NREL
NATIONAL RENEWABLE ENERGY LABORATORY

RENEWABLE ENERGY EVALUATION TOOLS




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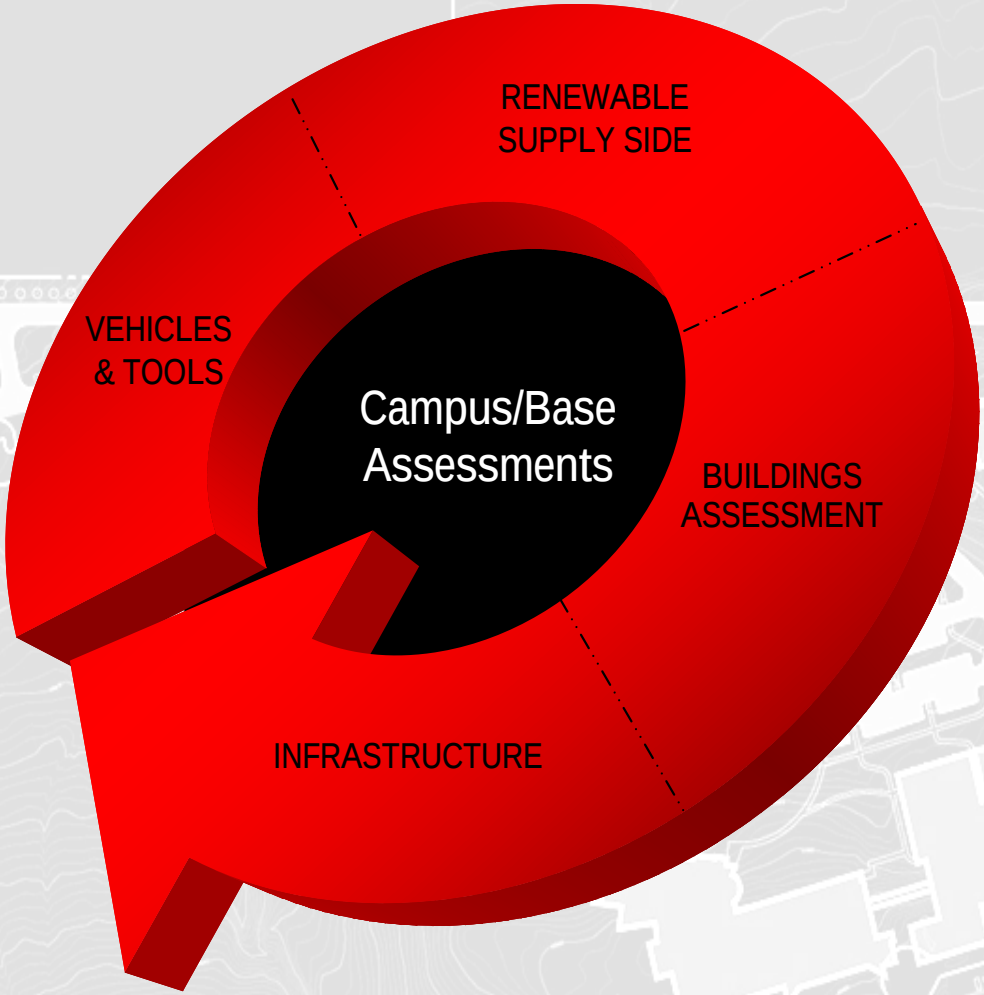
Renewable Energy Round Table

May 2, 2012

TECHNICAL ASSESSMENT AND SCREENING TOOLS WE USE IN OUR PROJECTS



Renewable Energy Technologies

Photovoltaics

Wind Power

Solar Water Heating

Solar Vent Air Preheat

Concentrating Solar Heat/Power

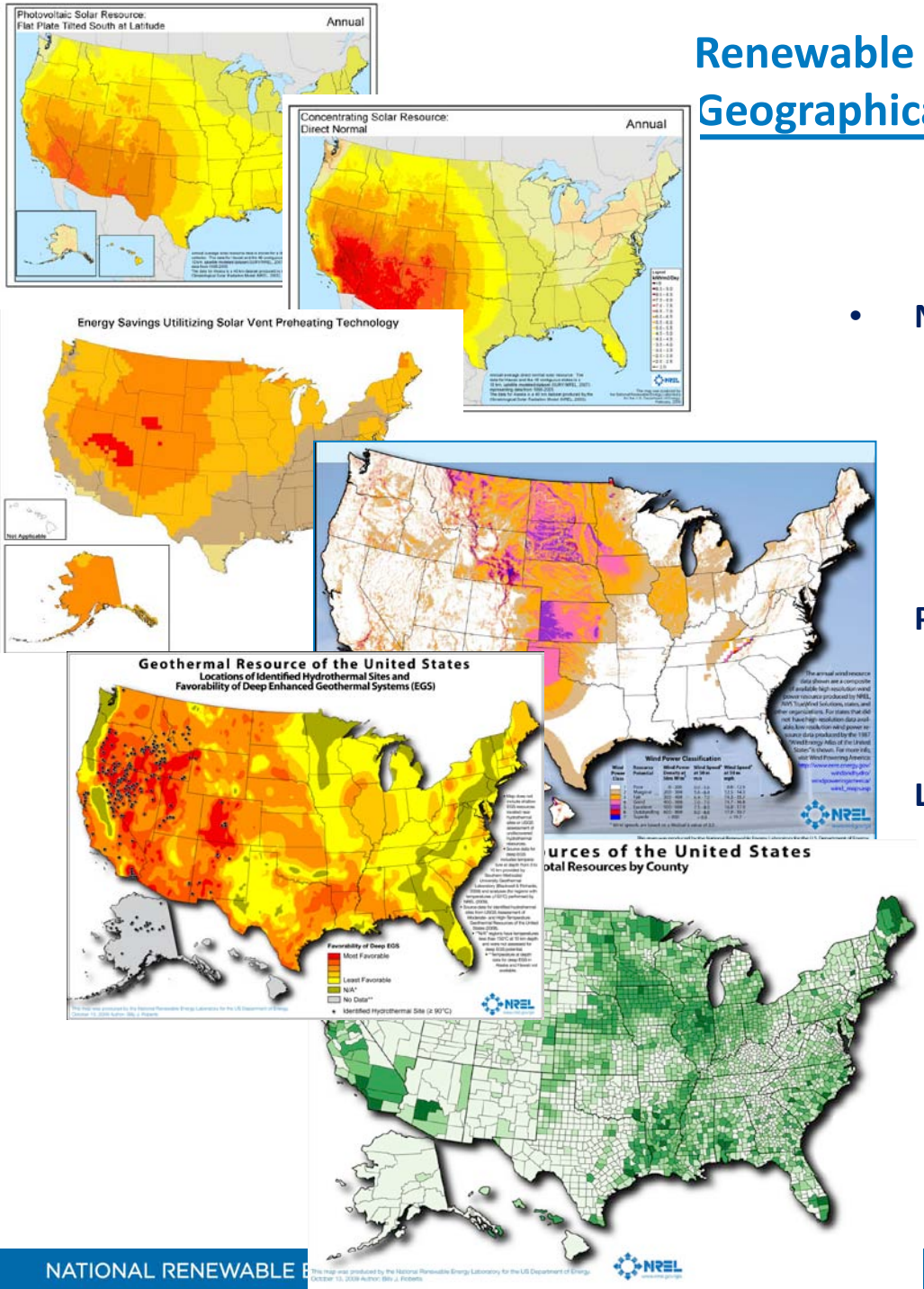
Biomass Heat/Power

Daylighting

Ground Source Heat Pump

Landfill Gas

Renewable Energy Resources
Geographical Information System (GIS) Datasets



- **NREL Datasets (http://www.nrel.gov/gis/)**
  - solar radiation 10x10 km grid
    - Horizontal, South-facing vertical, tilt=latitude
  - Wind Energy 200mx1000m grid
  - Biomass Resources
  - Illuminance for Daylighting
  - Temperature and Heating Degree Days

Purchased Datasets

- utility rates (wholesale/retail) for each service territory and customer class (residential, industrial, commercial) (Platts)
- City Cost Adjustments (RS Means & Co.)

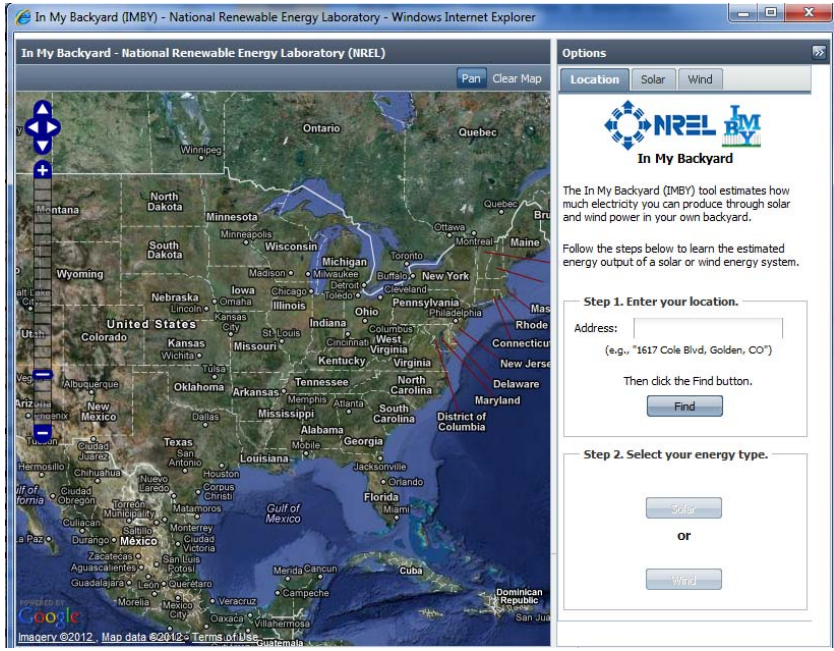
Location Independent

- State and utility incentives and utility policy (from www.DSIREUSA.org)
- Installed Hardware Costs from NREL technology databook
- Economic Parameters (discount rate, inflation rate)
  - http://www1.eere.energy.gov/femp/program/lifecycle.html

Photovoltaics Tools

- **Solar Energy Resources**
  - NREL
    - http://www.nrel.gov/rredc/
  - TMY or Weather Data
    - http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

- **Solar PV Analytical Tools**
  - Solar Advisor Model (SAM)
    - https://www.nrel.gov/analysis/sam/
  - HOMER
    - https://analysis.nrel.gov/homer/
  - PVWatts
    - http://www.nrel.gov/rredc/pvwatts/
  - IMBY
    - http://www.nrel.gov/eis/imby/

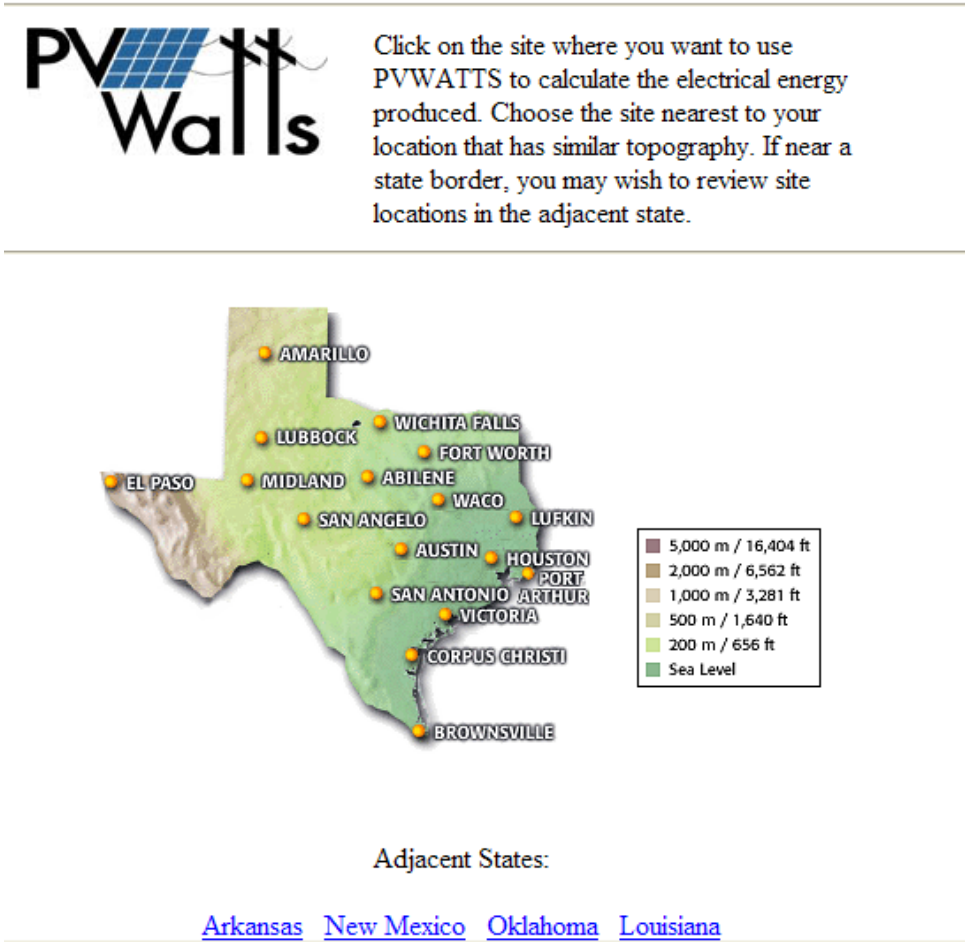


PV Watts

- **Version 1**
  - Users select a location from a map or text list of pre-determined locations throughout the world
- **Version 2**
  - Users to select any location in the United States

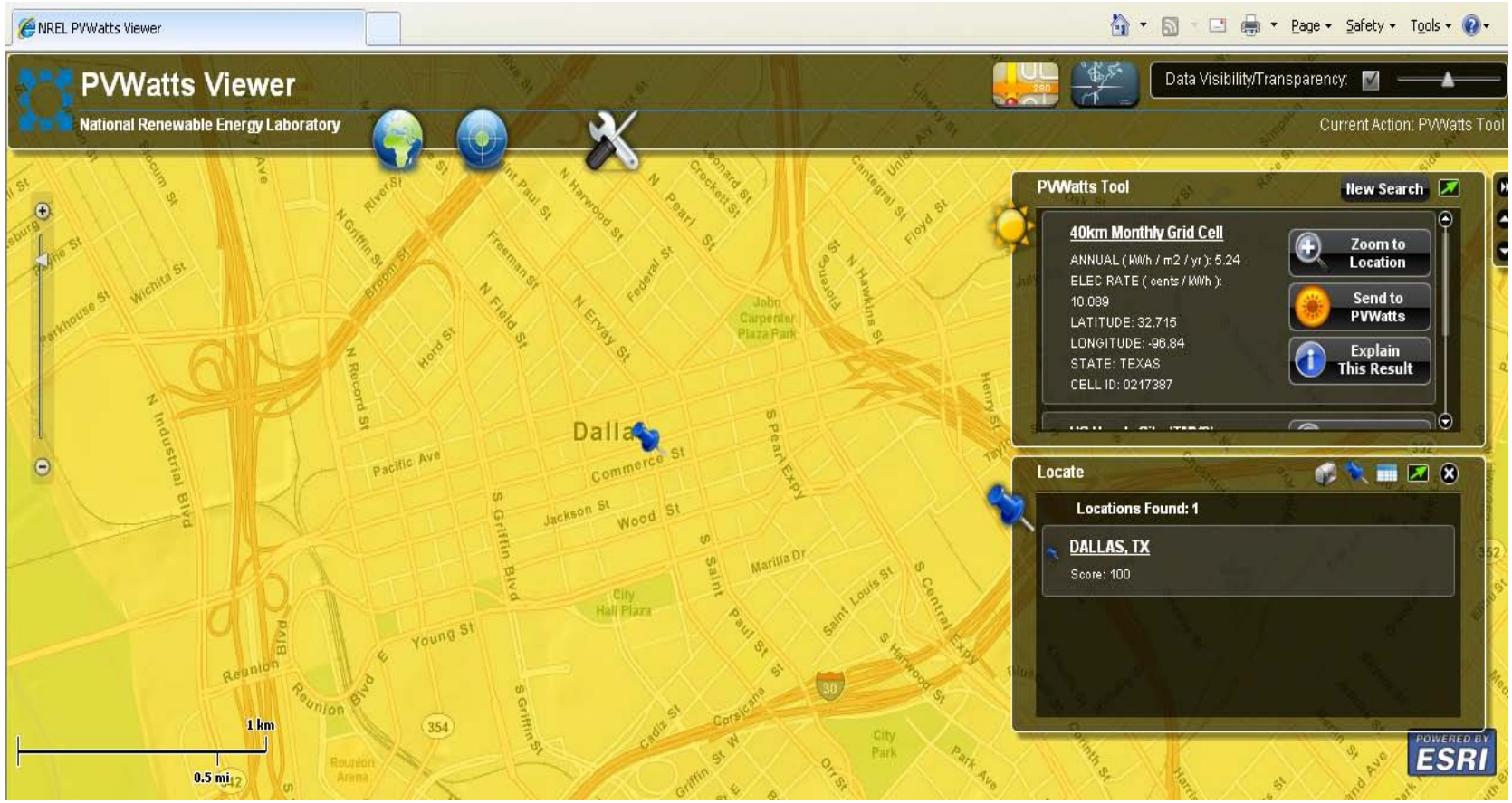
PV Watts v1

- Select a location
- Select default values *or* input customized system parameters for size, electric cost, array type, tilt angle, and azimuth angle
- Typical Meteorological Year weather data for the selected location (TMY files) used to calculate incident solar radiation and PV cell temperature for each hour of the year
- PVWatts calculator outputs monthly values of AC energy production (kW) expected from the specified PV system



PV Watts v2

- Flex Viewer
- Solar Atlas
- Internet Map Server



Solar Water Heating Tools

- **Resources**
  - FEMP Solar Hot Water System Calculator
    - http://apps1.eere.energy.gov/femp/solar_hotwater_system/index.cfm
    - DOE Energy Efficiency and Renewable Energy Solar Energy Technologies Program
    - http://www1.eere.energy.gov/solar/solar_heating.html
  - FEMP Federal Technology Alerts
    - www.eere.energy.gov/femp/pdfs/FTA_solwat_heat.pdf
    - www.eere.energy.gov/femp/pdfs/FTA_para_trough.pdf
  - FEMP Case Studies
    - www.eere.energy.gov/femp/technologies/renewable_casestudies.html
  - Resource maps
    - http://www.nrel.gov/gis/solar.html
  - Solar Radiation Data Manual
    - http://rredc.nrel.gov/solar/pubs/redbook

Training
Working Group
Contacts
Distributed Energy Resources/Combined Heat & Power

Total Calculated Load: 196.32 kWh/day
for 100 persons using 10 gallons/day/person

Estimated System Size: 74.15 m^2

Re-calculate Load

Step 2. Estimate System Cost and Annual Savings

Annual energy and cost savings are calculated based on the current hot water heater fuel type, fuel price, and water heater efficiency level. Select the appropriate fuel type from the drop-down menu. The average efficiency level and fuel cost is provided, but can be changed to match your conditions.

Annual Energy Savings: 113,345.71 kWh/year

Estimated System Cost: $71,839.00 based on $90.00 per-unit-area cost

Annual Cost Savings: $3,445.60 based on $9.15/1,000 cu. ft. of gas

System Efficiency: 0.434

Savings to Investment Ratio: 1.15

Simple Payback Period: 20.85 years

Solar Fraction: 90%

Annual Greenhouse Gas Reduction: 45,229.47 lbs. of CO_2

SOL OPT- SOLAR OPTIMIZATION TOOL

Solar Hot Water (SHW)

- Takes building information on the domestic hot water system, fuel costs, weather data files and runs an hourly production calculation

Photovoltaic (PV)

- Takes building orientation, electrical usage, electrical rates, weather data files, and runs an hourly production calculation

Finds the best mix of the two technologies

System Advisor Model SAM

- **Performance predictions for**
  - grid-connected solar,
  - small wind,
  - geothermal power systems
  - Solar hot water
  - Economic estimates
    - cost of generating electricity
    - type of financing,
    - applicable tax credits and incentives.
- **Free download https://www.nrel.gov/analysis/sam/**

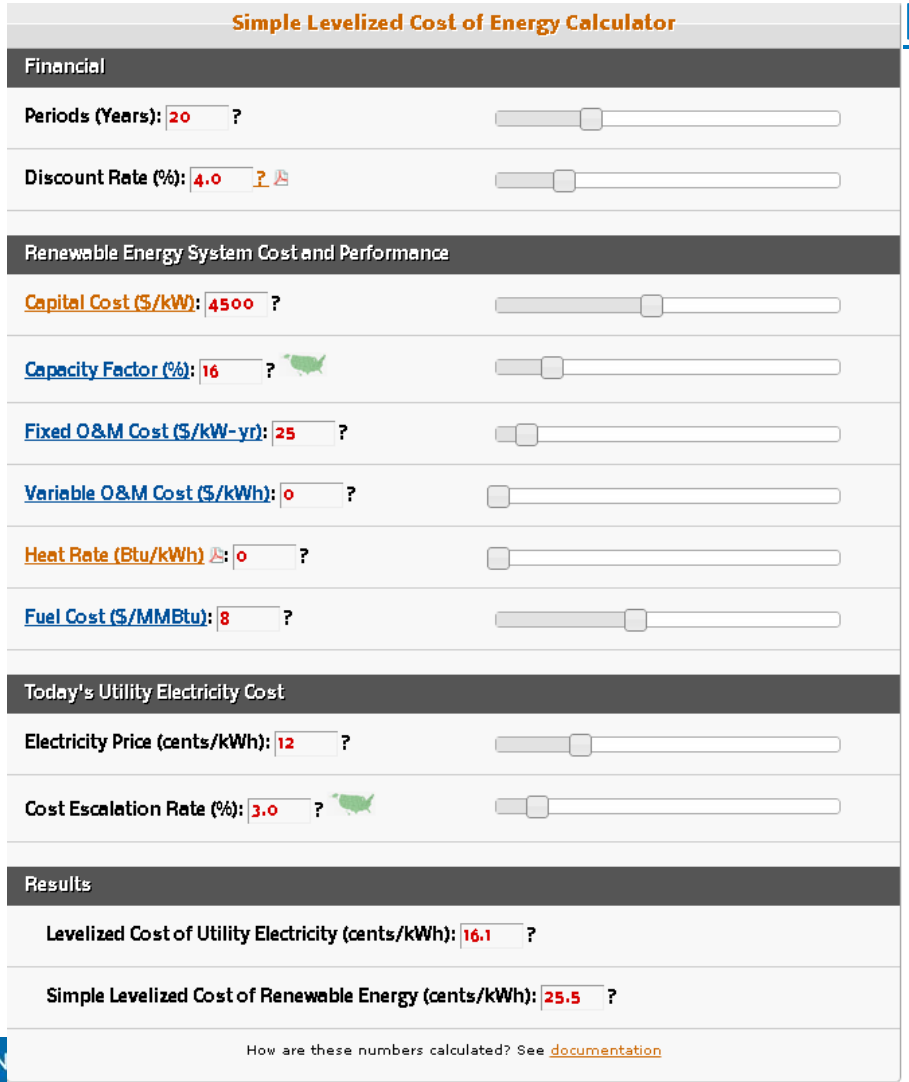
SAM


File Case Results Simulations Developer Help
Residential Flat Plate System
Commercial Flat Plate System
Utility Flat Plate System (PPA)
PVWatts Example
Utility Concentrating PV
Select Technology and Market...
System Summary
Climate
Financing
Tax Credit Incentives
Payment Incentives
View Graphs and Charts
Base Case Cashflow
Tabular Data Browser
Add a new graph...
Edit...
Remove
Remove All
Copy Graph Data
Show Graph Data
LCOE (Base Case)
Monthly Output (Base Case)
Net Output (kWh), Monthly
Annual Energy Flow (Base Case)
Stacked Costs (Base Case)
Present Value of Indirect Cost ($)
Contingency Cost ($)
Installation Cost ($)
BOS Cost ($)
Inverter Cost ($)
Module Cost ($)
Metric
Base
Annual Energy
LCOE Nominal
LCOE Real
Year 1 Revenue without System
Year 1 Revenue with System
Year 1 Net Revenue
Net Present Value
Payback Period
Capacity Factor
Year 1 kWh/kW
System Performance Factor
Total Land Area
Loan (Debt) Fraction (%)
Fixed Cost by Capacity ($/kW-yr)

Solar Vent Preheat Resources

- **FEMP Federal Technology Alert**
  - www.eere.energy.gov/femp/pdfs/FTA_trans_coll.pdf
  - Solar Ventilation Preheating Resources and Technologies
    - http://www1.eere.energy.gov/femp/technologies/renewable_svp.html
- **NREL**
  - Solar Process Heat
    - http://www.nrel.gov/learning/re_solar_process.html
  - Solar Space Heating Maps
    - http://www.nrel.gov/gis/femp.html#space

Levelized Cost of Energy Calculator



http://www.nrel.gov/analysis/tech_lcoe.html

- Web-based simple LCOE calculator
- Compares alternative to utility purchased energy
- Includes cost guidance for PV, wind, SWH, SVP

FRESA

- **PV, SWH, SVP, and wind**
- **Free, web-based tool**
  - For federal site energy managers to quickly screen viability
  - Easy to learn, easy to use
  - Returns economic viability using FEMP specified discount rates and energy cost escalation rates per 10CFR436
  - Savings to investment ratio (SIR), simple payback, energy and cost savings

Facility-Scale Photovoltaic Analysis Results

Below are results of the facility-scale photovoltaics (PV) analysis generated by the Federal Renewable Energy Screening Assistant (FRESA). Use the ? buttons to see more details on the specific results.

Your PV project is considered life-cycle cost effective according to 10 CFR 436 if the life-cycle cost of the PV system is less than the life-cycle cost of the base case.

Click "View Data Inputs" to make changes to your facility-scale inputs and re-run the analysis.

A full report can be exported in multiple file formats (.pdf, .csv, and .rtf) by using the Reports item in the left tree menu. Please note that RTF files can be opened with Microsoft Word, and CSV files can opened with Microsoft Excel.

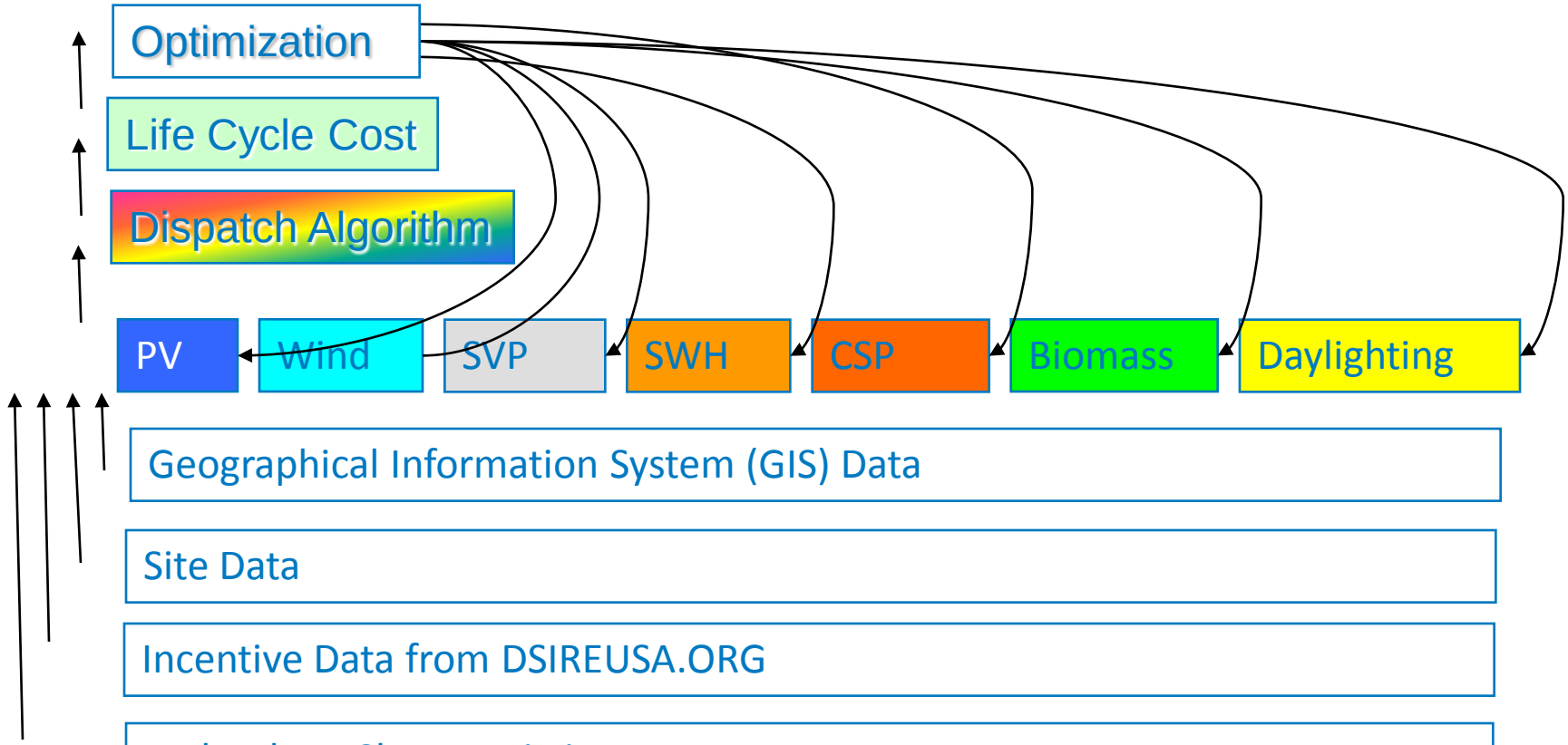
Additional information is available in the FRESA user manual.

View Data Inputs

Facility: Federal Facility PV Example

SIR	1.020
Simple Payback	17.0 years
Utility Electricity Savings	211,282 kWh/year
Electricity Cost Savings	$35,918 /year
Distillate Fuel Oil Savings	0.0 MMBTU/year
Distillate Fuel Oil Cost Savings	$0 /year
Natural Gas Savings	0.0 MMBTU/year
Natural Gas Cost Savings	$0 /year
Propane Savings	0.0 MMBTU/year
Propane Cost Savings	$0 /year
Base Case Life Cycle Cost	$24,325,300
Life Cycle Cost of PV	$24,309,829
Net Savings	$15,471
Rated Capacity	150 kW
Annual Energy Output	211,282 kWh
Footprint Area of PV Array	11,875.00 ft2
PV Panel Conversion Efficiency	18.00 %
Capital Cost	$750,000
Annual O&M Cost	$4,956

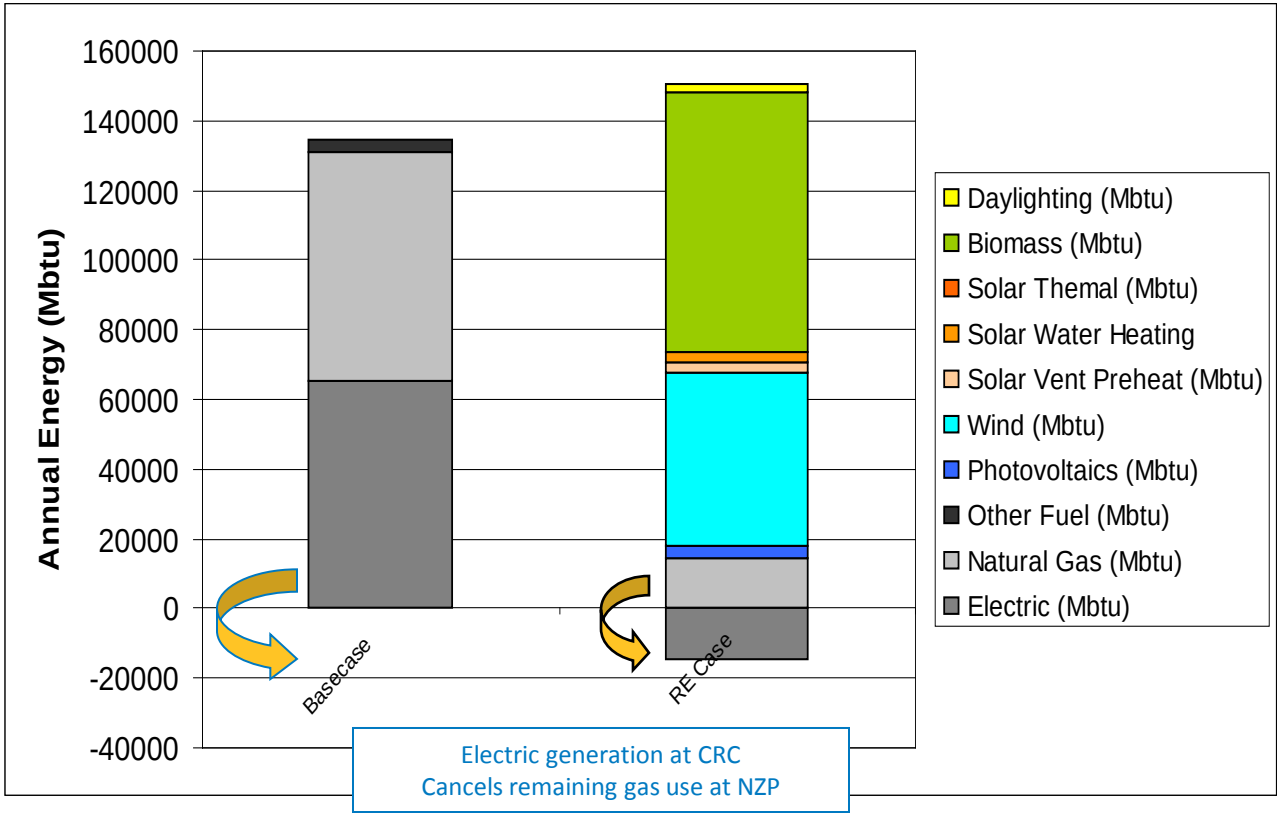
REO: Renewable Energy Optimization



RENEWABLE ENERGY OPTIMIZATION (REO)

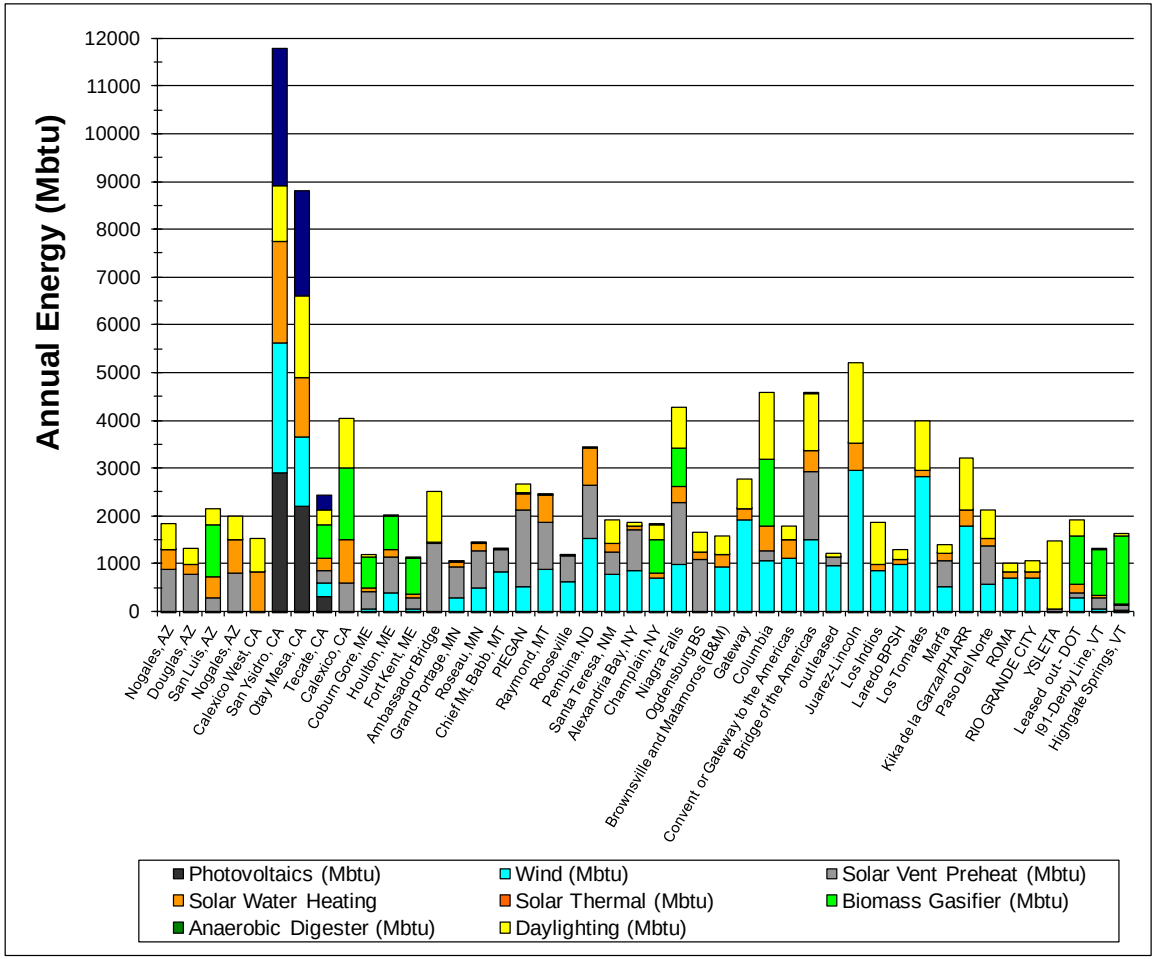
Example results using the Renewable Energy Optimization to create a "net zero" energy zoo.

National Zoological Park (NZP) and Conservation Research Center (CRC), Washington DC



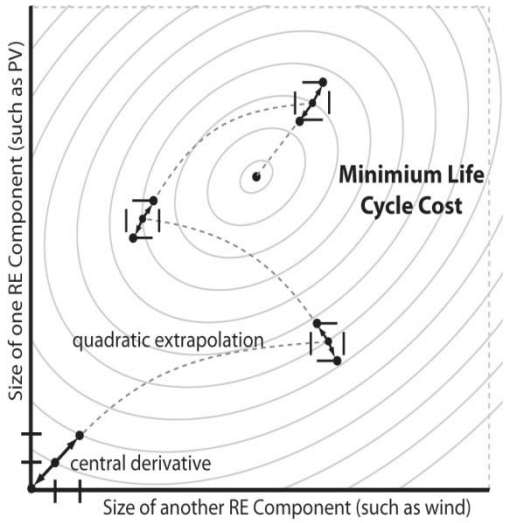
REO for Land and Ferry Points of Entry

	Without Tax Incentives	With Tax Incentives
PV (kW)	0	737
Wind Energy (kW)	2,491	3,689
Solar Ventilation Air Preheat (sf)	93,265	119,652
Solar Water Heating (sf)	28,464	90,703
Solar Thermal Parabolic Trough (sf)	0	0
Solar Thermal Electric (kW)	0	0
Biomass Gasification Boiler (MBH)	1.3	1.8
Biomass Gasification Cogen (kW)	134	193
Biomass Anaerobic Digester (ft3)	0	0
Biomass Anaerobic Digester Cogen (kW)	0	0
Skylight Area (sf)	190,951	209,666

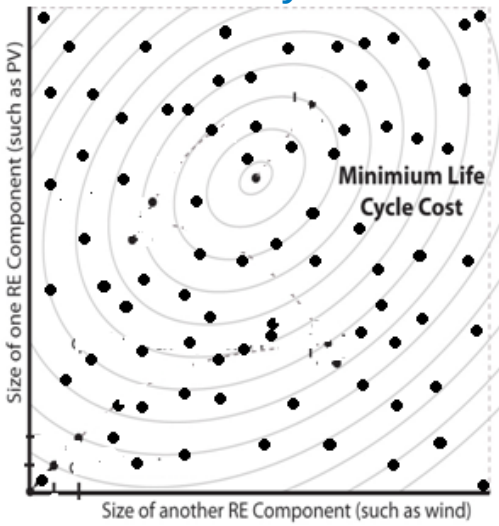


Optimization Problem

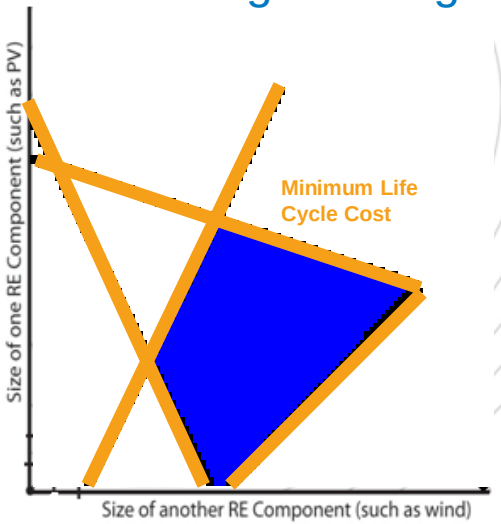
Gradient Reduction

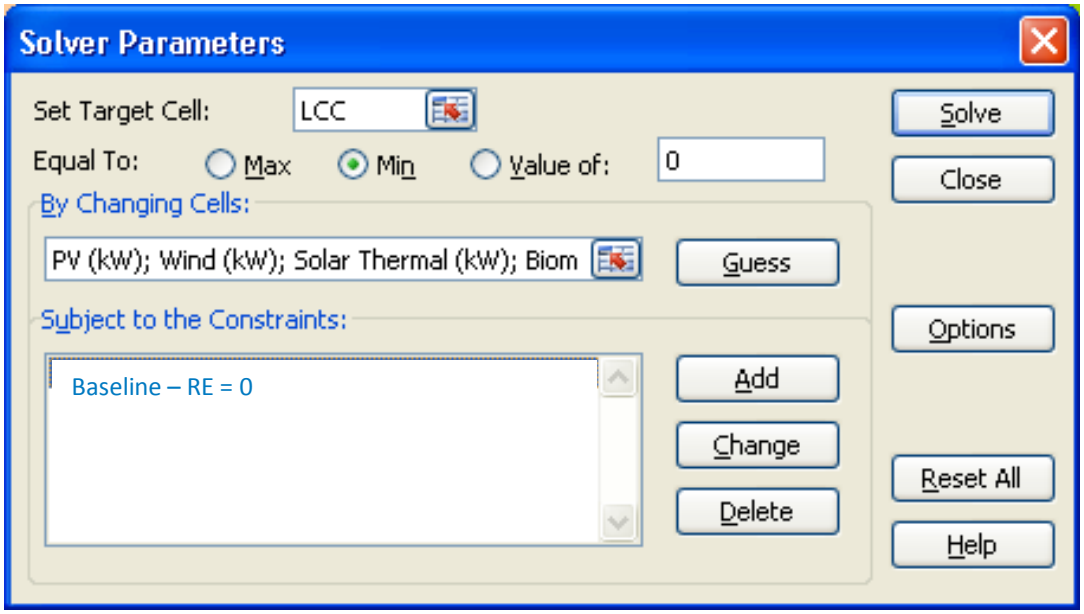


Evolutionary



Linear Programming





Objective: Minimize Life Cycle Cost ($)

Variables: Size of Each Technology (kW of PV, kW of wind, etc)

Constraints: examples:

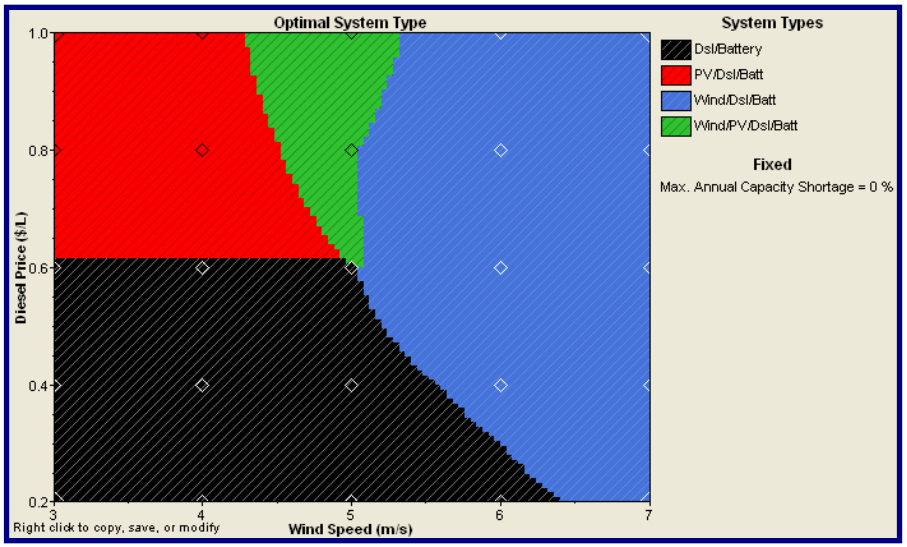
- 100% energy from renewables (Net Zero)
- $140M investment limit
- 14 acre land area limit
- 20% carbon reduction

The optimum is often along a constraint.

HOMER

A tool for comparing and evaluating micro-power technology options

- Community, villages and island power systems
- Stand-alone or grid-connected systems
- Conventional technologies (generators, batteries)
- Renewable technologies (photovoltaic, wind turbines, fuel cell, CHP)



HOMER uses simulation, optimization, and sensitivity analysis to:

- Find the combination of components that can serve a load at the lowest life-cycle cost
- Simulates typical year by performing energy balance calculations for 8,760 hours (=1 year)
- Performs sensitivity analysis to show how results can vary given different assumptions

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

PV (kW)	1.5sl	CoGen (kW)	Gen2 (kW)	Conv. (kW)	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Diesel (L)	CoGen (hrs)
	3	7500	2200		1000	$ 9,000,000	13,068,830	$ 176,063,5...	0.278	0.65	19,171,...	8,760
		7500	2200		1000	$ 0	20,791,870	$ 265,789,8...	0.420	0.00	29,180,...	8,760
120...	2	7500	2200	1970	1000	$ 967,556,...	28,091,176	$ 1,326,655...	2.096	0.92	19,200,...	8,760
120...		7500	2200	4800	1000	$ 963,792,...	30,226,336	$ 1,350,185...	2.134	0.87	21,958,...	8,760

Kauai HOMER Analysis

Kauai Base Case + Biomass + Landfill gas + 4 MW PV

System Architecture: 4,000 kW PV; 6,938 kW Hydro; 27,500 kW CT1; 4,000 kW Diesel 1 & 2; 26,700 kW Biomass; 2,750 kW Diesel 3; 5,500 kW Diesel 4&5; 1,600 kW Landfill recovery; 7,860 kW Diesel 6; 7,860 kW Diesel 7; 7,860 kW Diesel 8; 7,860 kW Diesel 9

Total NPC: $ 613,576,128
Levelized COE: $ 0.116/kWh
Operating Cost: $ 54,539,424

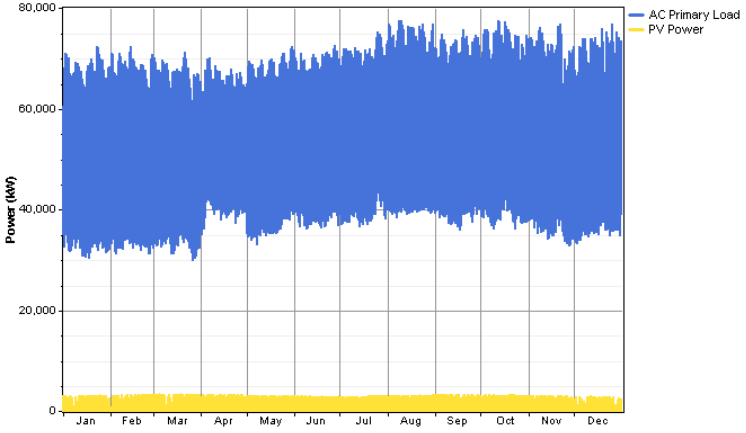
Cost Summary | Cash Flow | Electrical | PV | Hydro | CT 1 | D12 | BioM | D3 | D45 | LFG | D6 | D7 | D8 | D9 | Convert

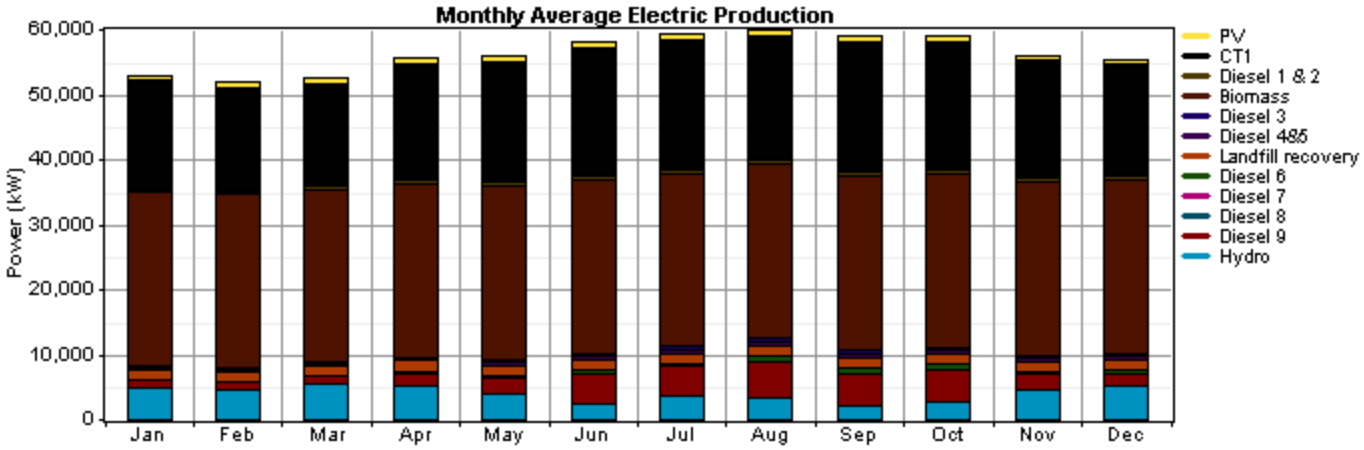
Production	kWh/yr	%
PV array	7,245,448	1
Hydro turbine	35,578,412	7
CT1	160,114,656	32
Diesel 1 & 2	4,832,380	1
Biomass	233,916,976	47
Diesel 3	2,900,795	1
Diesel 4&5	4,623,568	1
Landfill recovery	13,800,518	3
Diesel 6	3,293,276	1
Diesel 7	0	0

Consumption	kWh/yr	%
AC primary load	493,616,096	100
Total	493,616,096	100

Quantity	kWh/yr	%
Excess electricity	33,928	0.01
Unmet electric load	6.13	0.00
Capacity shortage	0.00	0.00

Quantity	Value
Renewable fraction	0.0866
Max. renew. penetration	19.0 %





Metric	Value
Present worth	$ 154,568,496
Annual worth	$ 14,479,788/yr
Return on investment	55.9 %
Internal rate of return	58.3 %
Simple payback	1.97 yrs
Discounted payback	1.99 yrs

- **Thank You!**