



Energy Modeling Tools

Jal Desai
National Renewable Energy Laboratory
(NREL)

July 31, 2019

Contents

- 1** Why do we need energy modeling software?
- 2** Modeling Inputs in General
- 3** Building Energy Modeling Tools
- 4** Common Energy, Water, and Renewable Measures

Why do we need energy modeling software?

- In 2018, the residential and commercial sectors accounted for about 40% (or about 40 quadrillion British thermal units) of total U.S. energy consumption [EIA, May 2019]
- Opportunity exists for project teams to utilize energy modeling software to help evaluate design decisions in terms of life-cycle cost impacts in order to maximize building performance
- Building energy performance is a function of numerous, interdependent internal and external factors, such as material selection, mechanical and electrical systems, solar orientation, climate, and occupant usage
- Modification of various design components can produce complex interactions that are difficult to analyze in isolation
- Building energy simulation softwares provide tools for evaluating energy impacts across dynamic interrelated systems

Source: <https://www.eia.gov/tools/faqs/faq.php?id=86&t=1>

Source: http://ecs.syr.edu/centers/SustainableEngineering/modules/13-53_Clevenger.pdf

Modeling Inputs in General

- These are the overall steps followed to create an energy model

Step 1

- Collects data at the site enough to fully define the building and energy consuming features
 - Inputs that are unknown should be highlighted and used as calibration parameters
 - List of data required to build an energy model
 - Drawings, as-built
 - Utility bills
 - Equipment schedules
 - Lighting drawings
 - Square footage
 - Occupancy (24/7, intermittent, conference rooms, etc.)
 - Schedule – mechanical and occupancy
 - Building function, purpose, usage

Step 2

- Fills out the model and run the simulation
 - Copies the monthly output tables to an excel spreadsheet and calibrates the model to within 5-10% of the monthly/annual utility bills

Step 3

- Uses the model to run various “what if” scenarios to calculate energy savings associated with identified energy conservation measures

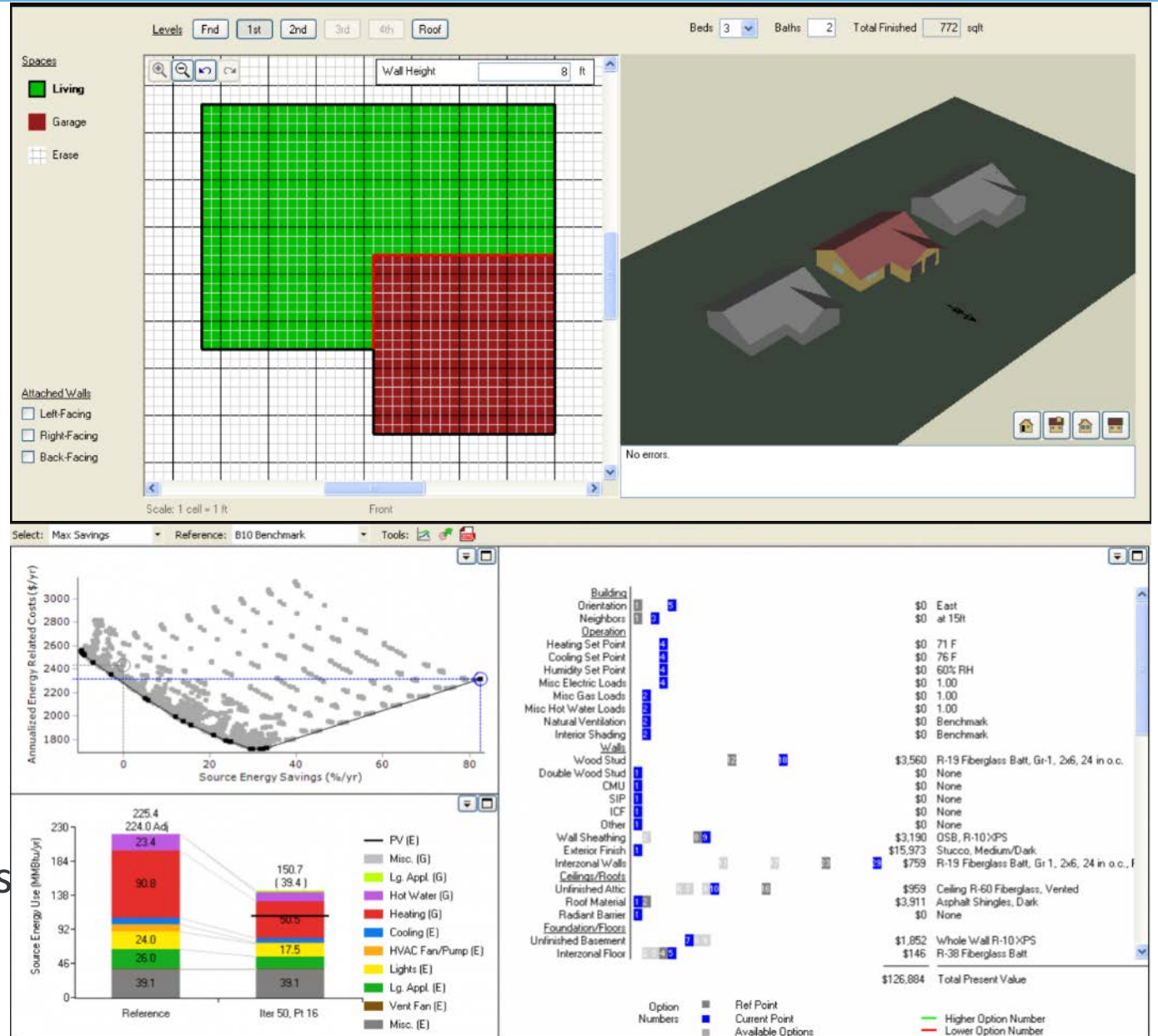
Building Energy Modeling Tools

BEopt : Residential Building Energy Modeling Tool

The BEopt™ (Building Energy Optimization Tool) software provides capabilities to evaluate residential building designs and identify cost-optimal efficiency packages at various levels of whole-house energy savings along the path to zero net energy

BEopt™ provides detailed simulation-based analysis based on specific house characteristics, such as size, architecture, occupancy, vintage, location, and utility rates. Discrete envelope and equipment options, reflecting realistic construction materials and practices, are evaluated

Free Web Download: <https://beopt.nrel.gov/home>



Case Study: Kwethluk, AK



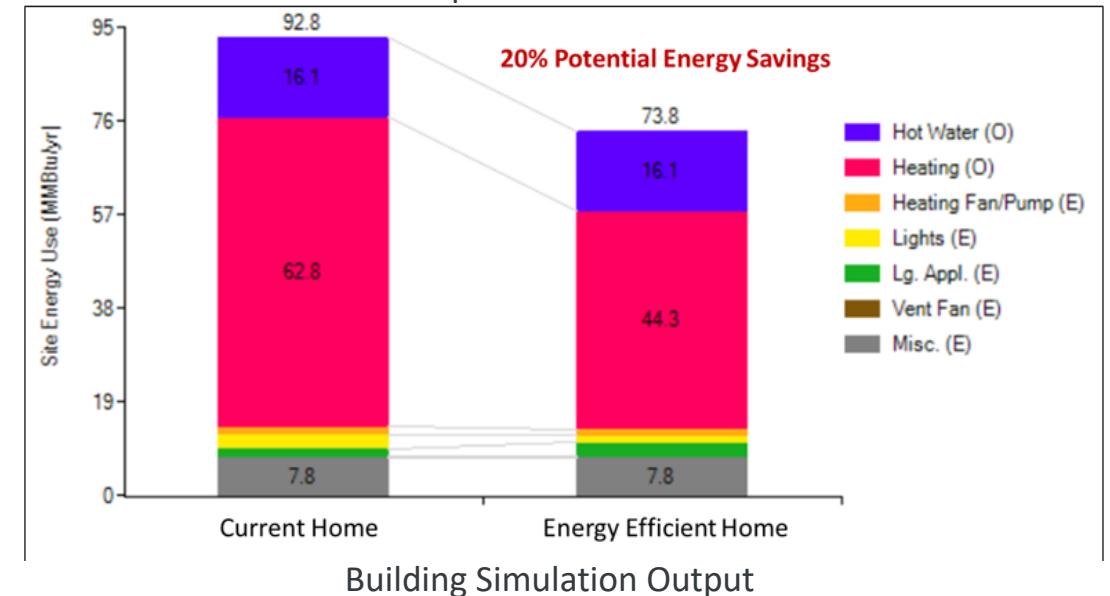
Actual House



BEopt Model

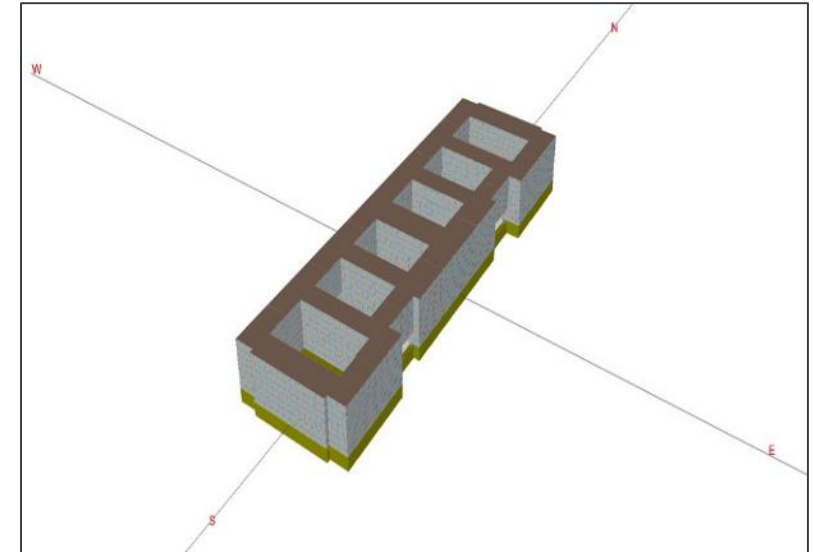
According to the model, there is an expected potential energy savings of 20 % in the energy efficient home. The following measured were analyzed in the energy efficient homes

1. Air sealing to 7 ACH50
2. Low-e double pane windows with high heat gain
3. R-60 attic blown-in cellulose
4. 100 % LED lights



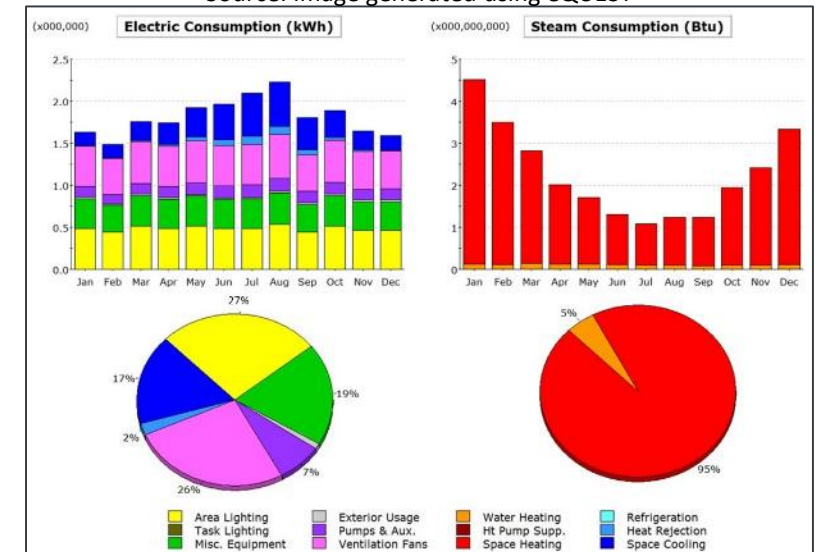
eQuest: Commercial Building Energy Modeling Tools

- The Quick Energy Simulation Tool, or eQUEST is a DOE-2 interface which allows users to develop 3-dimensional simulation models of a particular building design
- These simulations incorporate building location, orientation, wall/roof construction, window properties, as well as HVAC systems, day-lighting and various control strategies, along with the ability to evaluate design options for any single or combination of energy conservation measure(s)



eQUEST Model Representation

Source: Image generated using eQUEST



eQUEST calibrated baseline energy use estimates

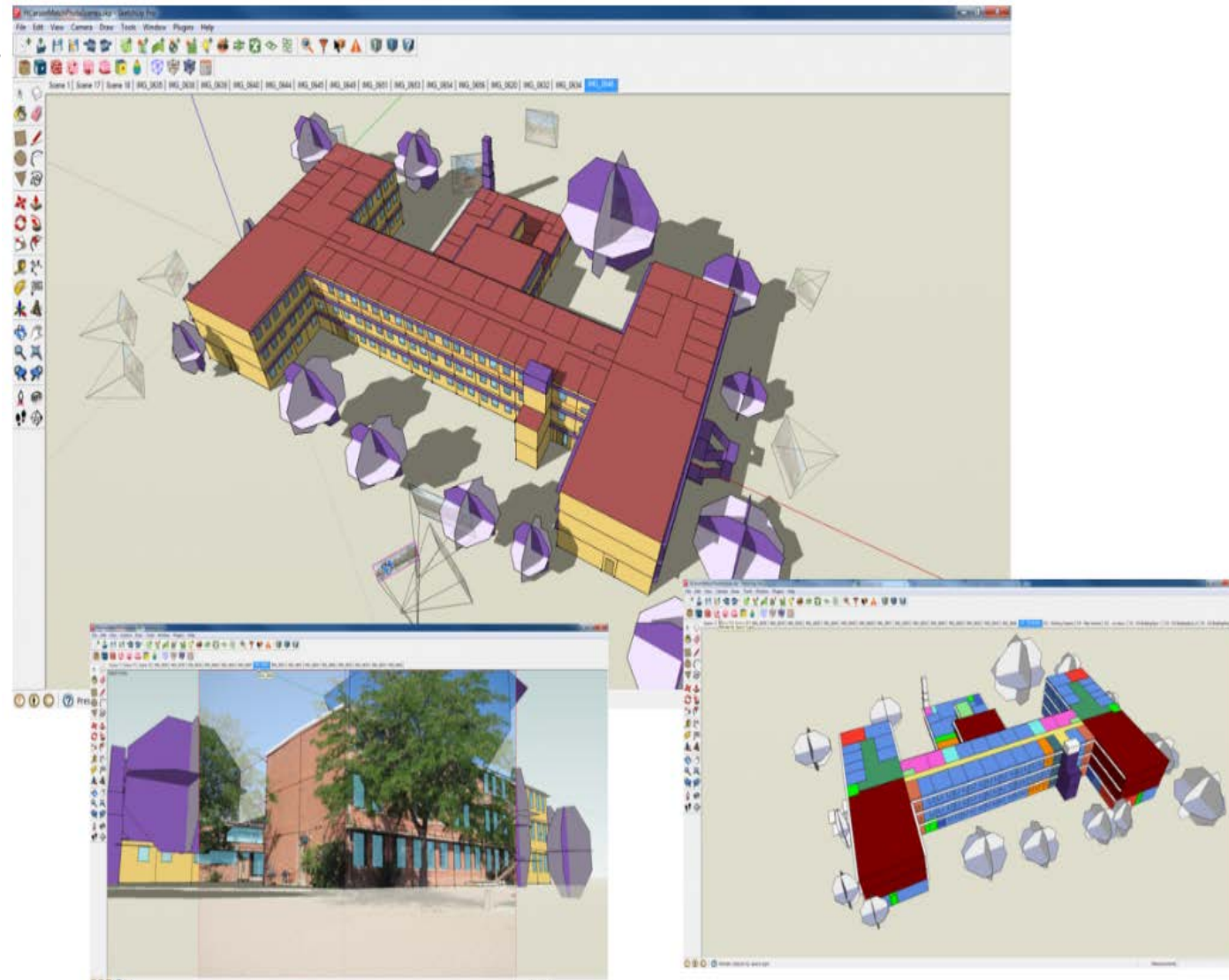
Source: Figures generated using eQUEST

Free Web Download: <http://www.doe2.com/equest/>

Source: <http://energy-models.com/software/equest>

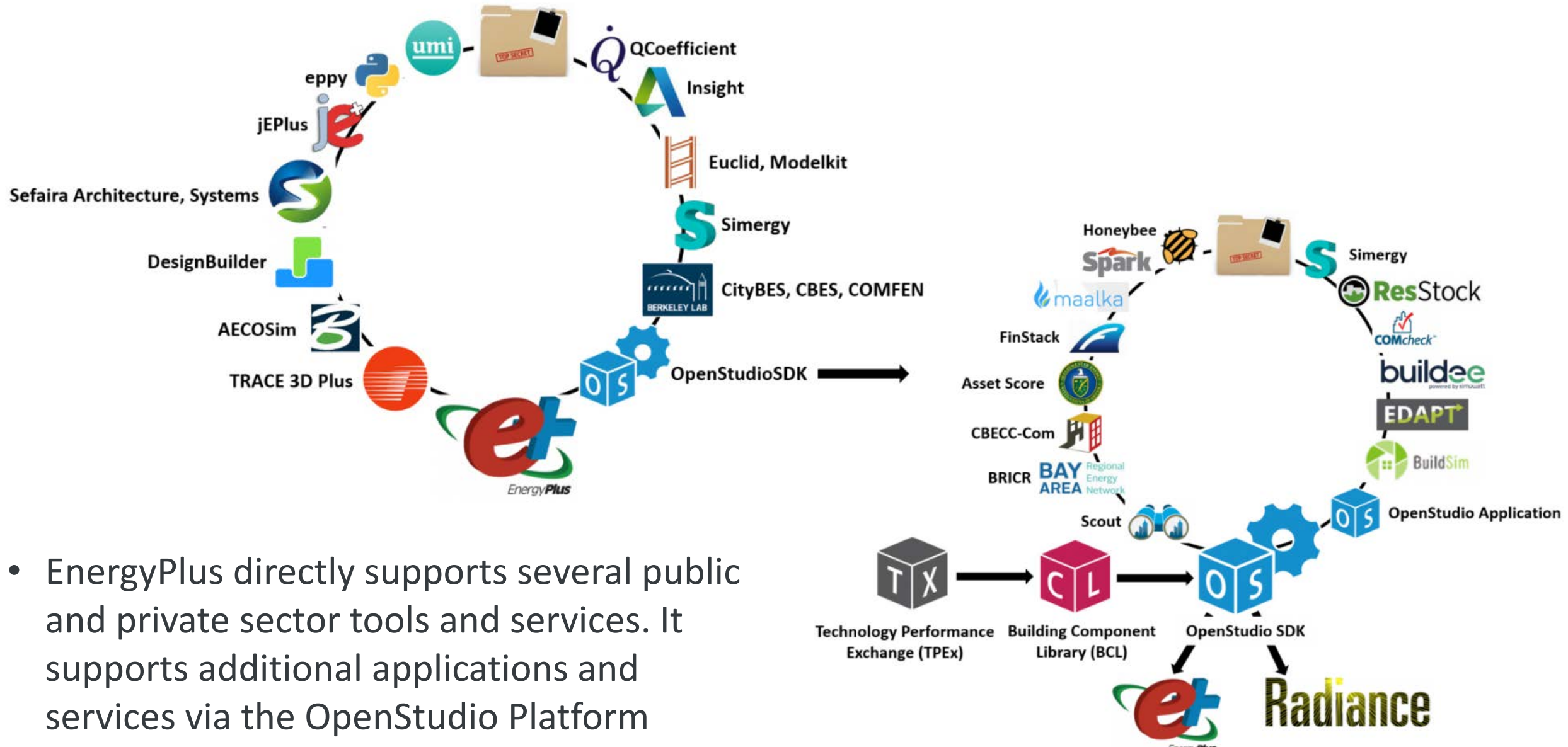
OpenStudio: Commercial Building Energy Modeling Tool

- OpenStudio® is a cross-platform (Windows, Mac, and Linux) collection of software tools to support whole building energy modeling using EnergyPlus and advanced daylight analysis using Radiance
- OpenStudio is the front-end of the EnergyPlus
- EnergyPlus is an energy analysis and thermal load simulation program
- EnergyPlus is not a user interface. It is intended to be the simulation engine around which a third-party interface can be wrapped



Source: <https://www.energy.gov/eere/buildings/about-building-energy-modeling>

OpenStudio and EnergyPlus Adoption



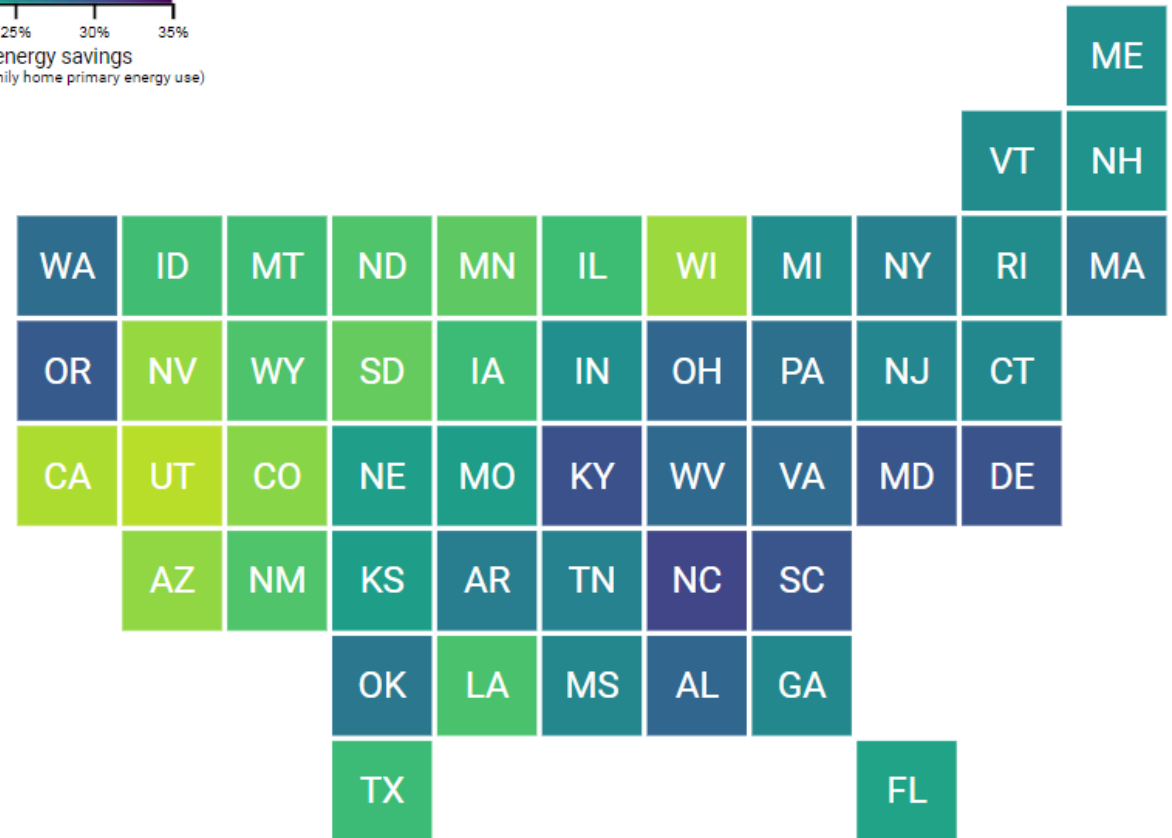
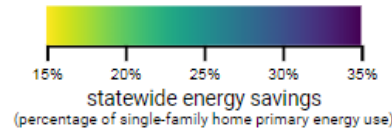
- EnergyPlus directly supports several public and private sector tools and services. It supports additional applications and services via the OpenStudio Platform

ResStock :Residential Stock Modeling Tool

- The ResStock analysis tool is helping states, municipalities, utilities, and manufacturers identify which home improvements save the most energy and money
- The ResStock software is offered at no cost, leveraging the U.S. Department of Energy's (DOE's) open-source building energy modeling ecosystem of OpenStudio[®] and EnergyPlus[™].

State Fact Sheets

Click on a state to view a summary of the cost-effective residential savings potential and top priority improvements in that state.



Free Download: <https://www.nrel.gov/buildings/resstock.html>

Details of the analysis approach are also available.

ResStock: Residential Stock Modeling Tool

ResStock [Back to all states](#) [Analysis approach](#) [Print](#)

COLORADO

Residential Energy Efficiency Potential

Cost-effective package savings potential in Colorado single-family homes

- \$ 511.2 million** dollars per year utility bill savings
- 22.9 trillion** Btu per year gas, propane, and fuel oil savings
- 2.5 billion** kWh per year electricity savings
- 685,994** cars of pollution reduction

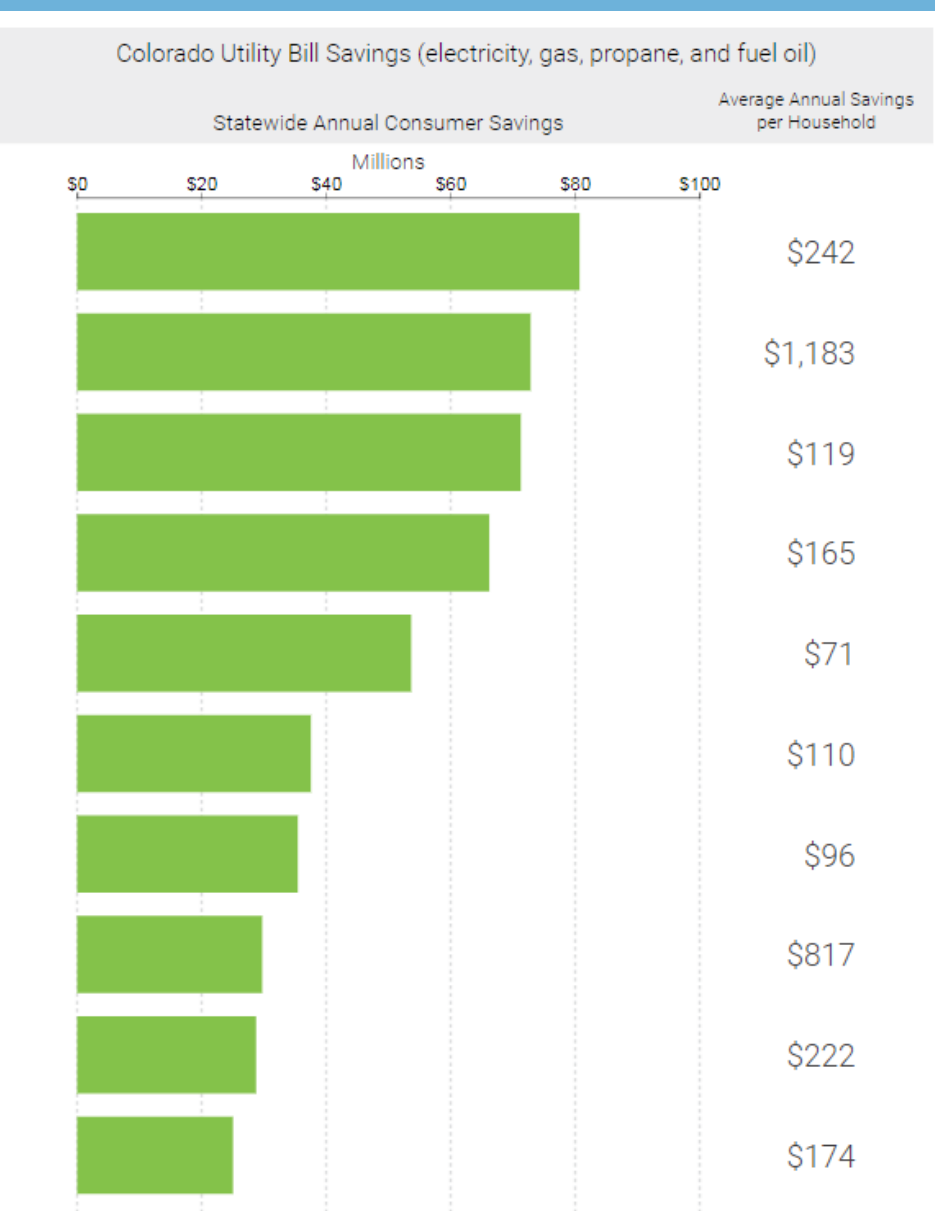
Energy used by Colorado single-family homes that can be saved through cost-effective improvements: **19%**

Colorado existing jobs in energy efficiency (2016)¹: **29,756**

Colorado Top 10 Improvements

* Pays back in less than 5 years for most households

Category	Improvement
Enclosure	Drill-and-fill wall cavity insulation
HVAC	High-efficiency heat pump (replace electric furnace at wear out)
Lighting	LED lighting
Enclosure	R-10 basement wall insulation
HVAC	Smart thermostat
HVAC	Duct sealing & insulating
Enclosure	R-49 attic insulation
HVAC	Ductless heat pump (displaces electric baseboard)
Enclosure	R-10 crawlspace walls
Enclosure	R-5 insulated wall sheathing (at siding replacement)



RETScreen Renewable Energy Modeling Tool

Models renewable energy technologies and energy efficiency

- Energy efficiency
- Renewable energy:
 - Wind power
 - Geothermal power
 - Solar PV
 - Solar thermal
 - Ocean
 - Tidal
 - Wave
- Other technologies:
 - Fuel cells
 - Micro-turbines

Also models conventional combustion technologies

- Steam turbine
- Gas turbine
- Gas turbine – combined cycle
- Reciprocating engine

The screenshot displays the RETScreen Expert software interface. At the top, there is a menu bar with options: File, Location, Facility, Energy, Cost, Emission, Finance, Risk, Data, Analytics, Report. Below the menu bar is a navigation pane on the left with options: Home, Open, Close, Settings, Help, Subscribe, Save, Save As, and Exit. The main workspace is divided into several sections: 'Getting started - Options' with a 'Virtual energy analyzer' button; 'Analysis type - Worksheets' with buttons for Benchmark, Feasibility, Performance, and All; 'Workflow' showing a circular diagram with four quadrants: Performance Tracker (top-left), Virtual Energy Analyzer (top-right), Financial Risk Assessor (bottom-left), and Smart Project Identifier (bottom-right). The diagram is surrounded by labels: Performance, Analytics, Report, Location, Benchmark, Facility, Energy, Cost, Emission, Feasibility, Finance, Risk, and Data. On the right side, there are 'Facility types' (Power plants, Buildings and factories, Industrial, Commercial/Institutional, Residential, Agricultural, User-defined, Individual measure, New, Existing) and 'Integrated features' (User manual, Databases, Product data, Cost data, Benchmark data, Climate data, Weather data, Dashboard). The bottom of the interface shows the title bar 'RETScreen Expert - Viewer - 6.0.7.67' and copyright information '© Minister of Natural Resources Canada 1997-2017'.

- Free web download

- <http://www.nrcan.gc.ca/energy/software-tools/7465>

Related (Non-Building) Energy Modeling Tools

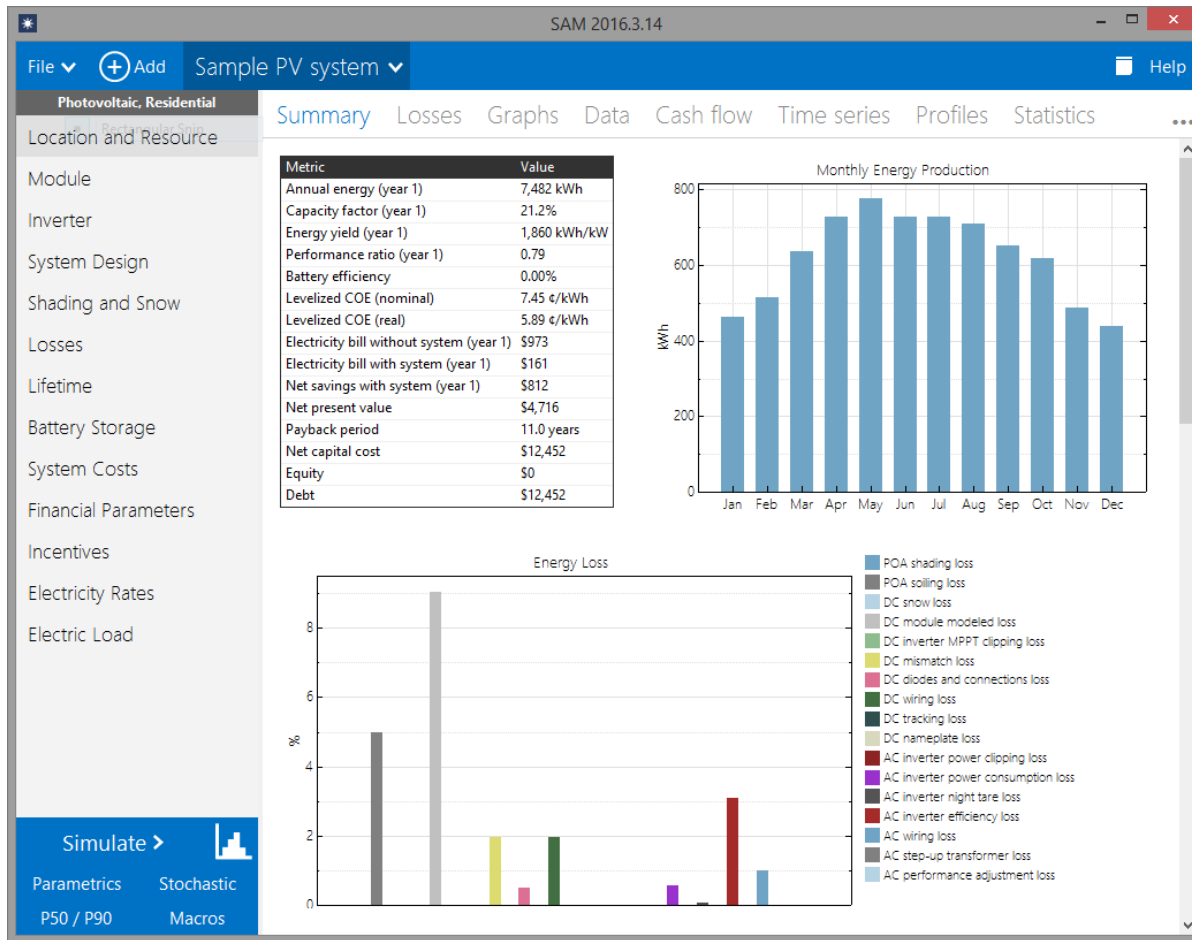
PVWatts Solar PV Modeling Tool

- Estimates the energy production and cost of energy of grid-connected photovoltaic (PV) energy systems throughout the world
- It allows homeowners, small building owners, installers and manufacturers to easily develop estimates of the performance of potential PV installations
- Free web-based tool
 - <http://pvwatts.nrel.gov/pvwatts.php>

The screenshot displays the PVWatts Calculator interface. At the top, the location is set to "Addis Ababa, Ethiopia". The "SOLAR RESOURCE DATA" section is active, showing the selected weather data source as "(INTL) ADDIS ABABA/BOLE, ETHIOPIA" at a distance of 3.4 miles. Below this, there is a section titled "Optionally, Select Different Weather Data" with a map of the region around Addis Ababa. The map includes a "Data Sources" legend with checkboxes for TMY2, TMY3, and International. The TMY2 and TMY3 options are checked. The map shows various locations and a red pin indicating the selected weather data source.

System Advisor Model (SAM) for Modeling Renewable Energy

Free software that combines detailed performance and financial models to estimate the cost of energy for systems



Technologies

- Photovoltaics, detailed & PVWatts
- Battery storage
- Concentrating solar power
- Wind
- Geothermal
- Biomass
- Solar water heating

Financials

- Behind-the-meter
 - residential
 - commercial
- Power purchase agreements
 - single owner
 - equity flips
 - sale-leaseback
- Simple LCOE calculator

<http://sam.nrel.gov/download>

MotorMaster

- Models motor energy use
- Extensive database of available motors
- Free web download
 - <http://www1.eere.energy.gov/manufacturing/downloads/MMInt14Setup.exe>

The screenshot shows the 'Motor Comparison' window with the following data:

Utility	Rate Schedule	Facility	Energy price (\$/kWh)	Demand charge (\$/kW)	Rebate Program	Motor Description and Features	Size/Speed	Enclosure/Voltage	Hours use/yr	Load (%)	Efficiency (%)	Rewind Effic Loss (%)	Dealer discount (%)	Price (\$)	Motor Rebate (\$)	Peak Months
Puget Sound Energy	Schedule 26 - Large D	<none>	0.061609	7.21	No rebate program in effect	Motor Description and Features	50 hp 1800 RPM	TEFC 460 Volts	6250	75.0	91.1	0.5		1488 (rewind)		12
							50 hp 1800 RPM	TEFC 460 Volts	6250	75.0	95.0			5414		12

Buttons: Savings, ? (Help), Exit

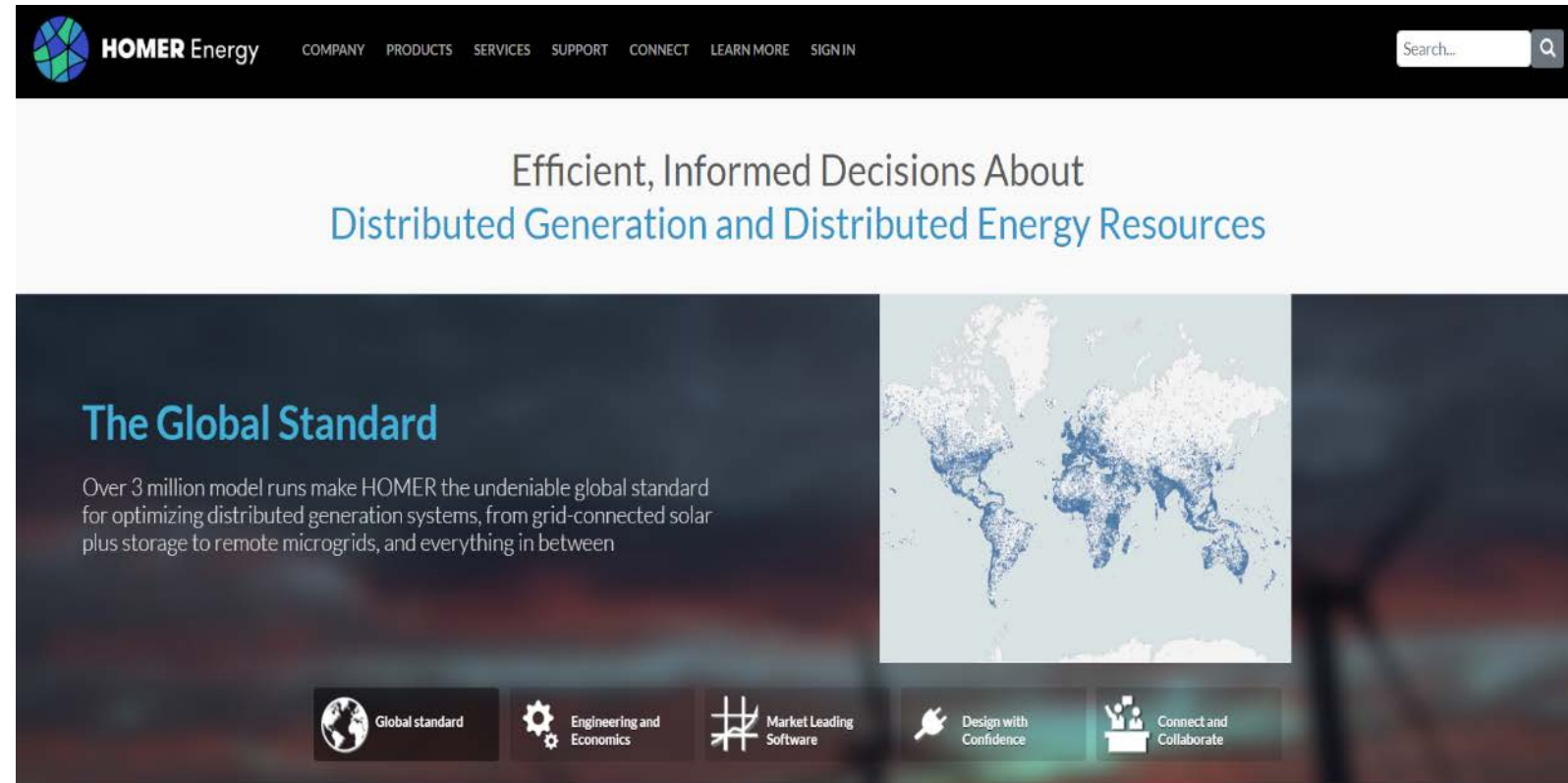
Options: New, Rewind, Replace Existing

Motor Selection: Energy-Efficient, Standard Efficiency, Premium Efficiency, Energy-Efficient

Buttons: Inventory, Catalog, Copy Values

HOMER Energy Microgrid Energy Modeling

- HOMER (Hybrid Optimization Model for Multiple Energy Resources) is used to model and optimize conventional electrical generation microgrids with a high penetration of renewable energy
- Free and pay versions available
http://www.homerenergy.com/HOMER_pro.html



The screenshot shows the HOMER Energy website homepage. At the top, there is a navigation bar with the HOMER Energy logo and links for COMPANY, PRODUCTS, SERVICES, SUPPORT, CONNECT, LEARN MORE, and SIGN IN. A search bar is located on the right side of the navigation bar. The main heading reads "Efficient, Informed Decisions About Distributed Generation and Distributed Energy Resources". Below this, there is a section titled "The Global Standard" with a world map background. The text states: "Over 3 million model runs make HOMER the undeniable global standard for optimizing distributed generation systems, from grid-connected solar plus storage to remote microgrids, and everything in between". At the bottom of the page, there are five icons with corresponding text: "Global standard" (globe icon), "Engineering and Economics" (gears icon), "Market Leading Software" (grid icon), "Design with Confidence" (lightbulb icon), and "Connect and Collaborate" (network icon).

Many Free Software Tools Available from NREL

- <https://www.nrel.gov/research/data-tools.html>

» Research » Data and Tools

Research Areas

Publications

Data & Tools

Directorates

Fellows

Collaborations

Highlights

Energy Basics

Data and Tools

NREL develops data sets, maps, models, and tools for the analysis of energy and energy-efficiency technologies.

Alphabetical

Explore our full collection of data, maps, models, and tools in the [alphabetical listing](#).

Popular

[PVWatts® Calculator](#)

[Geospatial Data Science](#)

[National Solar Radiation Database Data Viewer](#)

Featured

The [NREL Data Catalog](#) is a collection of publicly accessible data resulting from NREL research.

By Technology



Bioenergy



Buildings



Concentrating Solar Power



Energy Analysis



Grid Modernization



Geothermal



Hydrogen and Fuel Cells



Integrated Energy Solutions

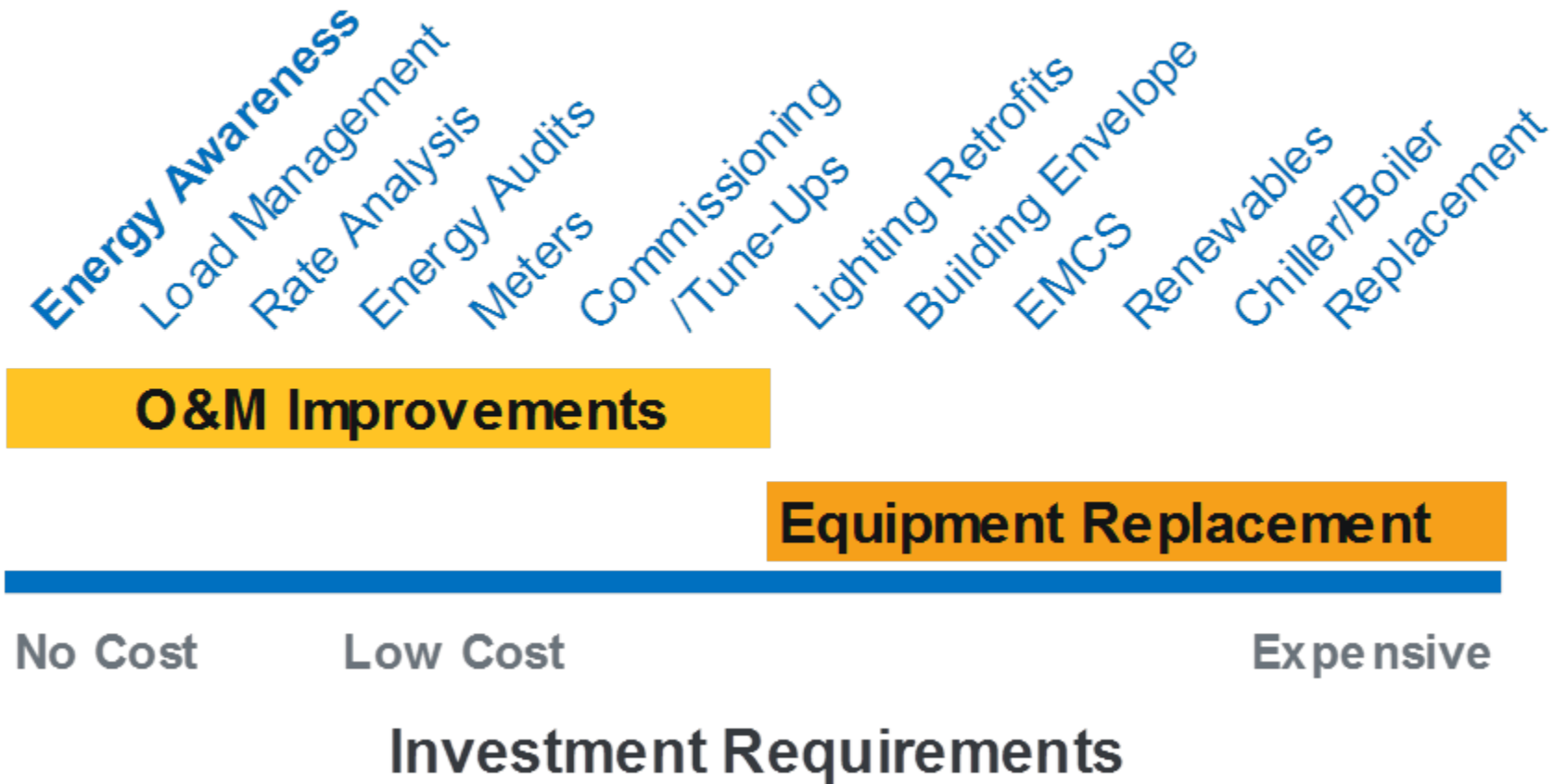


Transportation

Common Energy, Water, and Renewable Measures

Energy Conservation Measures

The Energy Management Continuum

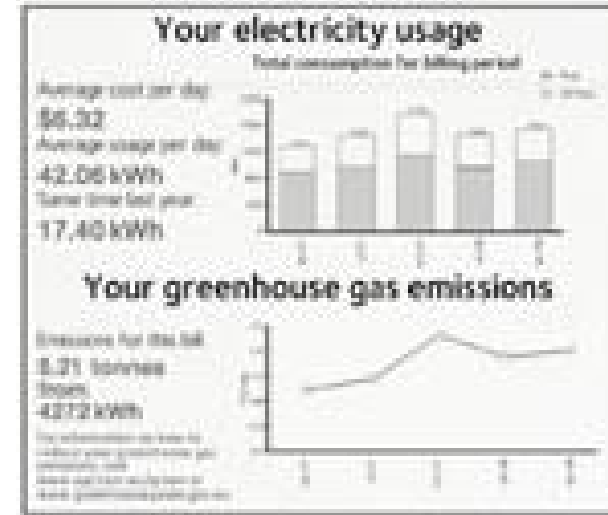


Typical Measures Considered

- **Energy Conservation Measures (ECMs)**
 - Heating, Ventilating, and Air-Conditioning (HVAC)
 - Lighting
 - Plug Loads
 - Building Envelope
- **Water Conservation Measures (WCMs)**
- **Renewable Energy Measures (REMs)**
 - ECMs are typically more financially viable when compared to REMs
 - REMs can be sized to meet the reduced loads after ECMs are implemented
- **O&M, Commissioning & Re-commissioning**

Behavioral & No-cost ECMs

- Analyze utility rate structure and track billing history
- Run an energy awareness campaign, promote occupants to:
 - Turn off lights in unoccupied rooms such as break rooms, private offices, conference rooms, etc.
 - Turn off exterior lighting during daytime hours
 - Wash hands, dishes, etc. with cold water
 - Turn off computers at nighttime; use automatic power settings when they're inactive
 - Eliminate and remove personal printers, refrigerators, coffeepots, etc.
- Use setback temperatures on all HVAC equipment



Energy Conservation Measure

- **HVAC**

- Install programmable thermostats for all zones and HVAC equipment.
- Install high coefficient of performance (COP) cooling system.
- Replace regular fan and motor belts with cogged V-belts.
- Regularly replace HVAC filters.
- Convert constant air volume (CAV) system to variable air volume (VAV) system
- Reduce outside airflow as per ASHRAE 62.1.
- Implement chilled water reset.
- Install variable frequency drive (VFD)
- Incrementally replace old motors with NEPA premium efficiency motors.



VFD

Source: Santek Systems

Energy Conservation Measure

- **Lighting**

- Replace all incandescent and CFL bulbs with LEDs
- Replace all T-12 fluorescent lamps and magnetic ballasts with low wattage T-8 lamps and electronic ballasts or LED replacements
- Implement task lighting
- Install LED exit signs
- Install occupancy sensors in common rooms, corridors, restrooms, etc.
- Install light sensors on exterior lighting
- Reduce lighting level in over lit areas by De-Lamping
- Install wireless lighting controls



- **Plug Loads**

- Select Energy Star office equipment and appliances.
- Use network printers to reduce the number of personal printers
- Activate power management on computers and monitors.
- Use laptops and LCD monitors instead of desktops and CRT monitors.
- Install vending machine misers and remove advertising lighting.
- Install power management surge protectors in offices.



Energy Conservation Measure

- **Building Envelope**

- Roofs

- Increase the amount of roof insulation
 - Retrofit existing roof with green roof
 - Retrofit existing roof with cool roof

- Walls

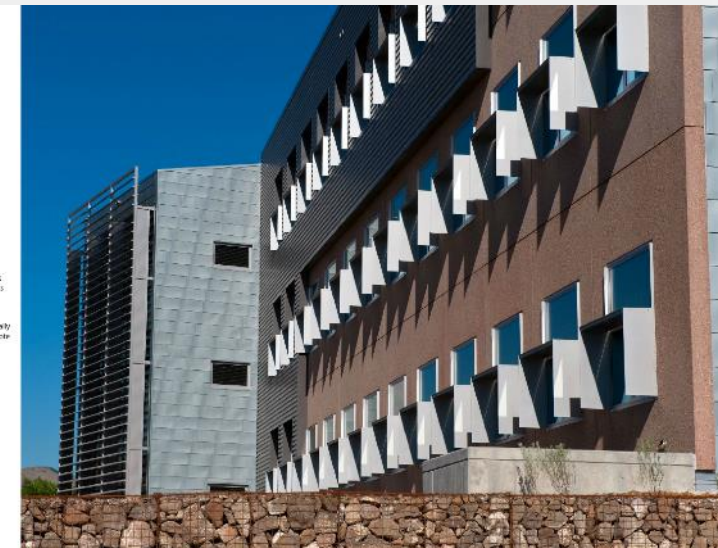
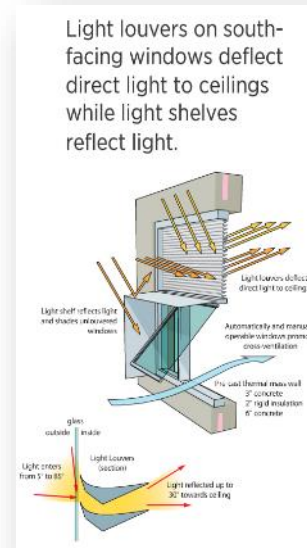
- Install additional insulation in exterior walls
 - Seal off all the infiltration points in exterior wall

- Windows

- Replace old or single pane window
 - Add shading features to south-facing facades for solar shading

- Doors

- Replace traditional doors with revolving doors
 - Create an entrance vestibule with two doors
 - Install adequate weather stripping



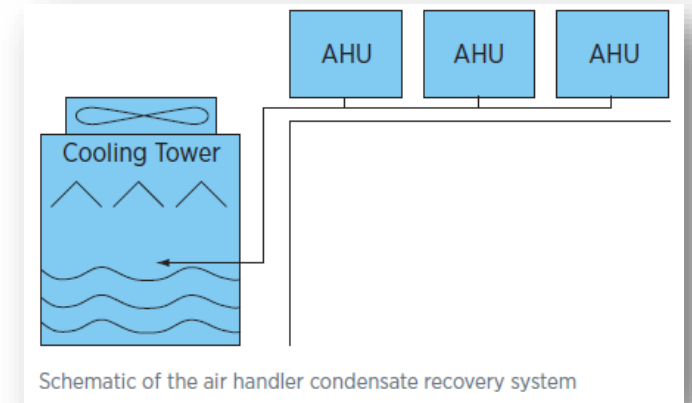
Water Conservation Measures

- Use EPA's WaterSense labeled products.
- Purchase EnergyStar Water-Consuming Appliances
- Toilets
 - Retrofit existing toilets
 - Displacement device
 - Dual flush adapters
 - Replace Toilets
 - Low flow or high efficiency toilet
 - Composting toilet
- Urinals
 - Retrofit existing urinals
 - Siphonic jet retrofits
 - Washout/Washdown retrofits
 - Replace Urinals
 - Low flow or high efficiency urinals
 - Waterless
- Showerheads
 - Install low –flow showerheads
 - Atomizer
 - Pulsator
 - Aerator mix



Water Conservation Measures

- **Cooling Tower**
 - Install air handling unit condensate recovery
 - Install cooling tower duct meter
- **Irrigation**
 - Reduce water needs by Xeriscaping
 - Procure water from alternate water source
 - Install efficient irrigation system
 - Low volume drip system
 - Sub surface drip system
 - Reuse system
 - Weather based irrigation system



Renewable Energy Measures

- Common renewable energy technologies are
 - Onsite Photovoltaic Array
 - Onsite Solar Hot Water System
 - Wind
 - Biomass
 - Solar Vent Preheat



O&M, Commissioning & Re-commissioning

- **General Operations and Maintenance (O&M)**
 - Energy Saving Strategies**
 - Verify Operation of HVAC Components
 - Calibrate HVAC Sensors
 - Periodically Retro-Commission HVAC Equipment
- **The goals of commissioning (Cx) are to:**
 - Provide a safe and healthy facility
 - Improve energy performance and minimize energy consumption
 - Reduce operating costs
 - Ensure adequate O&M staff orientation and training.
 - Improve systems documentation
- **Re-commissioning (Rx) is an ongoing process to:**
 - Resolve operational problems
 - Improve comfort
 - Optimize energy use
 - Rx does not ensure that the systems function as originally designed
 - Ensures the buildings and systems operate optimally to the current requirements

O&M programs targeting energy efficiency are estimated to save **5% to 20%** on energy bills without a significant capital investment. Many can be achieved with minimal cash outlays.

Thank you!

Questions?

www.nrel.gov

Jal.desai@nrel.gov

