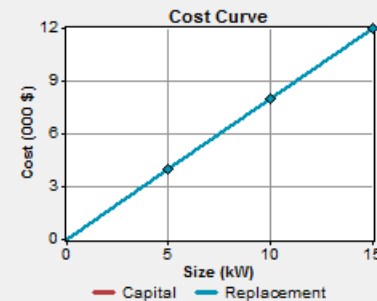
Costs

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 (%) { }

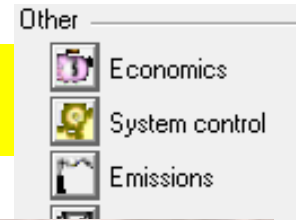
Efficiency (%) { }

Help

Cancel

OK

Other Information



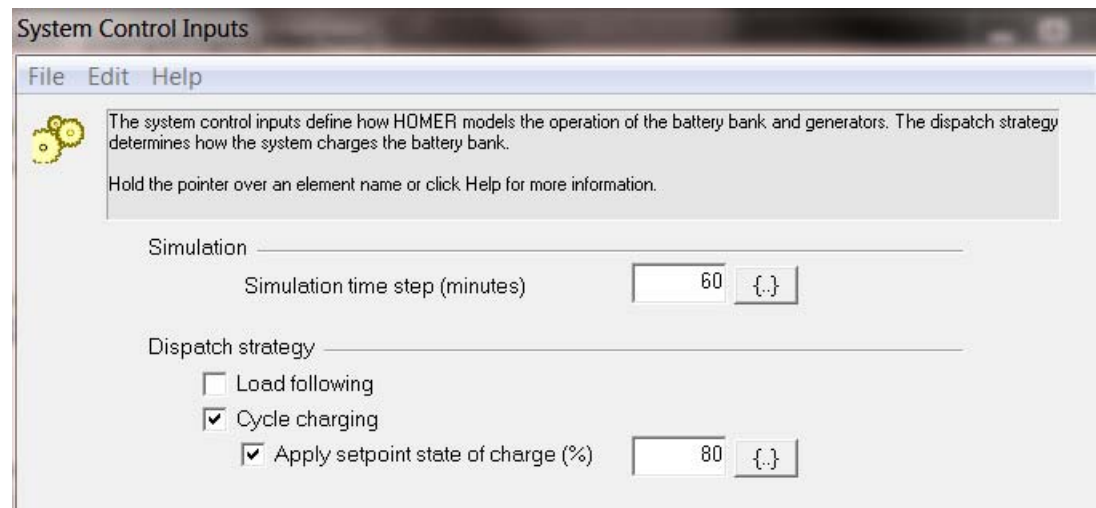
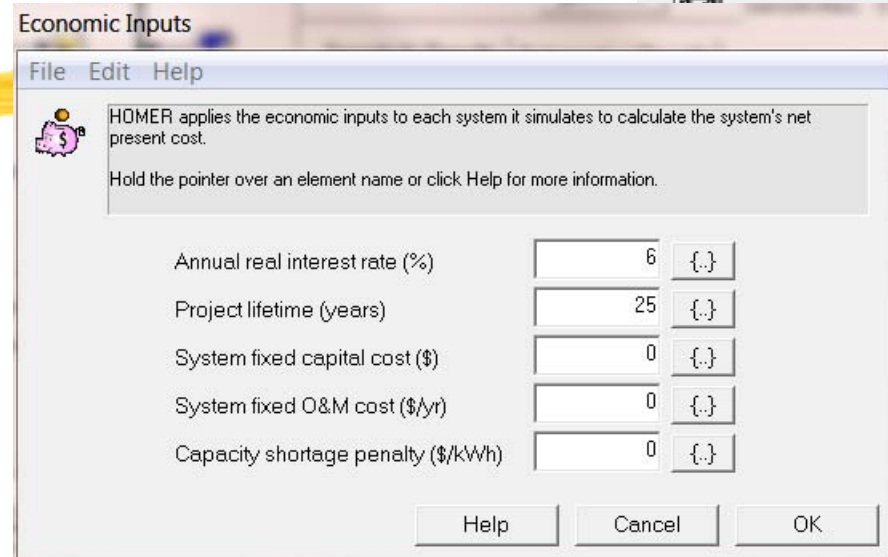
⌘ Economics

☑ 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 lc 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 (%) 0 {}

Minimum renewable fraction (%) 0 {}

Operating reserve

As percent of load

Hourly load (%) 10 {}

Annual peak load (%) 0 {}

As percent of renewable output

Solar power output (%) 25 {}

Wind power output (%) 50 {}

Primary energy savings

Minimum primary energy savings (%) 10 {}

Reference electrical efficiency (%) 33 {}

Reference thermal efficiency (%) 75 {}

Emission Calculation in HOMER

⌘ Carbon content of fuel

⌘ If CO2 is only interest

⏏ Set 0 to CO

⏏ Set 0 to UHC

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/m ³
Carbon content:	88 %
Sulfur content:	0.33 %

Help Cancel OK

⌘ Natural Gas


Fuel properties

Lower heating value:	45 MJ/kg
Density:	0.79 kg/m ³
Carbon content:	67 %
Sulfur content:	0.33 %

Help Cancel OK

⌘ Gasoline

Gasoline Fuel Properties



Lower heating value:	44 MJ/kg
Density:	740 kg/m ³
Carbon content:	86 %
Sulfur content:	0.33 %

ExportXML Help Close

Carbon Tax or Penalty

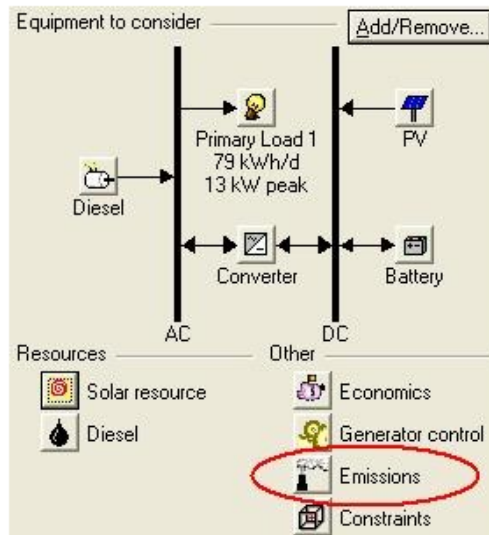
10397 - HOMER and Carbon

Posted by on 04 January 2011 11:50 AM

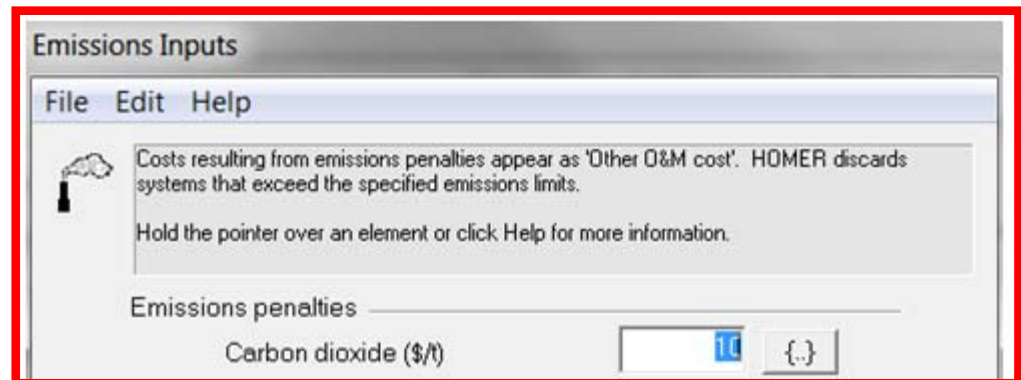


The best way to use HOMER and Carbon? Two scenarios suppose you are carbon capped would you just put in a fuel cap. If you are carbon taxed would you just add cost to fuel.

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

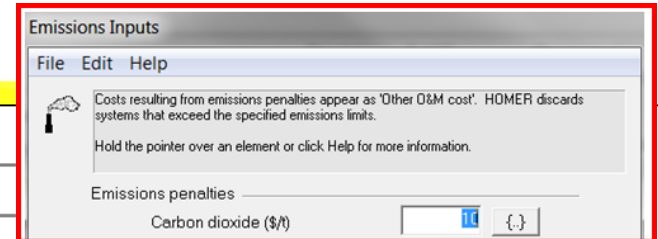
Project Period = 25 years

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

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



36,095,104 for no carbon penalty

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

2,823,602 for no carbon penalty

Check with MathCad



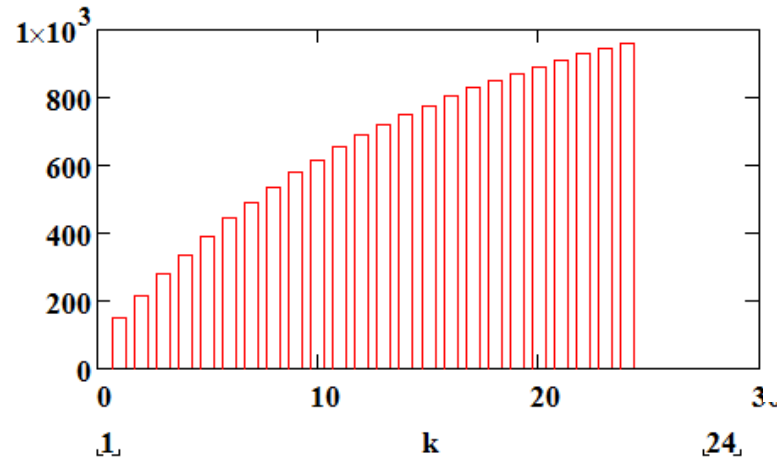
Function in MathCad (for Present value)

```
PV(Cash, Discount, n) :=
  Sum ← 0
  for i ∈ 1.. n
    Sum ← Sum +  $\frac{\text{Cash}_i}{(1 + \text{Discount})^i}$ 
  return Sum
```

Generation of Graphs

```
m := 0.. 24
Cm := 76.9
npv1_0 := C_0
k := 1.. 24
npv1_k := C_0 + PV(C, r, k)
```

958.892
npv1_k
148.769



npv1 =

	0
0	76.9000
1	148.7692
2	215.9366
3	278.7099
4	337.3765
5	392.2052
6	443.4469
7	491.3364
8	536.0929
9	577.9214
10	617.0134
11	653.5481
12	687.6926
13	719.6033
14	749.4265
15	777.2986
16	803.3473
17	827.6918
18	850.4438
19	871.7073
20	891.5797
21	910.1521
22	927.5094
23	943.7312
24	958.8918

Emission Input – Emission Penalty

The screenshot displays the HOMER software interface. The main window shows 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 list of emissions penalties with input fields. The 'Carbon dioxide (\$/t)' field is highlighted with a red circle and contains the value '2.00'. The dialog box also contains a menu bar (File, Edit, Help) and a text area with instructions.

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
 Calculate
 Sensitivity Results | Optimization Results
 Double click on a system below for optimization results.
 Export... Details...
 PV (kW) WS-... Gen1 (kW) Conv. (kW) Initial Capital Operating Cost (\$/yr) Total NPC

⌘ Click Overall: view all possible combinations

Calculate 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...
			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. Categori 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.

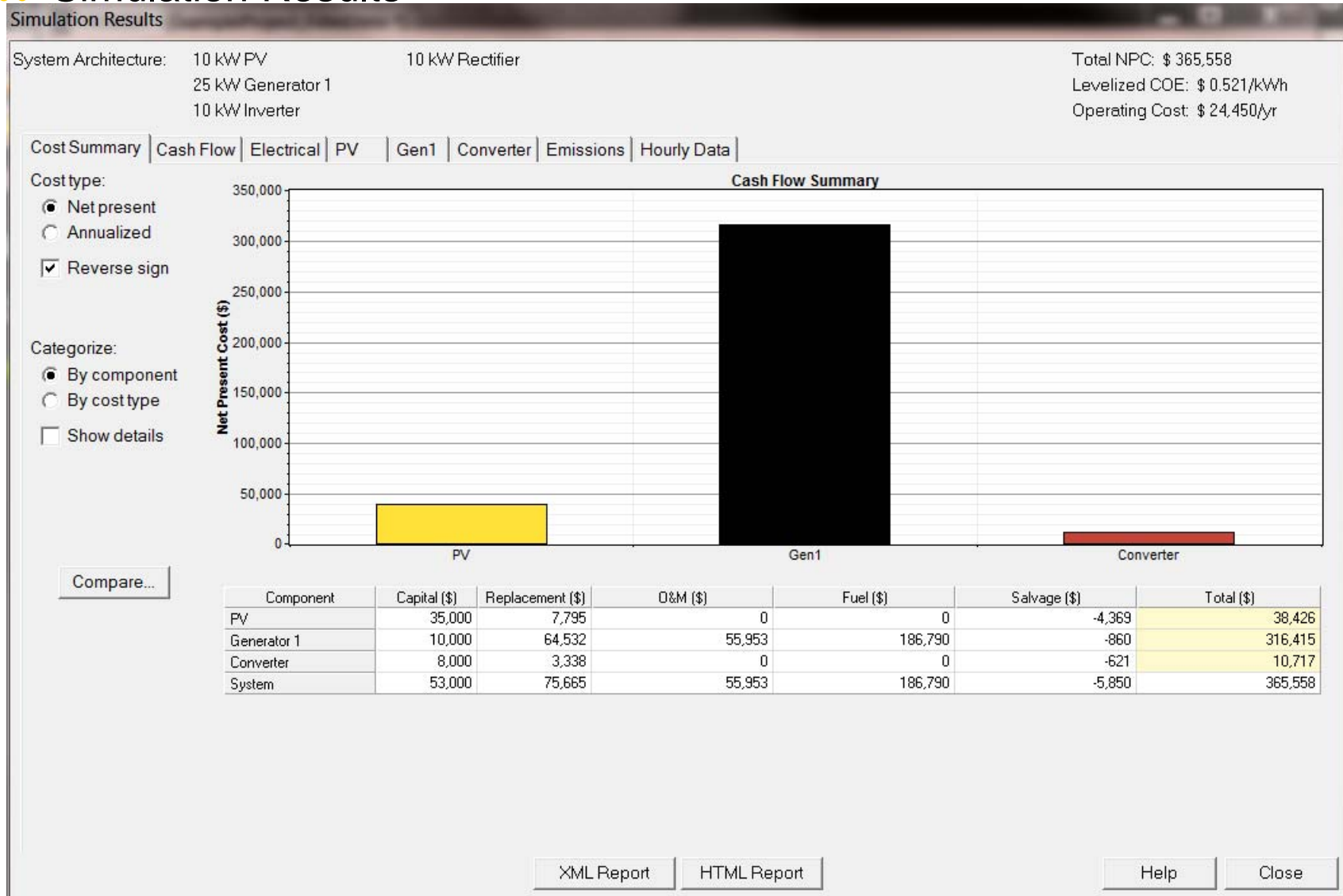
Sensitivity Results Optimization Results

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

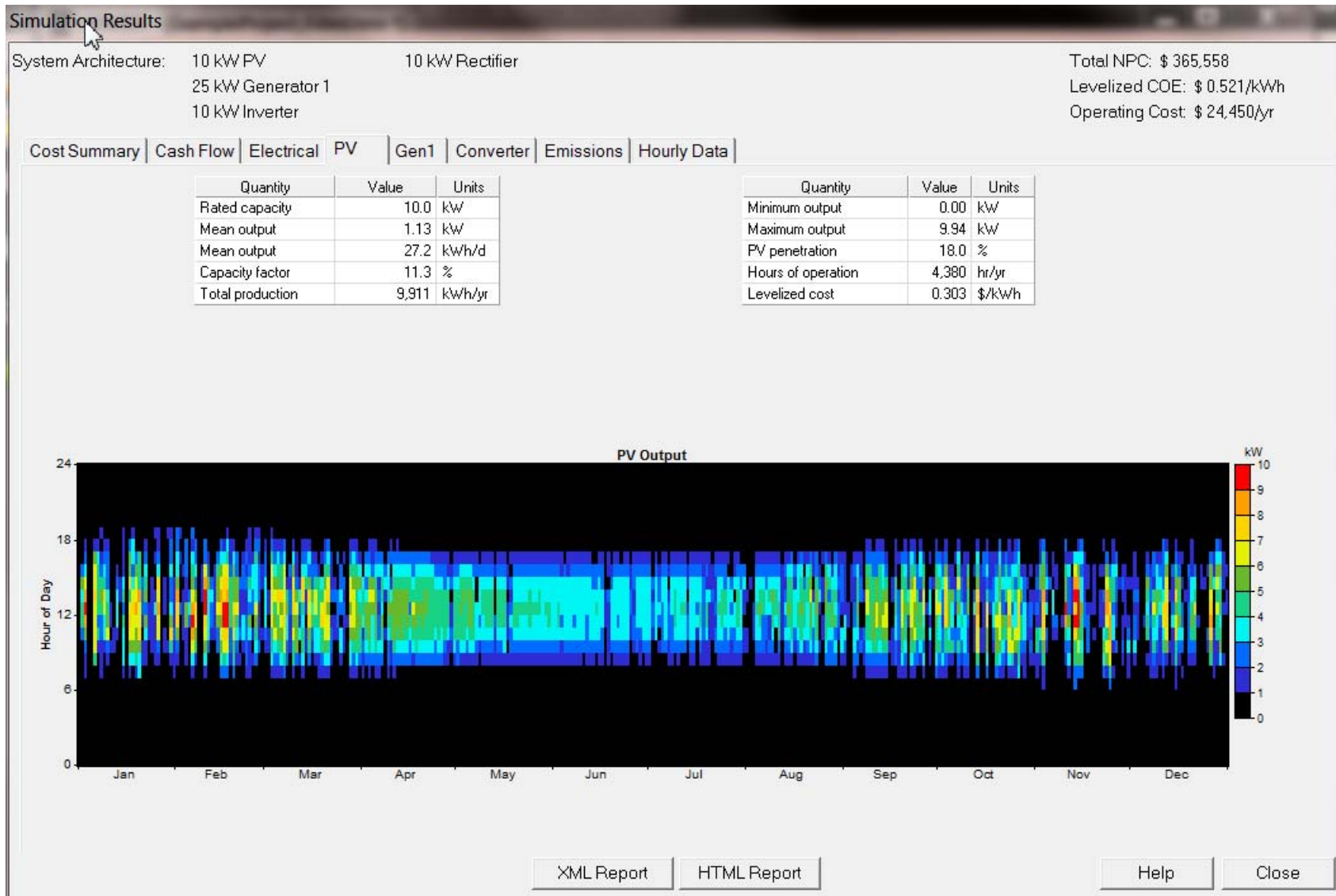
	PV (kW)	WS-...	Gen1 (kW)	Conv. (kW)	Initial Capital	Operating Cost (\$/yr)	Total NPC	COE (\$/kW...	Ren. Frac.	Diesel (L)	Gen1 (hrs)
			25		\$ 10,000	24,713	\$ 325,917	0.464	0.00	38,374	8,7...
	10		25	5	\$ 49,000	24,361	\$ 360,419	0.513	0.12	36,573	8,7...
	10		25	10	\$ 53,000	24,450	\$ 365,558	0.521	0.12	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	▲	Clear
2	5.500		
3	7.500		
4	9.500		
5			
6			
7			
8			
9			
10			
11			
12			

Help Cancel OK

Primary Load

Sensitivity Values

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

Values:

1	150,500	▲	Clear
2	100,000		
3	50,000		
4	25,000		
5			
6			
7			
8			
9			
10			
11			
12			

Help Cancel OK

Solar Resources

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			
11			
12			

Help Cancel OK

⌘ Diesel Fuel

Sensitivity Values

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

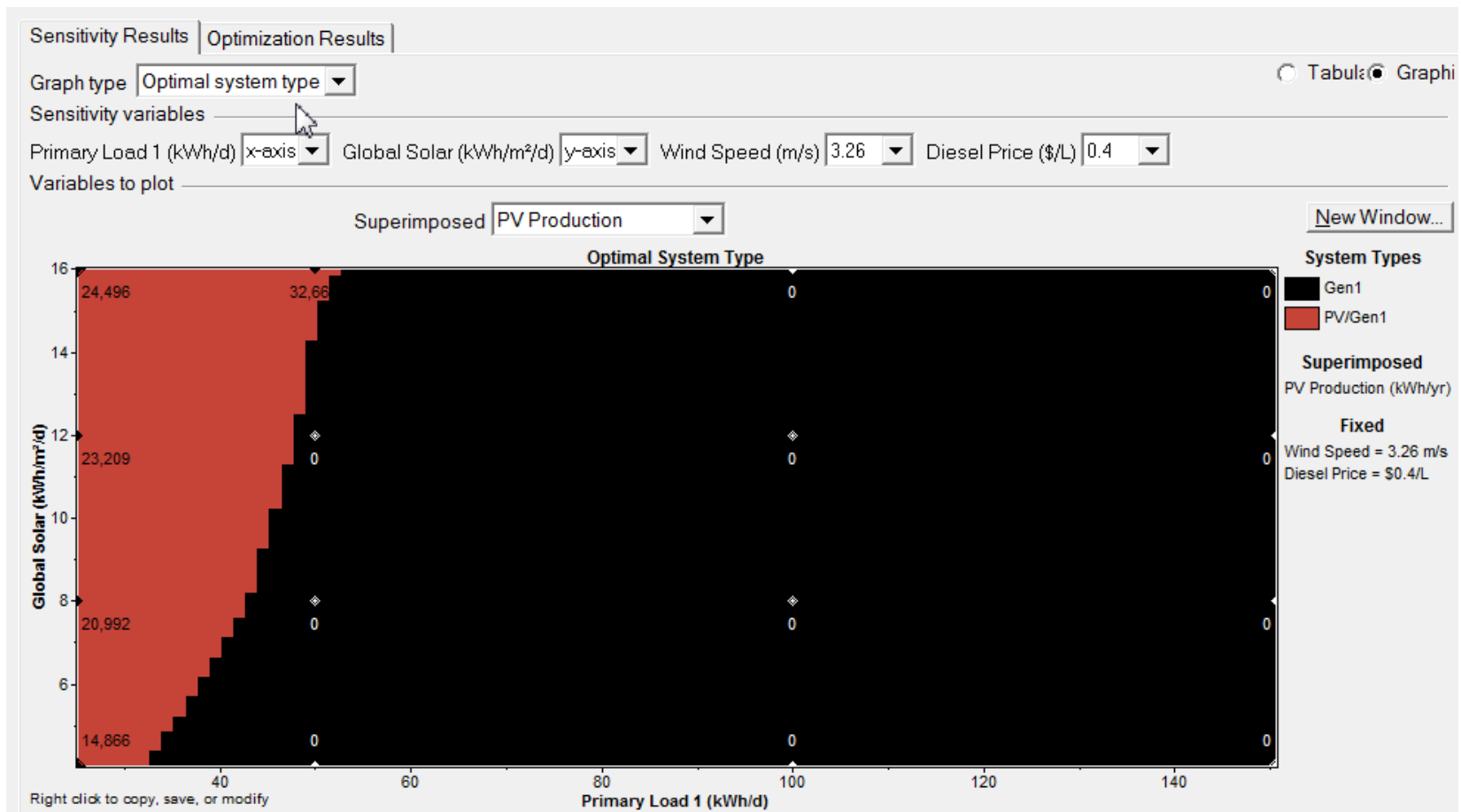
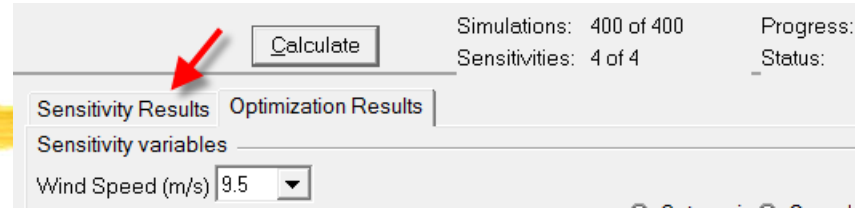
Values:

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

Help Cancel OK

Sensitivity Analysis

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

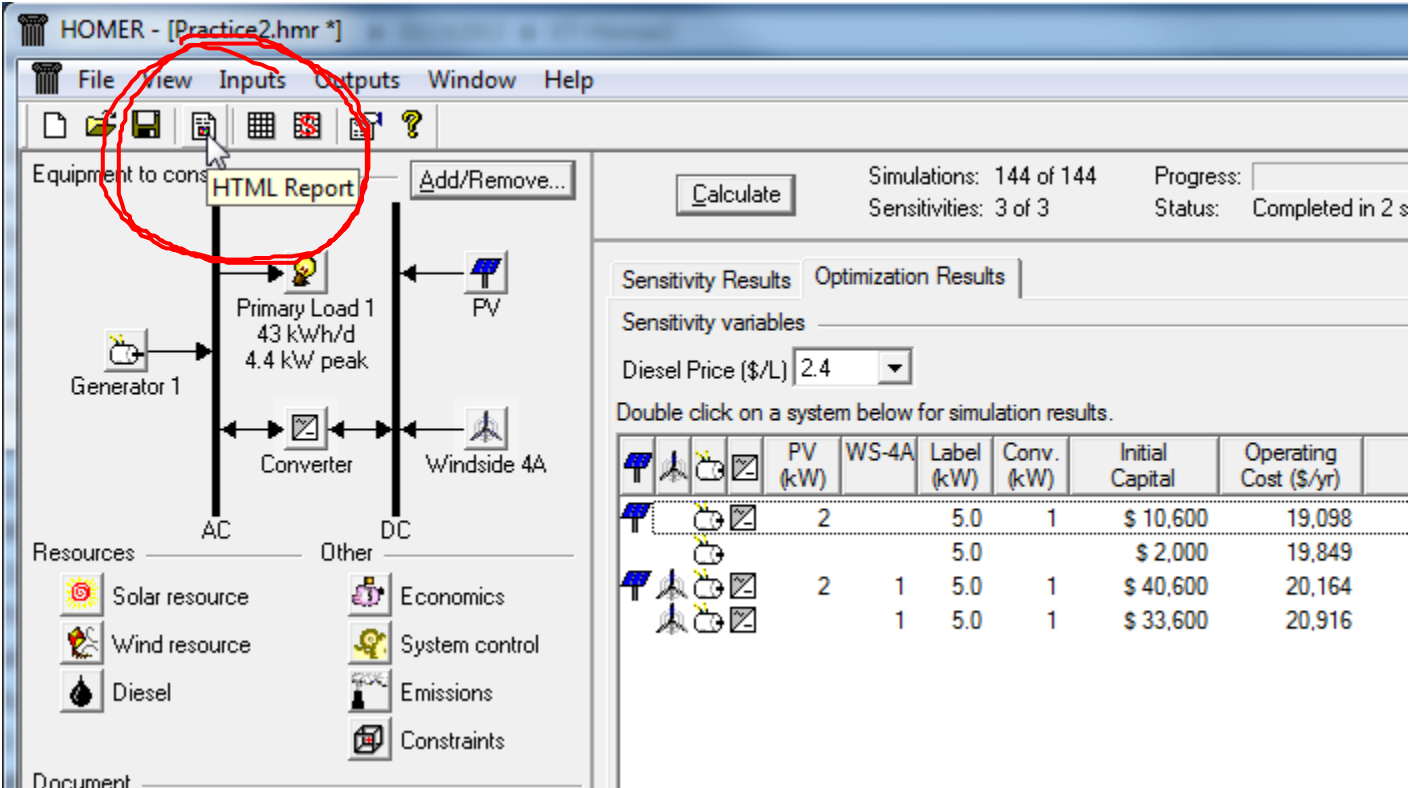


HOMER – Input Summary Report

⌘ 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 title bar reads "HOMER - [Practice2.hmr *]". The menu bar includes "File", "View", "Inputs", "Outputs", "Window", and "Help". The toolbar contains various icons, with the "HTML Report" icon (a document with a printer) circled in red. Below the toolbar, the main workspace displays a system diagram with components like "Generator 1", "Primary Load 1" (43 kWh/d, 4.4 kW peak), "PV", "Converter", and "Windside 4A". The diagram is divided into "AC" and "DC" sections. On the left, there are "Resources" (Solar, Wind, Diesel) and "Other" (Economics, System control, Emissions, Constraints). On the right, there are simulation controls including a "Calculate" button, "Simulations: 144 of 144", "Sensitivities: 3 of 3", and "Status: Completed in 2 s". Below these are tabs for "Sensitivity Results" and "Optimization Results". A "Sensitivity variables" section shows "Diesel Price (\$/L)" set to 2.4. A table below lists simulation results for different system configurations.

	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

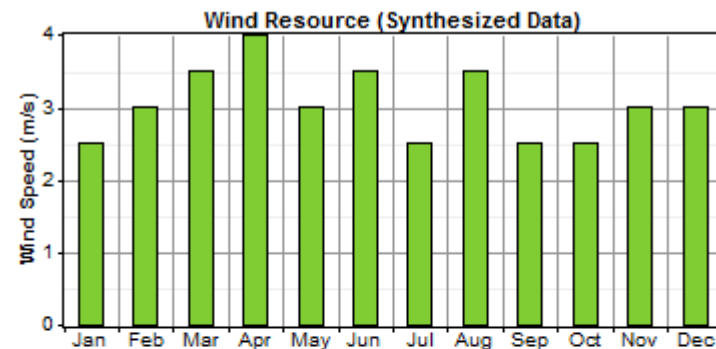
Load Profile (Synthesized Data)

Hour	Demand (kW)
0	1.3
1	1.3
2	1.3
3	1.3
4	1.3
5	1.3
6	1.4
7	1.5
8	1.6
9	1.8
10	2.0
11	2.2
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	1.7
22	1.6
23	1.5
24	1.3

PV

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

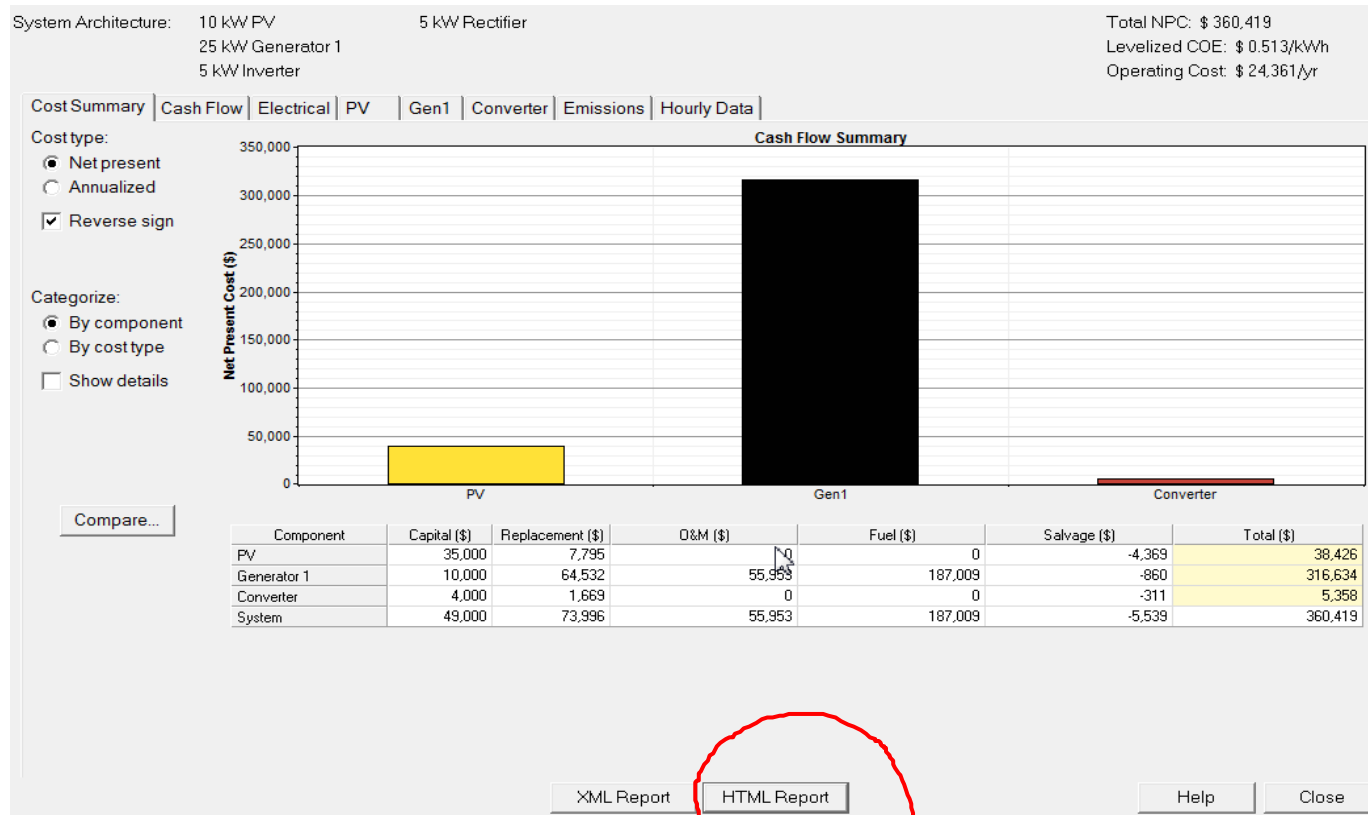
Sizes to consider: 0, 2, 4, 6 kW
 Lifetime: 20 yr
 Derating factor: 80%
 Tracking system: No Tracking
 Slope: 0 deg
 Azimuth: 0 deg
 Ground reflectance: 20%



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

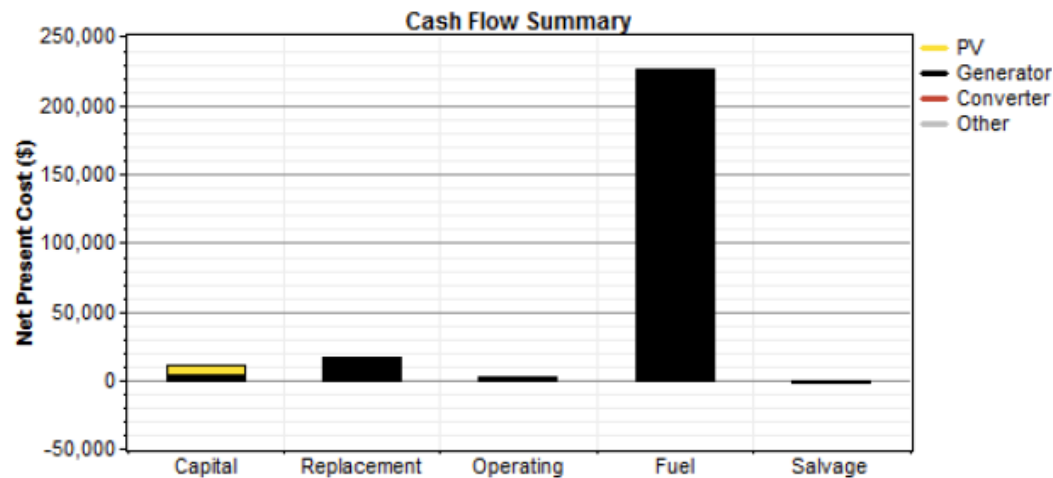
Diesel Price: 2.4 \$/L

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



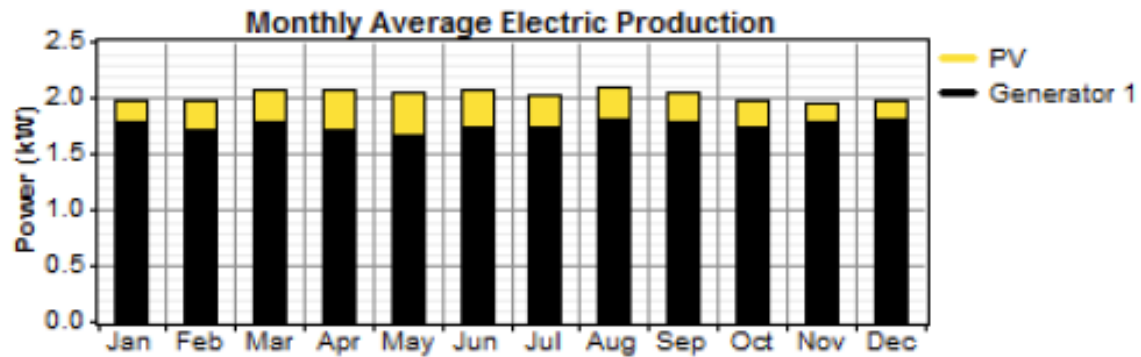
Net Present Costs

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

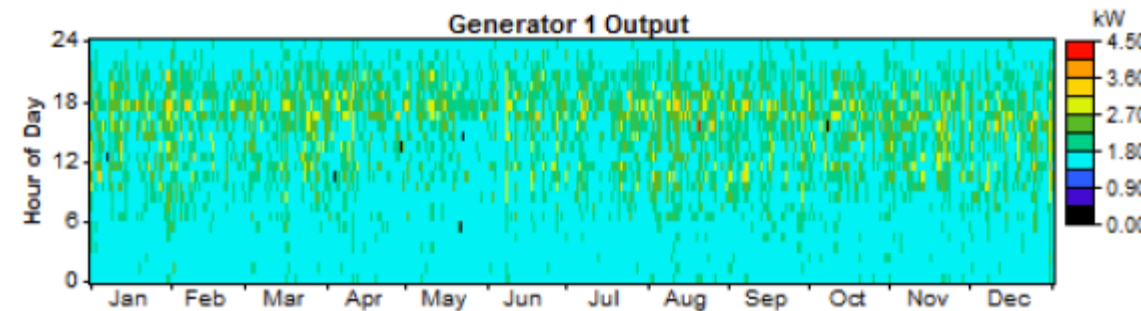
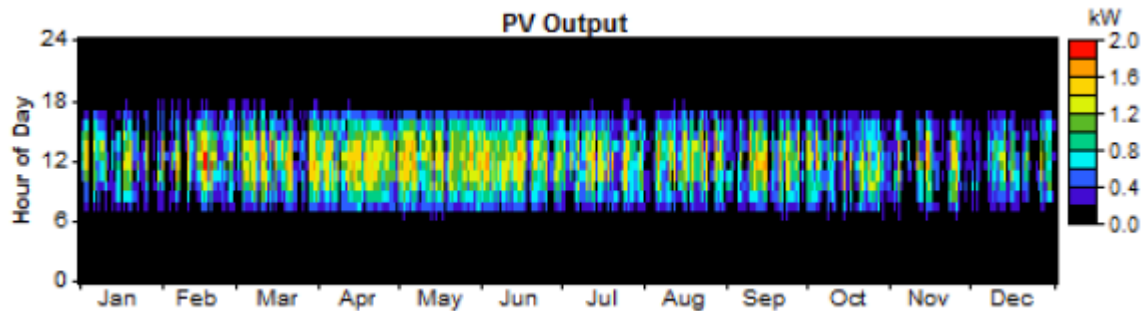
Component	Production	Fraction
	(kWh/yr)	
PV array	2,341	13%
Generator 1	15,396	87%
Total	17,737	100%

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 states: "Generator 1 search space may be insufficient." Below this, a status message says "Completed in 3 seconds." The main window displays the "Cost" tab, which includes a table for "Costs" and a "Cost Curve" graph. The "Costs" table has the following data:

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

The "Cost Curve" graph plots Cost (\$) on the y-axis (0 to 2,000) against Size (kW) on the x-axis (0 to 5). It shows two lines: a red line for Capital cost and a blue line for Replacement cost. The Replacement cost line is linear, starting at (0,0) and ending at (5,2000). The Capital cost line is a horizontal line at approximately 2000 dollars. The graph also shows a legend for "Capital" (red) and "Replacement" (blue).

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.