Project Evaluation Models

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*Alaska Native Village Energy Development Workshop*

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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.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel generators</td>
<td>Dispatchable, significant maintenance, fuel supply issues and costs</td>
</tr>
<tr>
<td>Wind turbines</td>
<td>Not dispatchable, maintenance requirements, variability of power</td>
</tr>
<tr>
<td>Solar PV</td>
<td>Not dispatchable, low maintenance, very seasonal</td>
</tr>
<tr>
<td>Biomass generators</td>
<td>Dispatchable, varying maintenance requirements, fuel supply issues</td>
</tr>
</tbody>
</table>

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
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
General Modeling Workflow

System
- Weather Data
- System Specs
- Electricity Production

Economics
- Financing Options
- Utility Rates & Incentives
- Cost Data

Results
Annual, Monthly, and Hourly Output, LCOE, NPV, Payback, Revenue, Capacity Factor
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

SAM Engine

- Solar Prospector Resource Data Service
- Sandia/CEC PV Module and Inverter Databases
- Default Costs through latest published Data and Experts (Al Goodrich)
- DOE-funded Utility Rate Database
- DOE-funded DSIRE Incentive web service
- Current best-in-class PV and CSP models
- Current best-in-class public finance models
- Impacted by new data and algorithms from other PV/CSP projects

- SAM Desktop Software Application (Windows and Mac)
- Web Services (generally PVWatts)
- Engine available to Programmers (SDK)
- Underpinnings for updated PVWatts Online Application
- Conferences, Journal Articles, Tech. Reports, Documentation
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.
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

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 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…
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

Double click on a system below for simulation results.

<table>
<thead>
<tr>
<th>PV</th>
<th>CoGen</th>
<th>Gen2</th>
<th>Conv.</th>
<th>Grid</th>
<th>Initial Capital</th>
<th>Operating Cost ($/yr)</th>
<th>Total NPC</th>
<th>COE ($/kWh)</th>
<th>Ren. Frac.</th>
<th>Diesel (L)</th>
<th>CoGen (hrs)</th>
</tr>
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<tbody>
<tr>
<td>3</td>
<td>7500</td>
<td>2200</td>
<td>1000</td>
<td>1000</td>
<td>$9,000,000</td>
<td>$13,068,830</td>
<td>$176,063,526</td>
<td>0.278</td>
<td>0.65</td>
<td>19,171</td>
<td>8,760</td>
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<tr>
<td>7500</td>
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<td>1000</td>
<td></td>
<td>$0</td>
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<td>120</td>
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<td>1,326,655,862</td>
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<td>0.92</td>
<td>19,200</td>
<td>8,760</td>
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<tr>
<td>120</td>
<td>7500</td>
<td>2200</td>
<td>4800</td>
<td>1000</td>
<td>$963,792</td>
<td>30,226,336</td>
<td>1,350,185,862</td>
<td>2.134</td>
<td>0.87</td>
<td>21,958</td>
<td>8,760</td>
</tr>
</tbody>
</table>
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
**Jobs & Economic Impacts from the JEDI Model**

**Economic Impact of Energy Projects**

**Wind energy's economic “ripple effect”**

**Local Revenue, Turbine, & Supply Chain Impacts**
- Blades, towers, gear boxes
- Boom truck & management, gas and gas station workers;
- Supporting businesses, such as bankers financing the construction, contractor, manufacturers and equipment suppliers;
- Utilities;
- Hardware store purchases and workers, spare parts and their suppliers

**Induced Impacts**
- Jobs and earnings that result from the spending supported by the project, including benefits to grocery store clerks, retail salespeople, and child care providers

**Project Development & Onsite Labor Impacts**
- Construction workers
- Management
- Administrative support
- Cement truck drivers
- Road crews
- Maintenance workers
- Legal and siting

**Construction Phase = 1-2 years**
**Operational Phase = 20+ years**

JEDI Model Version 1.09.05e
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.
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

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<th>Service</th>
<th>URL</th>
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</thead>
<tbody>
<tr>
<td>Map Apps at NREL</td>
<td><a href="http://maps.nrel.gov">http://maps.nrel.gov</a></td>
</tr>
<tr>
<td>IMBY</td>
<td><a href="http://mercator.nrel.gov/imby">http://mercator.nrel.gov/imby</a></td>
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<tr>
<td>HyDRA</td>
<td><a href="http://maps.nrel.gov/hydra">http://maps.nrel.gov/hydra</a></td>
</tr>
<tr>
<td>Wind Prospector</td>
<td><a href="http://maps.nrel.gov/wind_prospector">http://maps.nrel.gov/wind_prospector</a></td>
</tr>
<tr>
<td>PVDAQ</td>
<td><a href="http://maps.nrel.gov/pvdaq">http://maps.nrel.gov/pvdaq</a></td>
</tr>
<tr>
<td>GeoREServ API</td>
<td><a href="http://rpm.nrel.gov/docs/georeserv/">http://rpm.nrel.gov/docs/georeserv/</a></td>
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<td>Open Energy Info</td>
<td><a href="http://openei.org">http://openei.org</a></td>
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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

Unfiltered with Transmission

>6kWh/m²/day

Land Exclusions and <1% slope

~250,000 km² of potential is missing (classes 5, 6 and 7). Up to 750GW of highest quality, least cost resource*

* At 5 MW/km²
Technology Cost Database

OpenEI.org/TCDB
2011 U.S. Nameplate Electricity Capacity and Generation

U.S. Electric Nameplate Capacity (2011): 1,146 GW
- 30.3% Coal
- 9.3% Nuclear
- 12.8% Renewable Energy
- 0.4% Other
- 5.5% Petroleum

- 41.8% Natural Gas
- 12.8% Renewable Energy
- 0.5% Other
- 0.7% Petroleum

U.S. Renewable Capacity: 146 GW
- 6.8% Hydro
- 31% Wind
- 5.3% Solar
- 0.2% Geothermal
- 1.8% Biomass

U.S. Renewable Generation: 526 million MWh
- 7.3% Hydro
- 24.4% Wind
- 0.8% Solar
- 0.1% Geothermal
- 1.1% Biomass

Top States for RE Installed Capacity

Top Countries for Installed Renewable Generation

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

- Hydro
- Solar PV
- CSP
- Wind
- Geothermal
- Biomass
- All Renewables

2000:
- Hydro: 9.1%
- Solar PV: 0.0%
- CSP: 0.0%
- Wind: 0.3%
- Geothermal: 0.3%
- Biomass: 1.3%
- All Renewables: 11.0%

2001:
- Hydro: 8.6%
- Solar PV: 0.0%
- CSP: 0.0%
- Wind: 0.5%
- Geothermal: 0.3%
- Biomass: 1.2%
- All Renewables: 10.6%

2002:
- Hydro: 8.0%
- Solar PV: 0.0%
- CSP: 0.0%
- Wind: 0.5%
- Geothermal: 0.3%
- Biomass: 1.1%
- All Renewables: 10.0%

2003:
- Hydro: 7.6%
- Solar PV: 0.0%
- CSP: 0.0%
- Wind: 0.6%
- Geothermal: 0.3%
- Biomass: 1.1%
- All Renewables: 9.6%

2004:
- Hydro: 7.5%
- Solar PV: 0.0%
- CSP: 0.0%
- Wind: 0.7%
- Geothermal: 0.3%
- Biomass: 1.1%
- All Renewables: 9.5%

2005:
- Hydro: 7.4%
- Solar PV: 0.0%
- CSP: 0.0%
- Wind: 0.9%
- Geothermal: 0.3%
- Biomass: 1.1%
- All Renewables: 9.7%

2006:
- Hydro: 7.3%
- Solar PV: 0.0%
- CSP: 0.0%
- Wind: 1.1%
- Geothermal: 0.3%
- Biomass: 1.1%
- All Renewables: 9.9%

2007:
- Hydro: 7.3%
- Solar PV: 0.0%
- CSP: 0.0%
- Wind: 1.6%
- Geothermal: 0.3%
- Biomass: 1.1%
- All Renewables: 10.3%

2008:
- Hydro: 7.2%
- Solar PV: 0.1%
- CSP: 0.0%
- Wind: 2.3%
- Geothermal: 0.3%
- Biomass: 1.2%
- All Renewables: 11.0%

2009:
- Hydro: 7.1%
- Solar PV: 0.1%
- CSP: 0.0%
- Wind: 3.2%
- Geothermal: 0.3%
- Biomass: 1.2%
- All Renewables: 11.9%

2010:
- Hydro: 7.0%
- Solar PV: 0.2%
- CSP: 0.0%
- Wind: 3.6%
- Geothermal: 0.3%
- Biomass: 1.2%
- All Renewables: 12.3%

2011:
- Hydro: 6.8%
- Solar PV: 0.4%
- CSP: 0.0%
- Wind: 4.1%
- Geothermal: 0.3%
- Biomass: 1.2%
- All Renewables: 12.8%