SOLAR ENERGY TECHNOLOGY

ETC ENERGY

Modeling Software for RE Systems

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Jakarta
Indonesia

Training Course on Renewable Energy Part II - MEMR CASINDO

Structure of this Presentation

- Software categories
- Examples of available software
- Where to get software
- Evaluation of different software
- HOMER software

Software Categories

- Pre-feasibility Tools
- Sizing Tools
- Simulation Tools
- Open architecture environment

Trend:
Engineers tools => wider audiences

Considerations

- Software is a tool => it requires an expert to manipulate the tool
- Garbage in => Garbage out
- Software needs to be verifiable
- May not be designed for this region
- First obtain an idea of what is having the largest effect, before starting with details

Software Examples (1)

Program	Function	Plant	Outputs
RET Screen	Prefeasibility	Hybrids	Power, LCC, GHG Emissions
NSOL!	Sizing	Mainly PV	Power, Fuel Consumption
HOMER	Sizing, Optimisation	Hybrids	Cost, Configuration
Hybrid Designer	Sizing	Hybrids	Cost, Configuration
PVSYST	Sizing, Simulation	PV	Cost, Configuration

Software Examples (2)

PV*SOL	Sizing	PV	Cost, Emissions
ViPOR	Optimisation	Any	Costs/Profit, Configuration (mini-grid or stand alone)
Hybrid 2	Simulation	Hybrids	Performance predictions, Costs
PV Design Pro-S	Simulation	PV	Power, Load Consumption, Costs
SOMES	Simulation, Optimisation	Hybrids	Power, Reliability, Costs
Solar Pro	Simulation	PV	Power

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Where to Get? (1)

- **RETScreen**
http://retscreen.gc.ca
- **FATE2-P3.1.1**
www.nrel.gov/international/tools/tools.html
- **NSOL!**
Www.orionenergy.com/Nsol/nsolhome.html
- **HOMER**
www.nrel.gov/homer
- **Hybrid Designer**
www.edr.uct.ac.za
- **PVSYST3.21**
www.unige.ch/cuepe/pvsyst/index.htm
- PV*SOL Pro 2.2
- www.valentin.de

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Where to Get? (2)

- **PV*SOL Pro 2.2**
www.valentin.de
- **ViPOR**
www.nrel.gov/international/vipor
- **Hybrid2**
www.ecs.umass.edu/mie/labs/rerl
- **Solar Design Studio v5.0**
www.mauisolarsoftware.com
- **SOMES**
www.che.uu.nl
- **Solar Pro**
www.lapsys.co.jp/english/e_index.html
- **SUNDI**
www.ftp://emsolar.ee.tu-berlin.de/pub/progs/sundi

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Photovoltaic System Builder

- Developed in South Africa
- Inputs: load power, days autonomy, panel type, battery type, weather data, array tilt angle, system voltage, inverter efficiency, depth of discharge
- Outputs: number of batteries and panels, excess power

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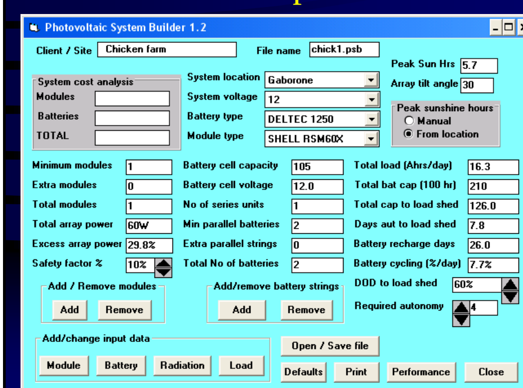
PSB Data Input Screen



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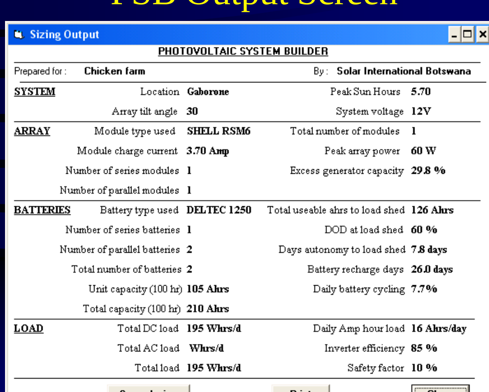
PSB Output Screen



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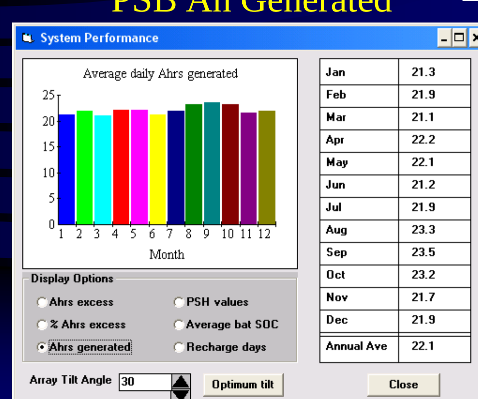
PSB Ah Generated



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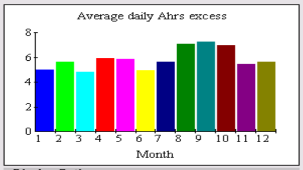
PSB Daily Ahr Excess

System Performance



Jan	5.0
Feb	5.6
Mar	4.8
Apr	6.0
May	5.8
Jun	4.9
Jul	5.6
Aug	7.1
Sep	7.3
Oct	7.0
Nov	5.4
Dec	5.6
Annual Ave	5.9

Display Options

- Ahrs excess
- % Ahrs excess
- Ahrs generated
- PSH values
- Average bat SOC
- Recharge days

Array Tilt Angle 30 — Optimum tilt — Close

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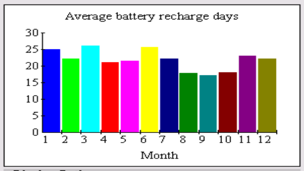
PSB Battery Recharge Days

System Performance



Jan	25.1
Feb	22.3
Mar	26.2
Apr	21.2
May	21.6
Jun	25.6
Jul	22.3
Aug	17.8
Sep	17.3
Oct	18.1
Nov	23.2
Dec	22.3
Annual Ave	21.9

Display Options

- Ahrs excess
- % Ahrs excess
- Ahrs generated
- PSH values
- Average bat SOC
- Recharge days

Array Tilt Angle 30 — Optimum tilt — Close

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RETScreen (PV2000)

- Pre-feasibility tool
- Developed by CEDRL Canada
- Excel based
- Freeware http://retscreen.gc.ca
- Sizing and costing
- Outputs: Power, LCC, GHG Emissions

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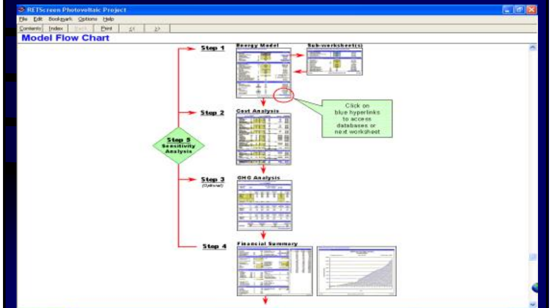
RETScreen Flow Chart



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Site and System Characteristics

RETScreen® Energy Model - Photovoltaic Project

Site Conditions		Estimate	Notes/Range
Project name		Telecom Station	
Project location		Nahual Mapi, Argentina	
Nearest location for weather data	-	Neuquen A	Complete SR&SL sheet
Latitude of project location	°N	-39.0	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	1.62	
Annual average temperature	°C	14.5	-20.0 to 30.0
DC energy demand for months analysed	MWh	2.845	
AC energy demand for months analysed	MWh	2.102	

System Characteristics		Estimate	Notes/Range
Application type	-	Off-grid	
PV system configuration	-	PV/bat./genset	
Base Case Power System			
Source	-	Genset	
Fuel type	-	Diesel (#2 oil)	
Specific fuel consumption	L/kWh	0.5500000	
Power Conditioning			
Suggested inverter (DC to AC) capacity	kW (AC)	0.36	
Inverter capacity	kW (AC)	0.5	
Average inverter efficiency	%	90%	80% to 95%
Miscellaneous power conditioning losses	%	0%	0% to 10%
Battery			
Days of autonomy required	d	2.0	1.0 to 15.0
Nominal battery voltage	V	24.0	12.0 to 120.0
Battery efficiency	%	85%	50% to 85%
Maximum depth of discharge	%	70%	20% to 85%
Charge controller (DC to DC) efficiency	%	95%	85% to 95%
Battery temperature control	-	Minimum	
Minimum battery temperature	°C	15.0	0.0 to 15.0
Average battery temperature derating	%	3%	0% to 50%
Suggested nominal battery capacity	Ah	1,770	
Nominal battery capacity	Ah	1,770	
PV Array			
PV module type	-	mono-Si	
PV module manufacturer / model #		ABC Inc.	See Product Database
Nominal PV module efficiency	%	13.0%	4.0% to 15.0%
NOCT	°C	45	40 to 55
PV temperature coefficient	% / °C	0.40%	0.10% to 0.50%
PV array controller	-	MPPT	
Miscellaneous PV array losses	%	0.0%	0.0% to 20.0%
Suggested nominal PV array power	kWp	1.30	
Nominal PV array power	kWp	1.30	

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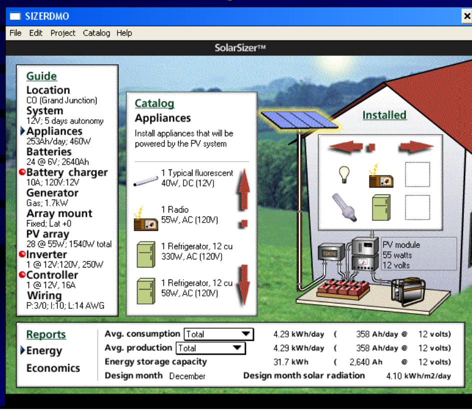
Screen Layout SIZER



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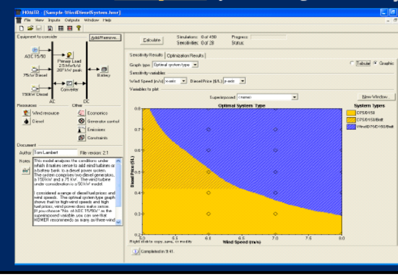
What is HOMER?

Tim Weis, M.Sc.
Pembina Institute for Appropriate Development

- Originally: Hybrid Optimization Model for Electric Renewables
- Now: A tool for micropower system design and analysis



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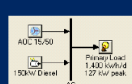
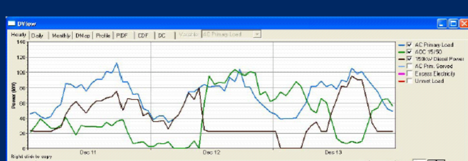
What does HOMER do?

- Simulates many types of systems using a one-hour time step





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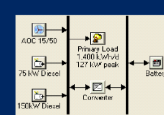
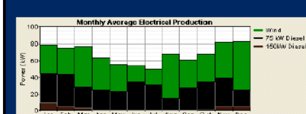
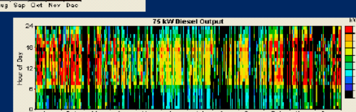
Technology Combinations

- Analyzes system performance…







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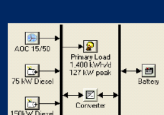
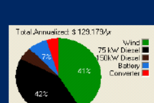
Technology Combinations

- … and economics

Component	Initial Capital ($)	Annualized Capital ($/yr)	Annualized Replacement ($/yr)	Annual O&M ($/yr)	Annual Fuel ($/yr)	Total Annualized ($/yr)
AOC 15/50	530,000	41,460	0	12,000	0	53,460
75 kW Diesel	30,000	2,347	1,984	368	49,183	53,882
150kW Diesel	40,000	3,129	-509	306	3,955	6,881
Battery	72,000	5,632	2,390	1,440	0	9,462
Converter	60,000	4,694	0	800	0	5,494
Totals	732,000	57,262	3,865	14,914	53,137	129,179





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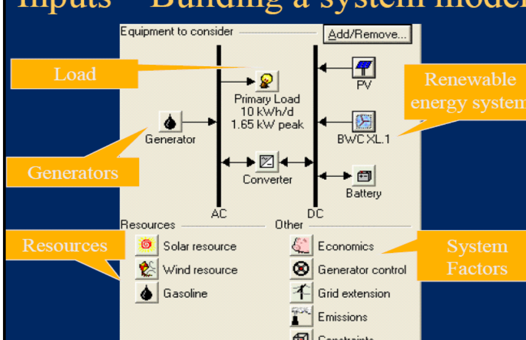
Inputs – Building a system model



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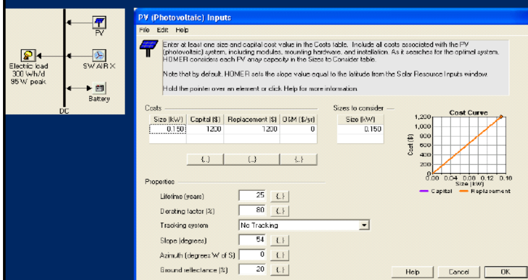
Inputs – Renewable Energy System



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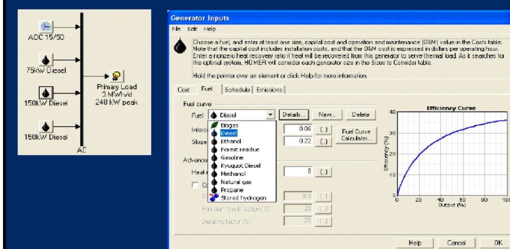
Inputs – Fuel Generators



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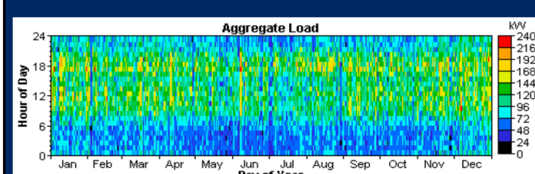
Inputs - Load



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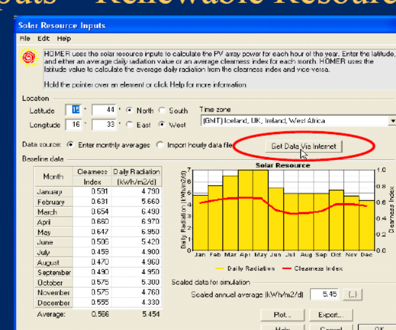
Inputs – Renewable Resource



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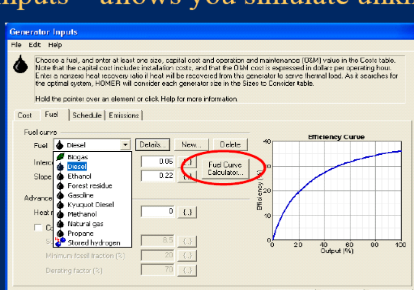
Inputs – allows you simulate unknowns



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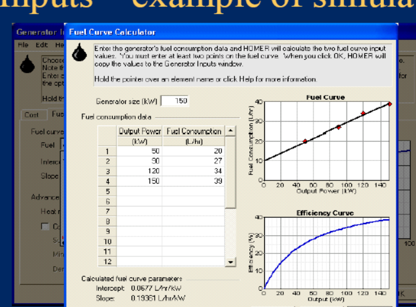
Inputs – example of simulation



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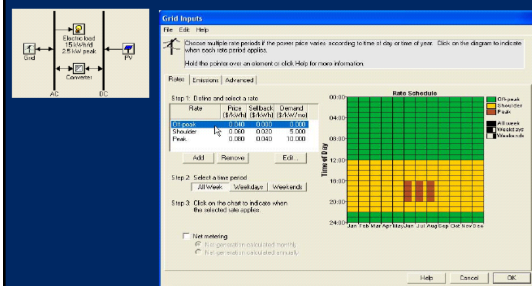
Inputs - Grid



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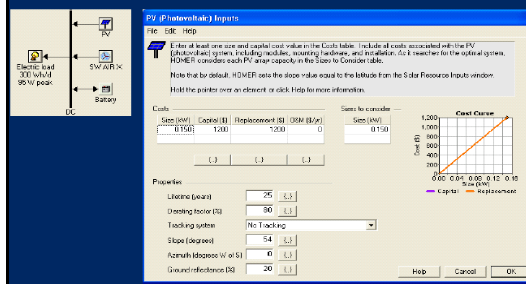
Help System



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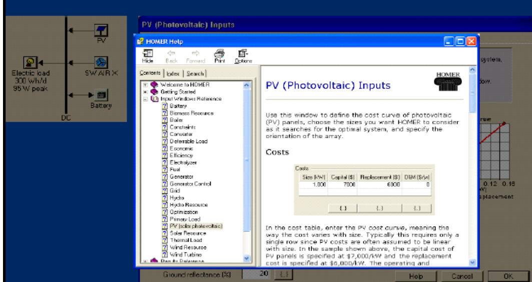
Help System



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HOMER Calculates Life-Cycle Cost

- The total cost of a system over its useful life
  - Initial capital costs
  - Operating and maintenance costs
  - Fuel costs
  - Component replacement costs
  - Grid purchases and sales
  - Salvage value
- Expressed as a lump sum in "today's dollars"

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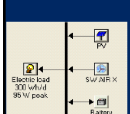
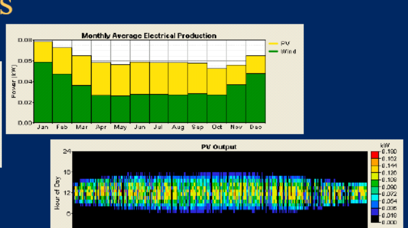
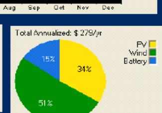
Outputs





Component	Initial Capital ($)	Annualized Capital ($/yr)	Annualized Replacement ($/yr)	Annual O&M ($/yr)	Annual Fuel ($/yr)	Total Annualized ($/yr)
PV Array	1,200	94	0.0	0	0	94
SW AIR X	1,200	94	29.2	20	0	143
Battery	260	20	13.8	8	0	42
Totals	2,660	208	43.0	28	0	279



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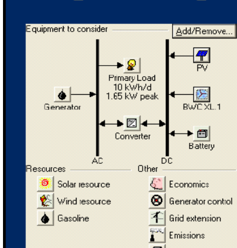
Outputs - Optimization



- What size PV array?
- How many wind turbines?
- How many batteries?
- What size generator?
- RET vs. Generator

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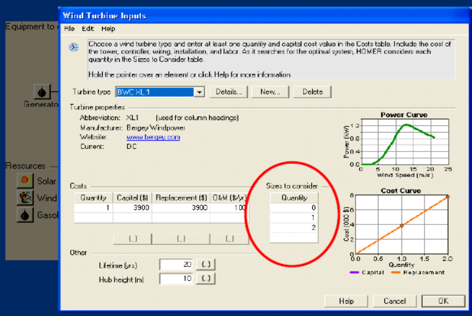
Optimization



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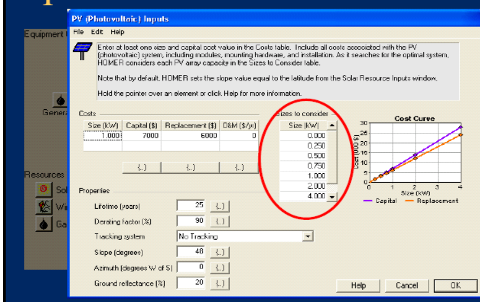
Optimization



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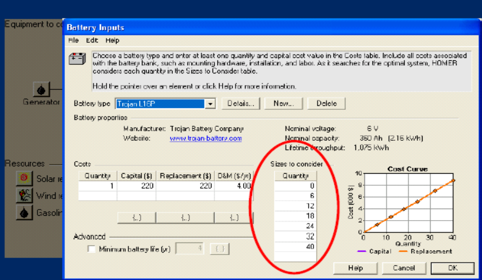
Optimization



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Optimization Results

Sensitivity Results | Optimization Results

Double click on a system below for simulation results. (•) Categorized ( ) Overall Export

PV (kW)	XL1	Gen (kW)	Batt.	Conv. (kW)	Initial Capital	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Gasoline (L)	Gen (hrs)
1.00	1	2.6	12	1.00	$ 15,190	$ 25,406	0.652	0.73	0.00	705	880
	2	2.6	12	2.00	$ 12,840	$ 26,589	0.682	0.70	0.00	829	858
2.00	1		18	2.00	$ 23,360	$ 28,400	0.739	1.00	0.01		
2.00		2.6	12	1.00	$ 18,290	$ 29,069	0.746	0.69	0.00	789	976
		2.6	12	2.00	$ 5,040	$ 32,319	0.829	0.00	0.00	2,415	2,400
4.00			32	2.00	$ 36,540	$ 42,564	1.113	1.00	0.02		
	2	2.6		1.00	$ 9,450	$ 48,081	1.234	0.52	0.00	3,238	6,289
1.00	2	2.6		1.00	$ 16,450	$ 48,385	1.242	0.66	0.00	2,637	5,114
		2.6			$ 900	$ 50,893	1.306	0.00	0.00	4,570	8,760
1.00		2.6		0.75	$ 8,463	$ 52,763	1.354	0.26	0.00	4,039	7,753

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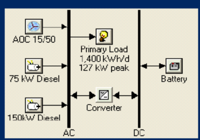
Outputs - Sensitivity Analysis



- Key variables may be uncertain
  - Wind speed
  - Fuel price
  - Wind turbine life
- What if our guesses are wrong?

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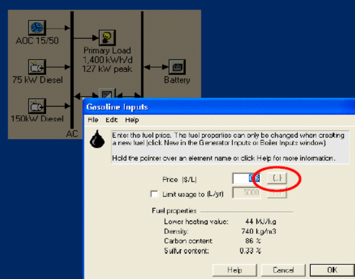
Sensitivity Analysis



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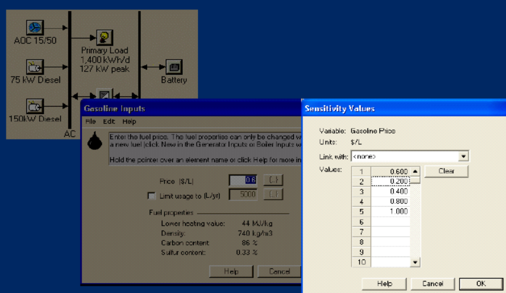
Sensitivity Analysis



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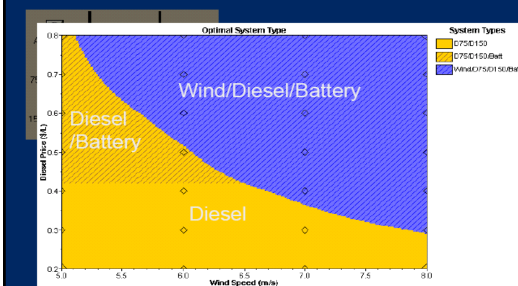
Results - Sensitivity Analysis



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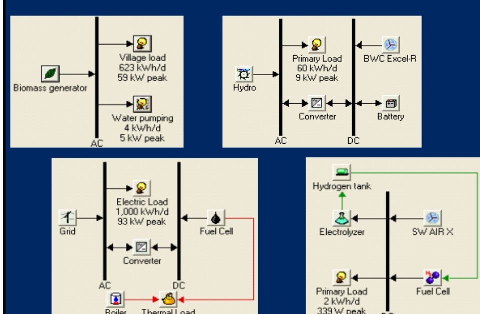
Many Other Kinds Of Systems



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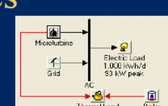
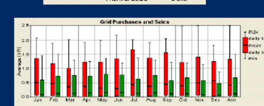
Other Features

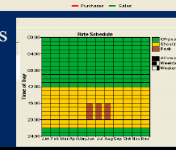
- Cogen systems



- Net Metering



- Multiple Grid Rates



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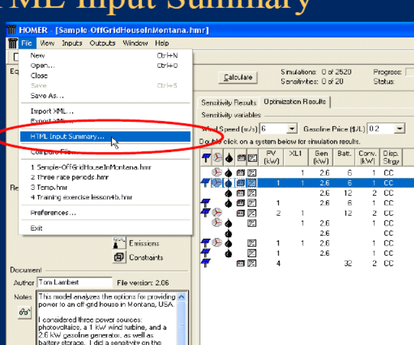
HTML Input Summary



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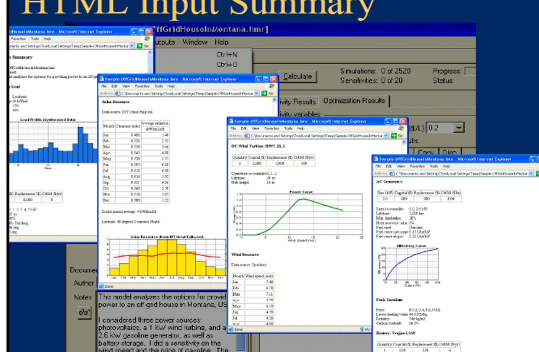
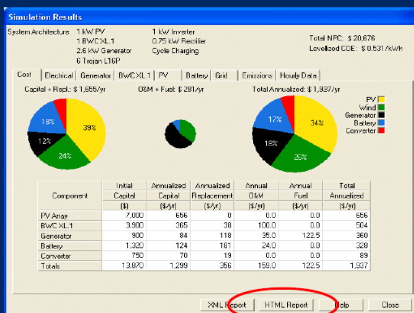
HTML Input Summary

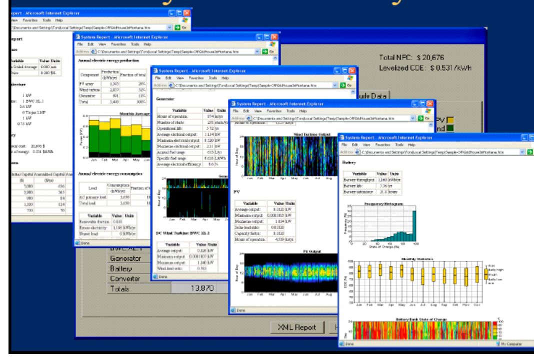


HTML System Summary



Component	Initial Capital ($)	Annualized Capital ($/yr)	Annualized Replacement ($/yr)	Annual O&M ($/yr)	Annual Fuel ($/yr)	Total Annualized ($/yr)
PV Array	7,000	656	0	0.0	0.0	656
BWC XL.1	3,900	365	38	100.0	0.0	504
Generator	900	84	118	35.0	122.5	360
Battery	1,320	124	181	24.0	0.0	328
Converter	750	70	19	0.0	0.0	89
Totals	13,870	1,299	356	159.0	122.5	1,937

HTML System Summary



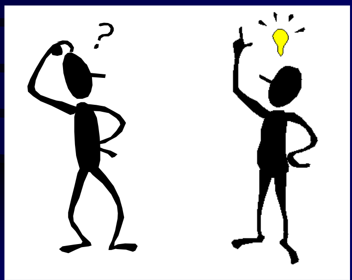
HOMER summary - Pros

- Directly compares and optimizes system alternatives
- More realistic model of relationship between resource and load
  - although not too detailed keeping it manageable to build
  - often as good as the estimates you can make
- Excellent graphical outputs
- Sensitivity analysis
- Flexibility

HOMER Summary - Cons

- Cannot model purely thermal systems
- More complex model to build
  - and see
  - building model is non-linear
- Required input data is often not available and needs to be simulated
  - note: simulations can be made with reasonable accuracy and ease
  - still better than a single number input

QUESTIONS ?



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