NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Project Evaluation Models

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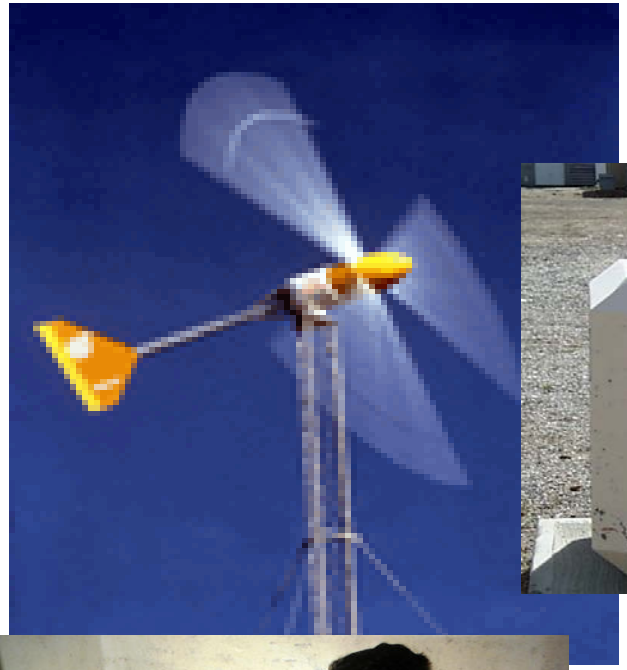
Alaska Native Village Energy Development Workshop

April 30, 2014

Why do we need options analysis?

There are many different energy resources

Which ones are available in Alaska?



...and many energy conversion technologies

wind turbines

photovoltaics

batteries

diesels

microturbines

fuel cells

small hydro

small modular biomass

grid connection

…which have different operating requirements, advantages, disadvantages, costs, etc.

Diesel generators	Dispatchable, significant maintenance, fuel supply issues and costs
Wind turbines	Not dispatchable, maintenance requirements, variability of power
Solar PV	Not dispatchable, low maintenance, very seasonal
Biomass generators	Dispatchable, varying maintenance requirements, fuel supply issues

Different technology combinations require different additional equipment to insure reliability including different storage options, power converters, synchronous condensers, etc.

These components can be combined in a variety of ways

From a techno-economic standpoint, the most effective technology choice & system configuration generally depends on:

- Available energy resources
- Energy demand characteristics (load size, composition, reliability requirements, etc.)
- The ability to provide long term service to the energy choices selected

So the question is...

What technologies should be used, in what quantities, and in what combinations?

This is what we call

"Rural Energy Options Analysis"

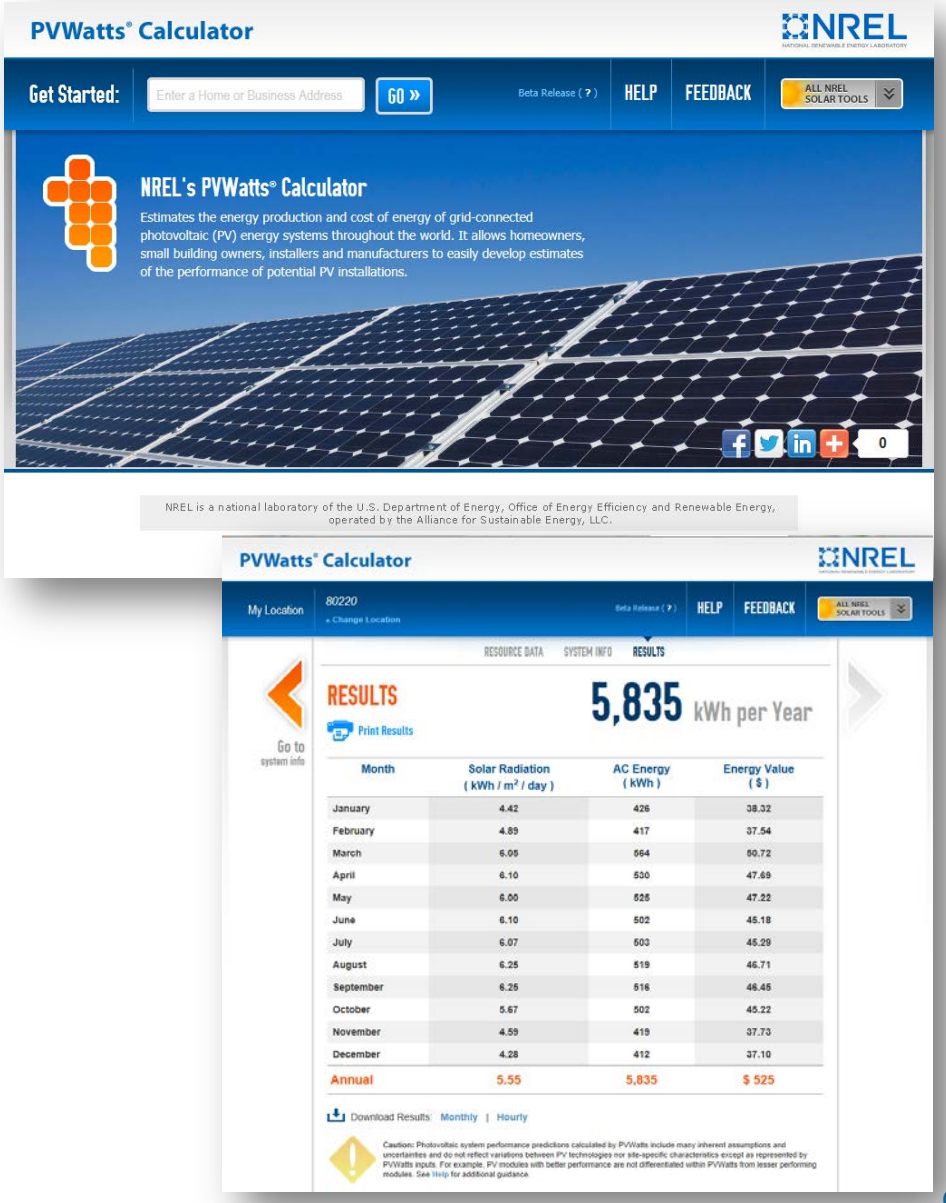
Options Analysis Helps Answer Questions & Guide Decision-making

- Questions about markets, policies, and impacts ("policy analysis")
- Questions about system costs and performance ("project analysis")

Different applications often imply different options analysis methods

PVWatts

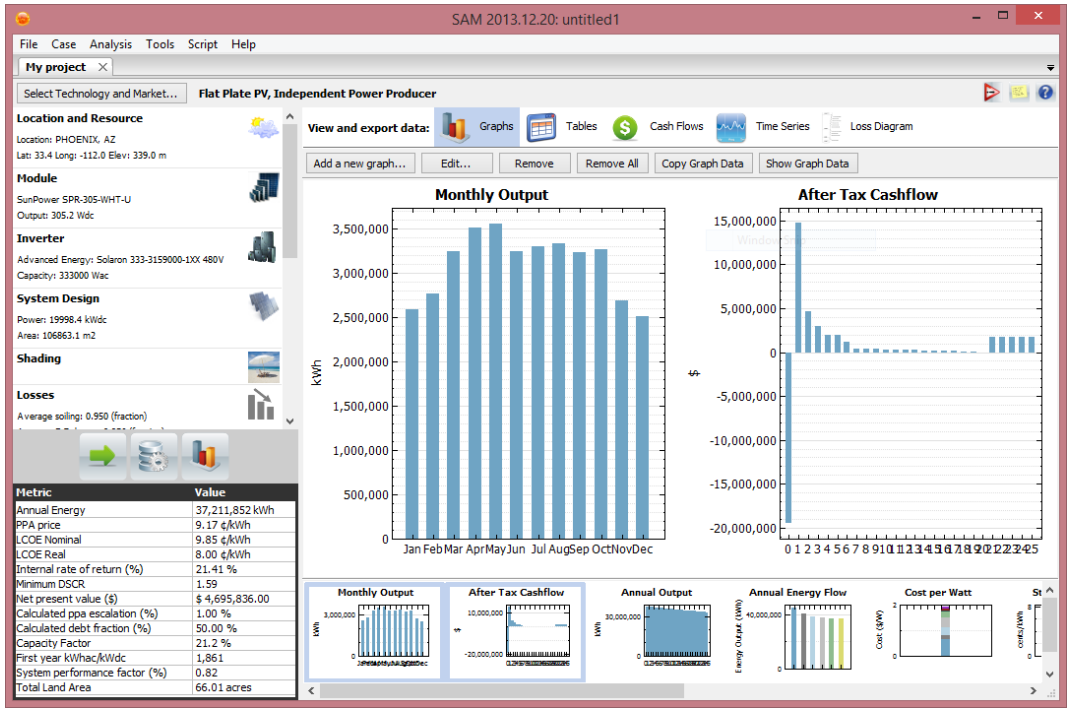
- Simple online tool for non-experts needing basic solar performance estimation
- Used extensively by solar installers to qualify for subsidies
- SolarCity, Sunrun, etc. use PVWatts
- One of NREL's most heavily trafficked websites
- Currently under development for both improved interface and improved accuracy



System Advisor Model

The System Advisor Model (SAM) is a free user-friendly computer program that **calculates a renewable energy system's hourly energy output** over a single year, and **calculates the cost of energy** for a renewable energy project over the life of the project.

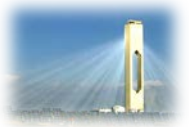
These calculations are done using detailed performance models, a detailed cash flow finance model, and a library of reasonable default values for each technology and target market.



Technologies SAM can model:

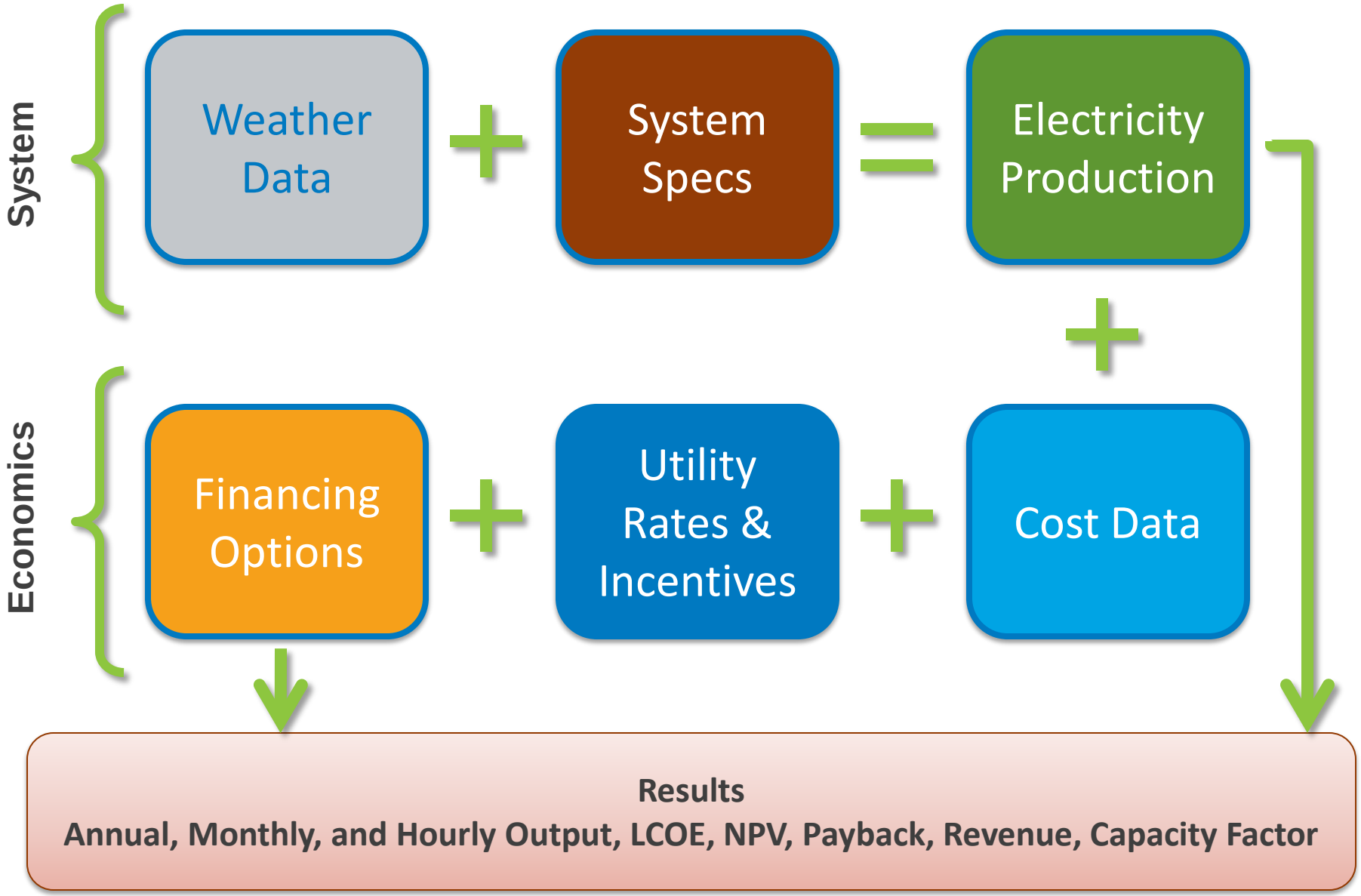
- Photovoltaics (Flat plate, CPV)
- Solar Water Heating
- Concentrating Solar Power (Trough, Tower, Linear Fresnel, Dish Stirling)
- Geothermal
- Wind (Small + Utility scale)
- Biomass Power



Weather Data + System Specs » Energy Production + Cost Data + Utility Rates & Incentives + Financing Options » Annual, Monthly, and Hourly Output, LCOE, NPV, Payback, Revenue, Capacity Factor

General Modeling Workflow



Technologies in SAM

Photovoltaics

Concentrating PV

Solar Water Heating

Geothermal

Parabolic Trough

Power Tower

Linear Fresnel

Dish-Stirling

Small Wind

Utility-scale Wind

Biomass Power

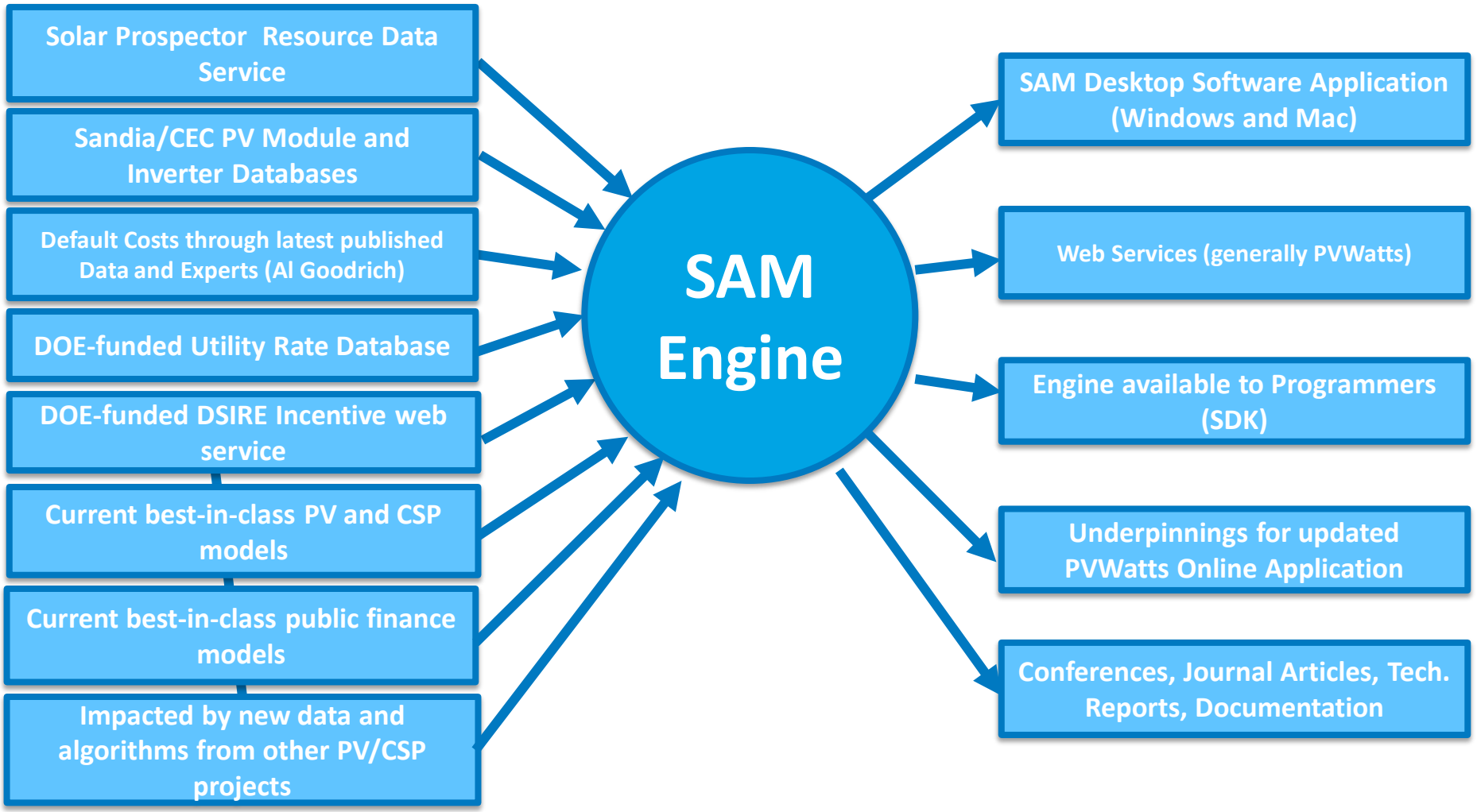
Conventional

Applications

- **Feasibility studies**
  - Project developers, Federal Energy Management Program
- **Use as benchmark for other models**
  - System integrators and utilities
- **Research projects**
  - Universities and engineering firms
- **Plant acceptance testing for parabolic trough systems**
- **Evaluate technology research opportunities and grant proposals**
  - Department of Energy
- **Provide integration of calculation engine into 3rd party tools via SDK (SunRun, SunEdison, APS, Locus, PNNL, etc....)**
- **Use of our data and algorithms via web services within other web tools**

Over 45,000 downloads since initial release

Integrated Expertise and Capabilities enabled at NREL



RETScreen Clean Energy Project Analysis Software

The Software can be used to evaluate various types of Power Projects. It permits analysis with a wide range of renewable and conventional (fossil) fuels (which can be used in parallel), including wind; hydro; solar; landfill gas; biomass; bagasse; biodiesel; biogas; hydrogen; natural gas; oil/diesel; coal; municipal waste, etc.

Photo credit: Northwest Territories Power Corp

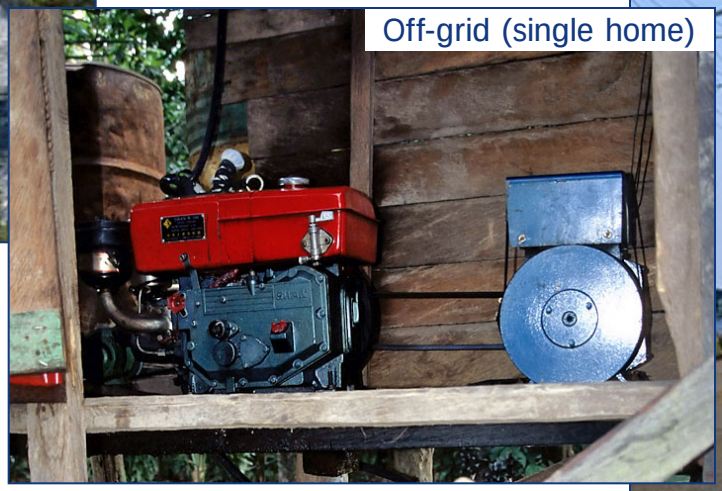


Photo credit: RER Renewable Energy Research

Photo credit: RER Renewable Energy Research

RETScreen Technologies

Renewable Technologies
- Wind turbines
- Hydroelectric
- Geothermal power
- Solar photovoltaics
- Solar thermal power
- Ocean current power
- Tidal power
- Wave power

Conventional Combustion Technologies
- Steam turbine
- Gas turbine
- Gas turbine - Combined cycle
- Reciprocating engine

Other technologies
- Fuel cells
- Microturbines

On-grid PV, Bavaria, Germany

Photo credit: RER Renewable Energy Research

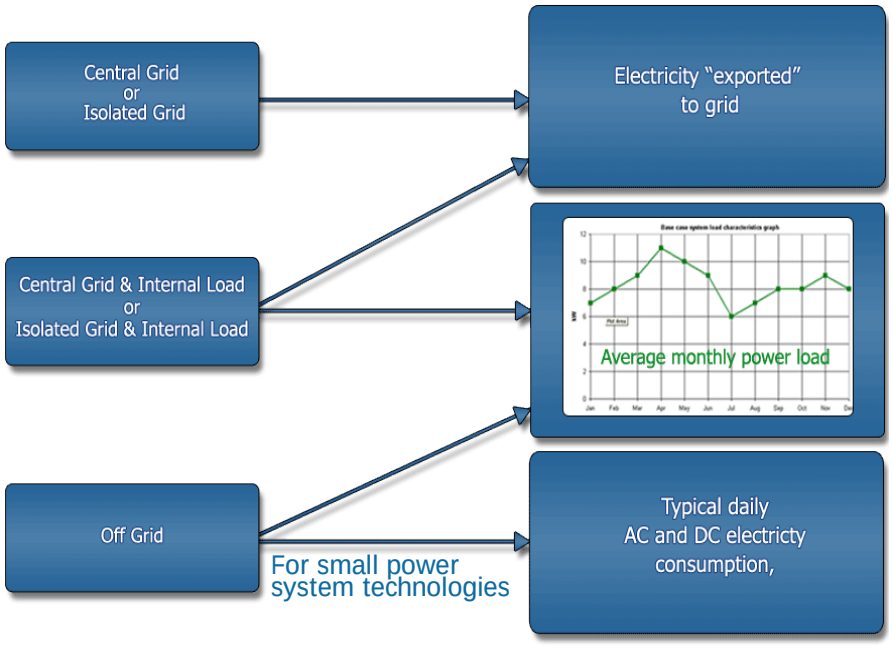
Fuels and System Types

Combustible Fuels

- Fossil fuels: coal, diesel, natural gas, propane, oil, etc.
- Biomass: bio-diesel, ethanol, bagasse, wood, bark, coconut fibre, straw, hemp, peat, willow, switch grass, etc.
- Waste: tires, landfill gas, food waste, forest residue, coffee refuse, Christmas trees, poultry litter, packaging waste, etc.
- Hydrogen

Renewable Energy “Fuels”

- Sunshine, wind, waves, tides, geothermal, water, etc.



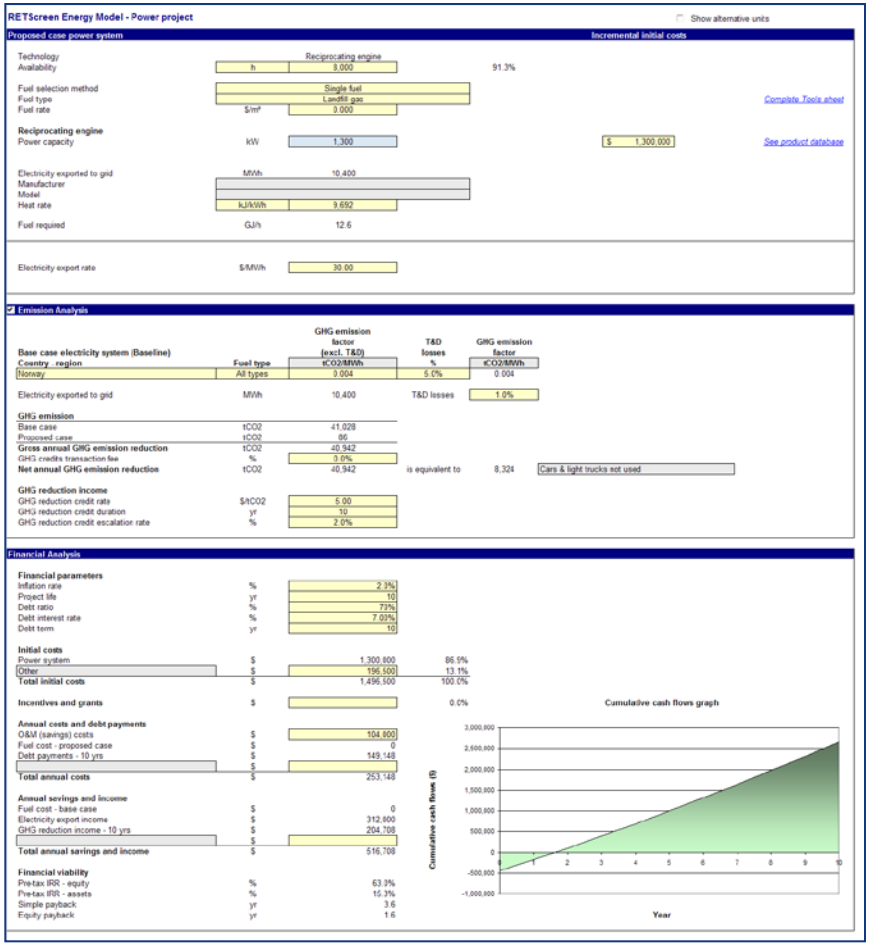
Power Projects with RETScreen

Analysis steps:

- Base case load and power system characteristics (for off-grid systems and internal loads)
- Proposed case power system characteristics (energy + costs)
- Operating strategy
- Summary (energy)
- Emission analysis
- Financial analysis (including sensitivity and risk analysis)

Project Types:

- Choose technology (steam turbine, geothermal, photovoltaic, wind, etc.)
- Power-Multiple Technologies
- Other project types:
  - Heating & Power
  - Cooling & Power
  - Heating, Cooling & Power
  - Project types unrelated to power



What is HOMER?

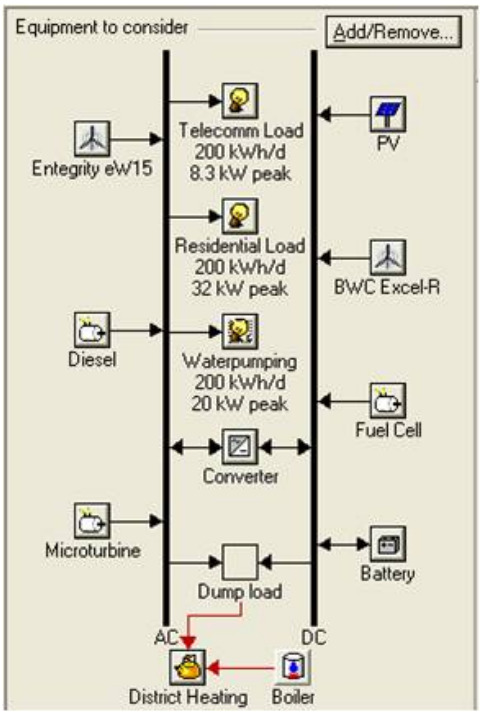
A tool for comparing and evaluating power technology options for a wide range of applications

- Isolated power systems
- Stand-alone applications
- Grid-connected systems

HOMER uses simulation, optimization, and sensitivity analysis to:

- Find the combination of components that can serve a load at the lowest life-cycle cost
- Show how this result can vary given different assumptions

HOMER
The Micropower Optimization Model



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

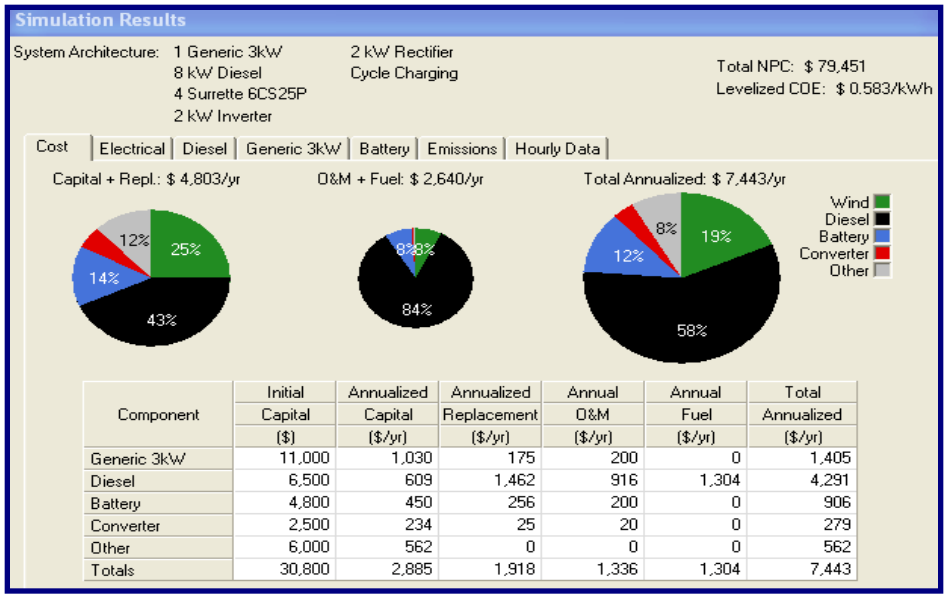
HOMER Simulation Tool – Results

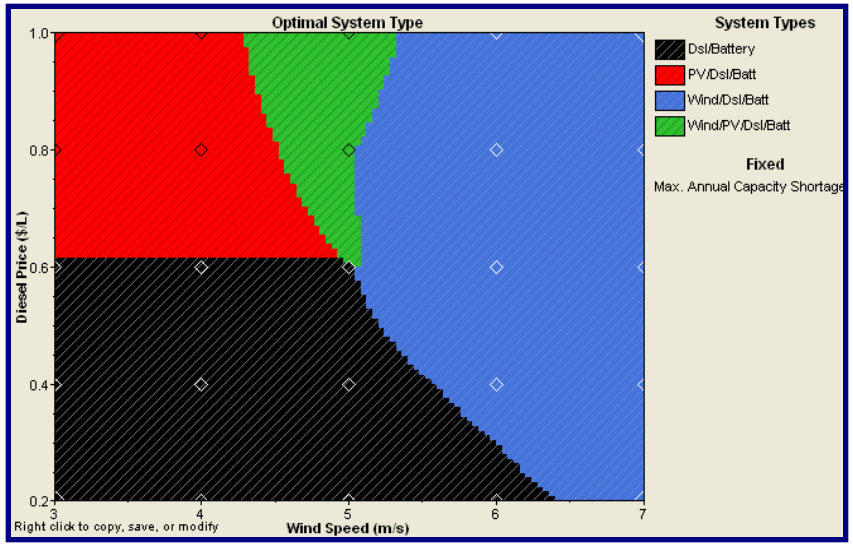
HOMER Simulation Results

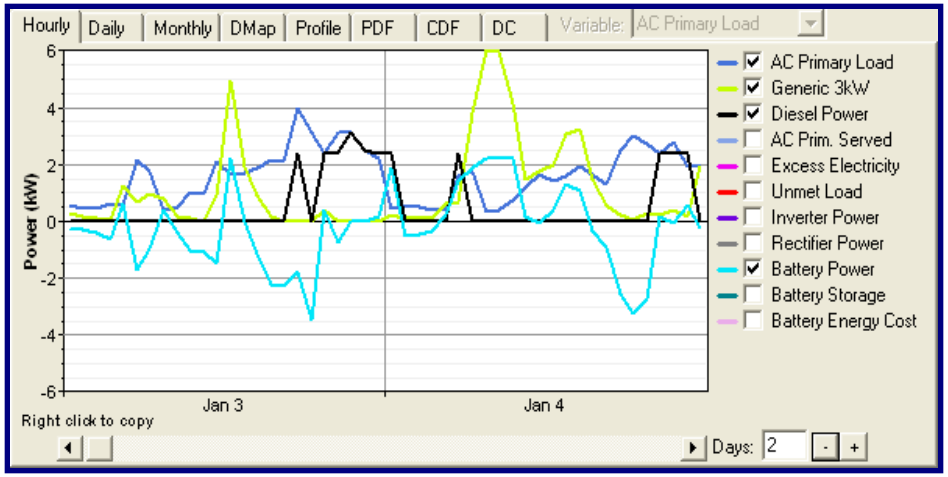
- Cost of a particular system configuration
- Performance of a system
- Sensitivity analysis displayed as graphs

Questions that HOMER can answer

- Purchase wind turbine, PV array, or both?
- Will 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 Simulation Tool - Data Inputs

Load Profile

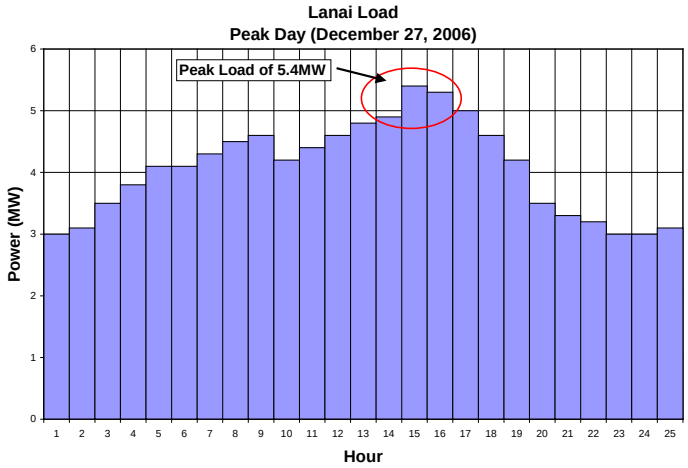
- Simulates hour-by hour operation of the system and load profile to evaluate its performance and lowest cost of energy
- Uses hourly resource data for wind and solar

Renewable Energy Options

- Models existing generation (Grid, backup generators, Cogeneration)
  - fuels include biogas, diesel, gasoline, propane
- PV- Capacities (kW) and operational maintenance
- Wind Turbines – Capacities (kW)
- Hydro generation
- Batteries, pumped hydro

Simulation Results

- Results include all combinations of system configuration
- Monthly or hourly fuel use, output and runtime
- % of renewable energy used in the system configuration



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HOMER Simulation Tool (Overview)

Simulate a system design

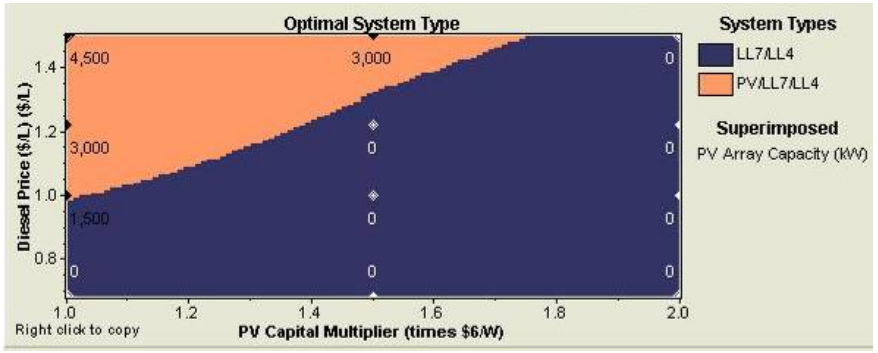
- HOMER optimizes the system design by simulating the various configurations of RE.
- HOMER ranks the feasible system configuration according to total net present cost.

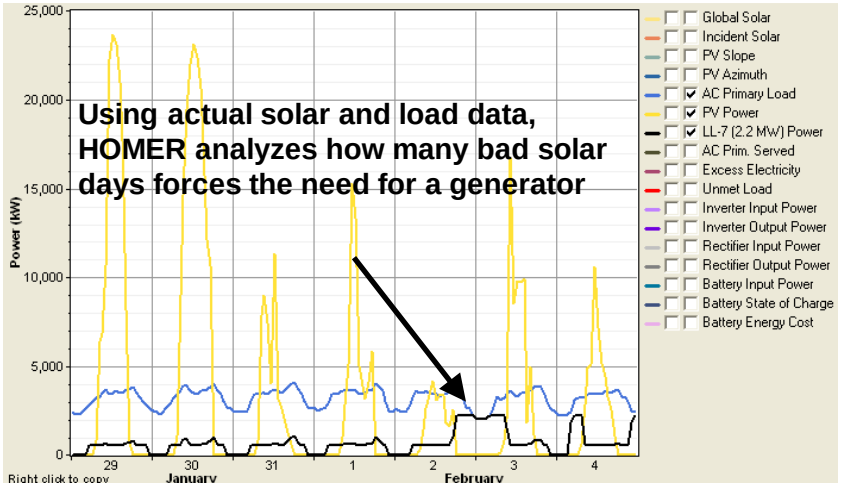
Sensitivity Analysis

- Explore the effects of uncertainty or changes in one or more input variables.
- Compare various PV system with the variable cost of natural gas. Indicates when PV system is more cost effective

Backup Analysis

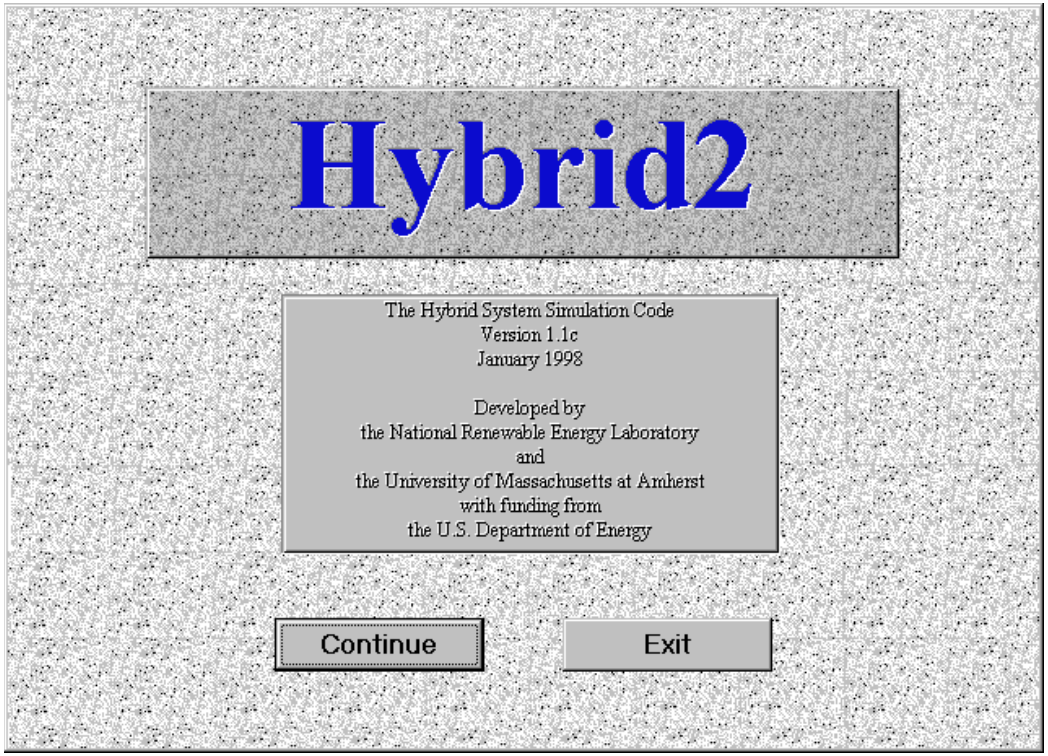
- Using the hourly solar resource data and hourly load to analyze hybrid system to determine how many days of poor solar resource would require grid or backup generation. Details of cost required to meet the backup load if grid goes down





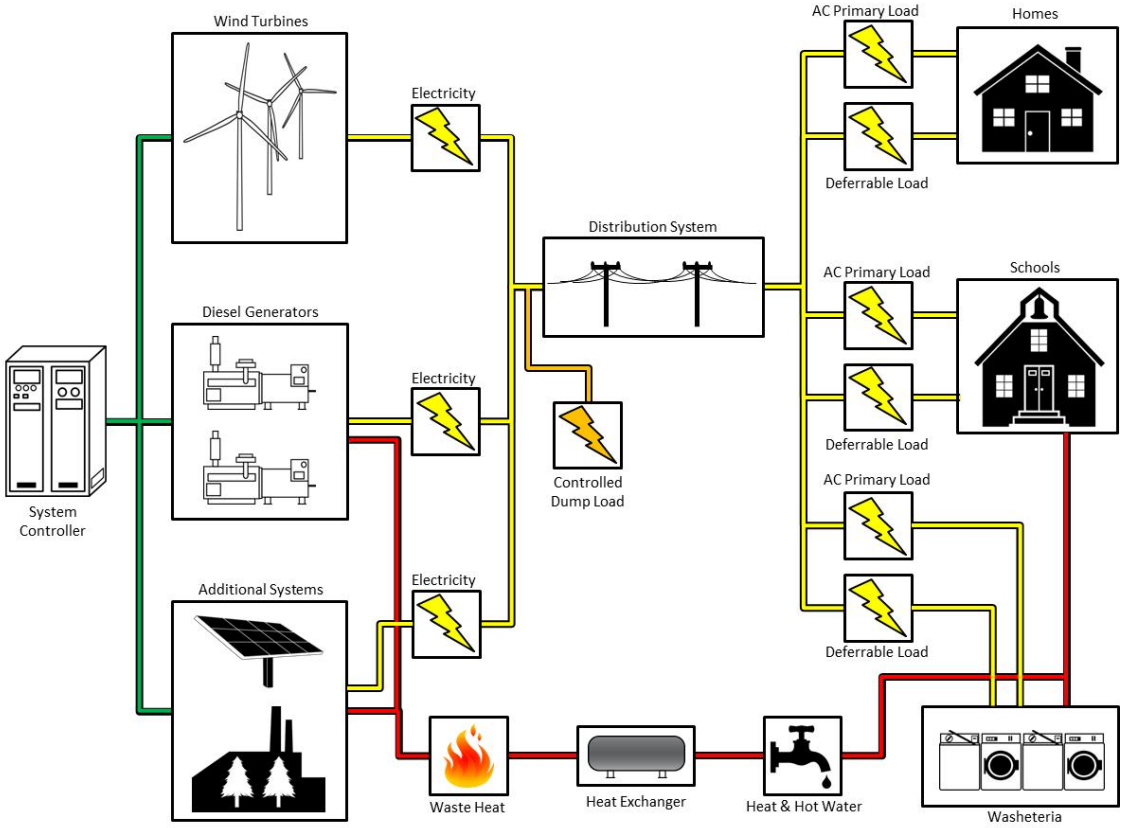
Hybrid2 Simulation Software

A simulation tool designed to accurately predict long term performance of a wide variety of power systems made up of conventional fuel generators, wind generators, photovoltaics and battery storage



Alaska Energy Financial Model

- Simple financial model for Alaskan isolated power systems
- Spreadsheet model with open architecture (go Inside the box)
- Wind, Diesel and other energy options
- Electric and Thermal options
- Use performance data from other tools
- Allows calculation of:
  - Internal Rate of Return
  - Power Price
  - Payback Period
- Beta version – really looking for feedback



Step 1: Model Setup	Units	Value	Info	Check
Model Calculation Method: Select Primary User Input →		IRR	?	
Target After-Tax Equity IRR	%	6.00%	?	
Ratios of Energy Prices				
AC Primary Load | AC Primary Load	ratio	1.00	?	
Deferrable Load | AC Primary Load	ratio	0.75	?	
Thermal Load | AC Primary Load	ratio	0.40	?	

Step 2: Annual Cost & Revenue Escalation	Units	Value	Info	Check
Annual Escalation: Single Value or Multiple Values?		Multiple Values	?	

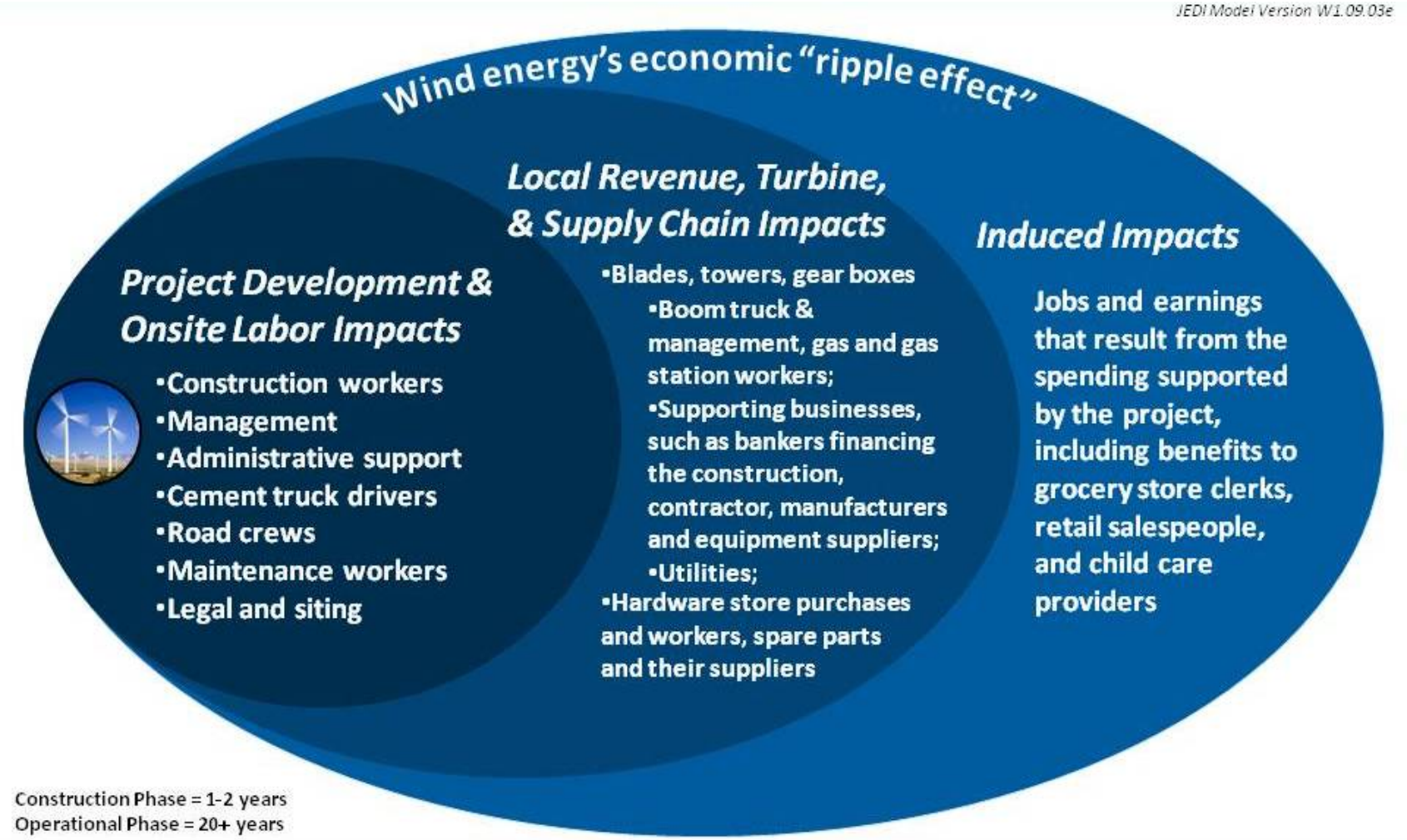
Step 3: Project Characteristics	Units	Value	Info	Check

Step 8: Renewable System (Wind or Solar)	Units
Initial Capital Costs	$
Depreciation Schedule	
Federal Incentive	
PTC Rate	¢/kWh
PTC Annual Escalation Rate	%
Production, Year 1	kWh/yr
O&M Cost, Year 1	$/yr
O&M Cost Annual Escalator	%
Replacement Reserves, Year 1	$/yr
Reserves Cost Annual Escalator	%

Step 9: Diesel Generators (All)	Units
Initial Capital Costs (for improvements/additions)	$
Depreciation Schedule	
Total Electrical Production, Year 1	kWh/yr
Will Project Earn Revenue from Diesel Generator(s) Waste Heat?	
Waste Heat Captured from Diesel Generator(s), Year 1	kWh/yr
Fuel Consumption, Year 1	$/yr

Jobs & Economic Impacts from the JEDI Model

Economic Impact of Energy Projects

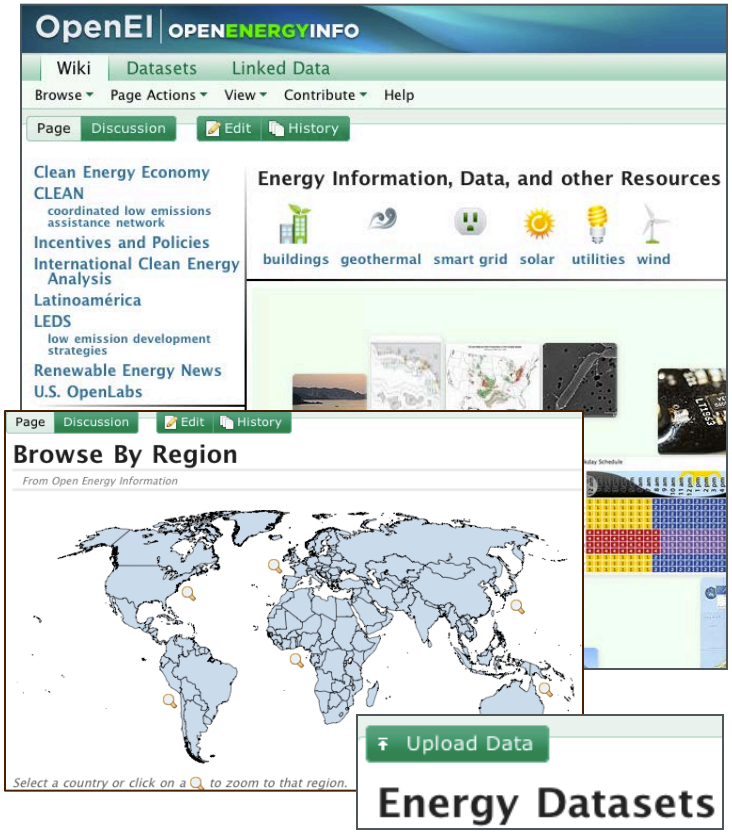


JEDI Model Availability

- **Current JEDI models**
  - Utility-scale wind
  - Natural gas (combined cycle)
  - Coal (pulverized coal)
  - Marine and hydrokinetic
  - Concentrating solar power
  - Dry mill corn ethanol
  - Lignocellulosic ethanol
  - Photovoltaic.
- **JEDI models under development**
  - Hydropower (conventional)
  - Natural gas (combined cycle)
  - Offshore wind & small wind
  - Transmission
  - Geothermal
  - Biopower
  - Petroleum.

Photo from Sally Wright, Renewable Energy Research Lab - Umass, NREL/PIX15160

Open Energy Information



http://openei.org

Data Analysis and Visualization Group
Project Lead:
Debbie Brodt-Giles, NREL
Debbie.brodt.giles@nrel.gov

Project Description

OpenEI is an **open source web platform**—similar to the one used by Wikipedia—developed by DOE/NREL to make the large amounts of energy-related **data and information more easily searched, accessed, and used** both by people and automated machine processes. Built utilizing the standards and practices of the **Linked Open Data** community, the OpenEI platform is much more robust and powerful than typical web sites and databases. All users can search, edit, add, and access data in OpenEI – for free. The user community contributes the content and ensures its accuracy and relevance; as the community expands, so does the content's comprehensiveness and quality. The **data are structured and tagged with descriptors to enable cross-linking among related data sets, advanced search functionality, and consistent, usable formatting**. Although DOE/NREL is developing OpenEI and seeding it with initial data, it is designed to be a true community model with millions of users, a large core of active contributors, and many sponsors.

Project Impact

- 280,000+ web visits from 190 countries
- Creation of over 300 datasets
- Creation of over 42,000 content pages
- Upload of over 3,400 images and files
- More than 350,000 contributor actions
- Over 220,000 unique visitors
- More than 2,200 registered users
- Over 7,000 Twitter followers
- More than 400 Facebook fans
- Over 2 million RDF triples

Project History and Timeline

OpenEI supports the U.S. Department of Energy's fulfillment of **open government and linked data standards**: transparency, public participation, and collaboration.

September 2009 Launched OpenEI: Wiki
October 2010 Launched OpenEI: Datasets

NREL Tools Links

Map Apps at NREL	http://maps.nrel.gov
MapSearch	http://www.nrel.gov/gis/mapsearch/
REAtlas	http://maps.nrel.gov/reatlas
IMBY	http://mercator.nrel.gov/imby
HyDRA	http://maps.nrel.gov/hydra
BioFuels Atlas	http://maps.nrel.gov/biomass
BioPower Atlas	http://http://rpm.nrel.gov/biopower/biopower/launch
Solar Prospector	http://maps.nrel.gov/prospector
Wind Prospector	http://maps.nrel.gov/wind_prospector
PVDAQ	http://maps.nrel.gov/pvdaq
LCOE Calculator	http://www.nrel.gov/analysis/tech_lcoe.html
GeoREServ API	http://rpm.nrel.gov/docs/georeserv/
REEDS	http://www.nrel.gov/analysis/reeds/
PV JEDI	http://www.nrel.gov/analysis/jedi/
Open Energy Info	http://openei.org
Smartgrid.gov	http://smartgrid.gov

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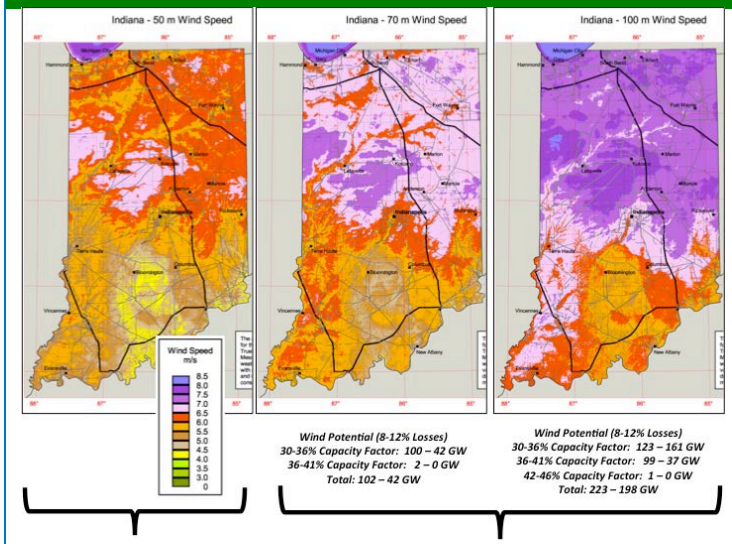
Siting and Geospatial Resource Analysis

..from resource potential to economic potential

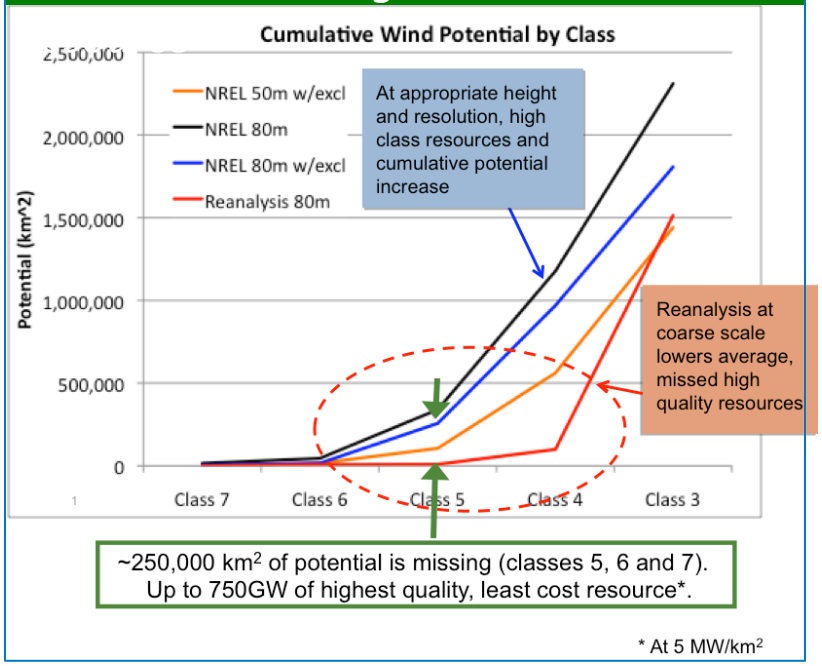
Measure the resource in the right place



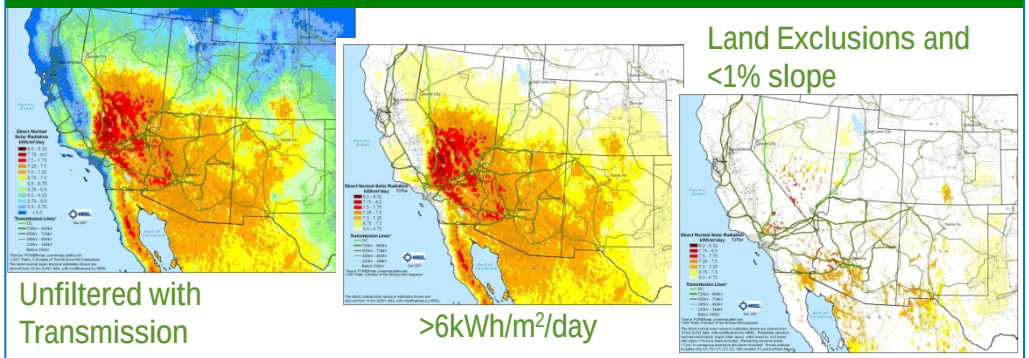
At 50 m height, Indiana's wind resource is small.

When assessed at modern onshore hub heights*, the resource is significant.

Scale matters: *Coarse scale data underestimates high wind class*

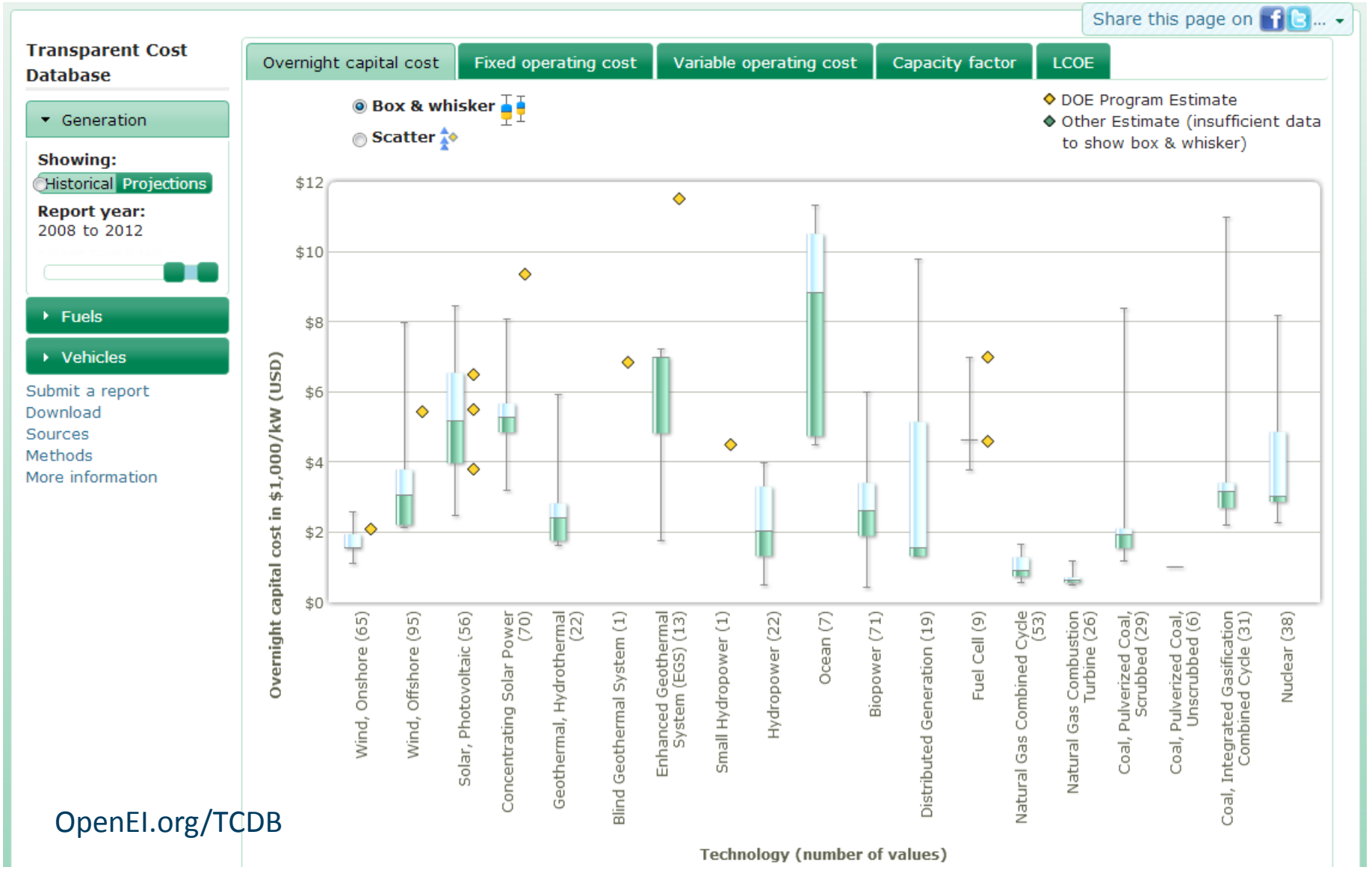


Filter appropriately



NREL works with the global research community to improve the representation of RE technologies in integrated assessment models

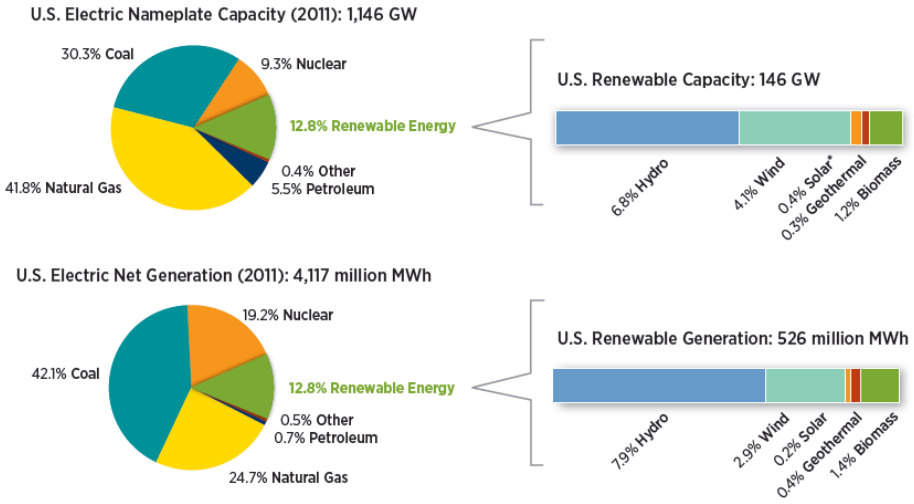
Technology Cost Database



OpenEI.org/TCDB

Renewable Energy Data Book

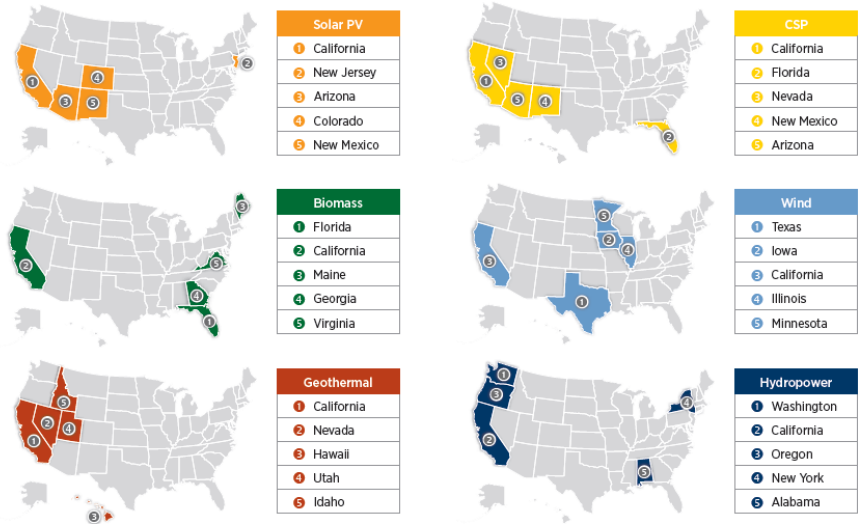
2011 U.S. Nameplate Electricity Capacity and Generation



U.S. RE Capacity as % of Total Generating Capacity

	Hydro	Solar PV	CSP	Wind	Geothermal	Biomass	All Renewables
2000	9.1%	0.0%	0.0%	0.3%	0.3%	1.3%	11.0%
2001	8.6%	0.0%	0.0%	0.5%	0.3%	1.2%	10.6%
2002	8.0%	0.0%	0.0%	0.5%	0.3%	1.1%	10.0%
2003	7.6%	0.0%	0.0%	0.6%	0.3%	1.1%	9.6%
2004	7.5%	0.0%	0.0%	0.7%	0.3%	1.1%	9.5%
2005	7.4%	0.0%	0.0%	0.9%	0.3%	1.1%	9.7%
2006	7.3%	0.0%	0.0%	1.1%	0.3%	1.1%	9.9%
2007	7.3%	0.0%	0.0%	1.6%	0.3%	1.1%	10.3%
2008	7.2%	0.1%	0.0%	2.3%	0.3%	1.2%	11.0%
2009	7.1%	0.1%	0.0%	3.2%	0.3%	1.2%	11.9%
2010	7.0%	0.2%	0.0%	3.6%	0.3%	1.2%	12.3%
2011	6.8%	0.4%	0.0%	4.1%	0.3%	1.2%	12.8%

Top States for RE Installed Capacity



Top Countries for Installed Renewable Generation