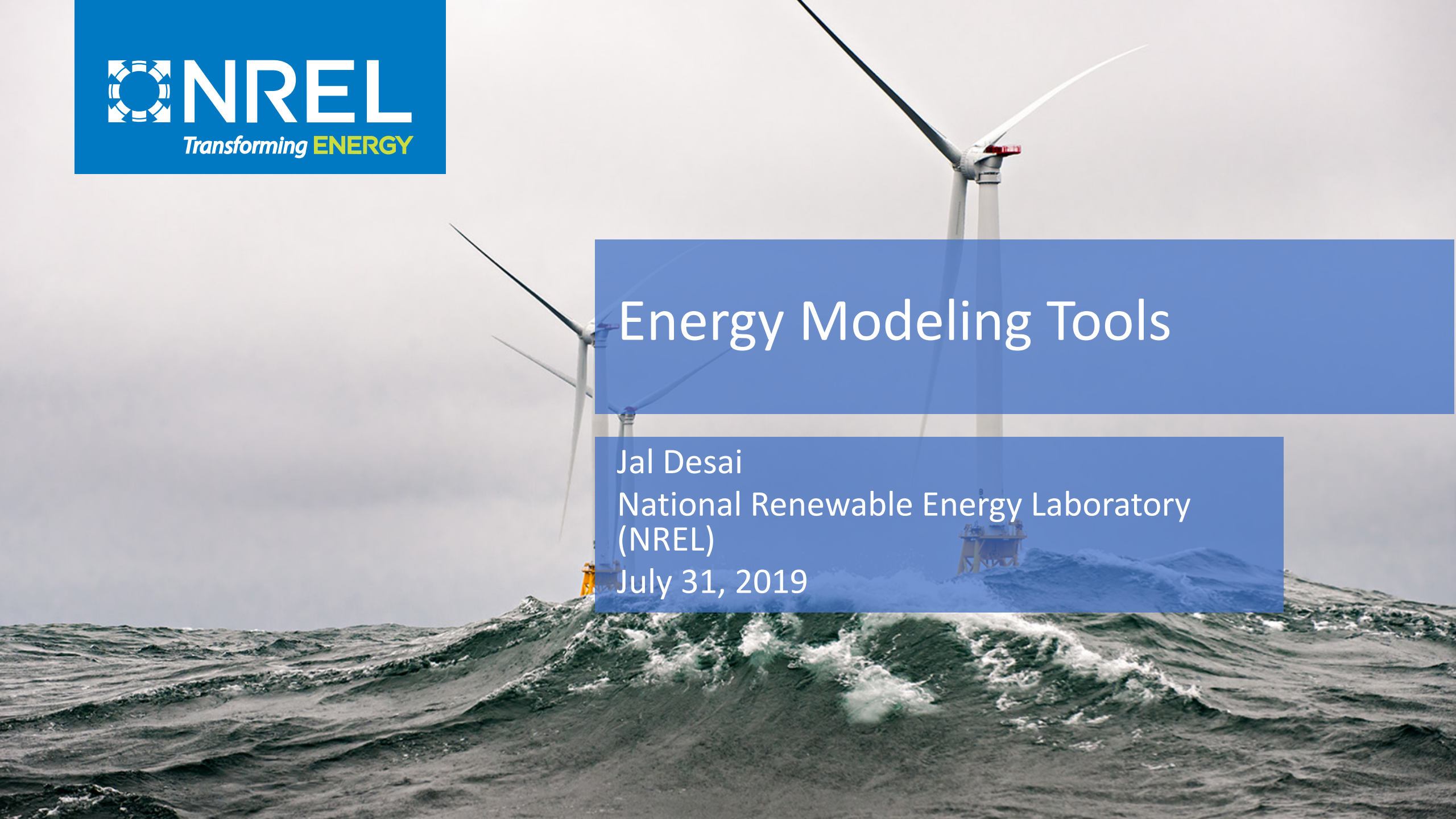


Energy Modeling Tools

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

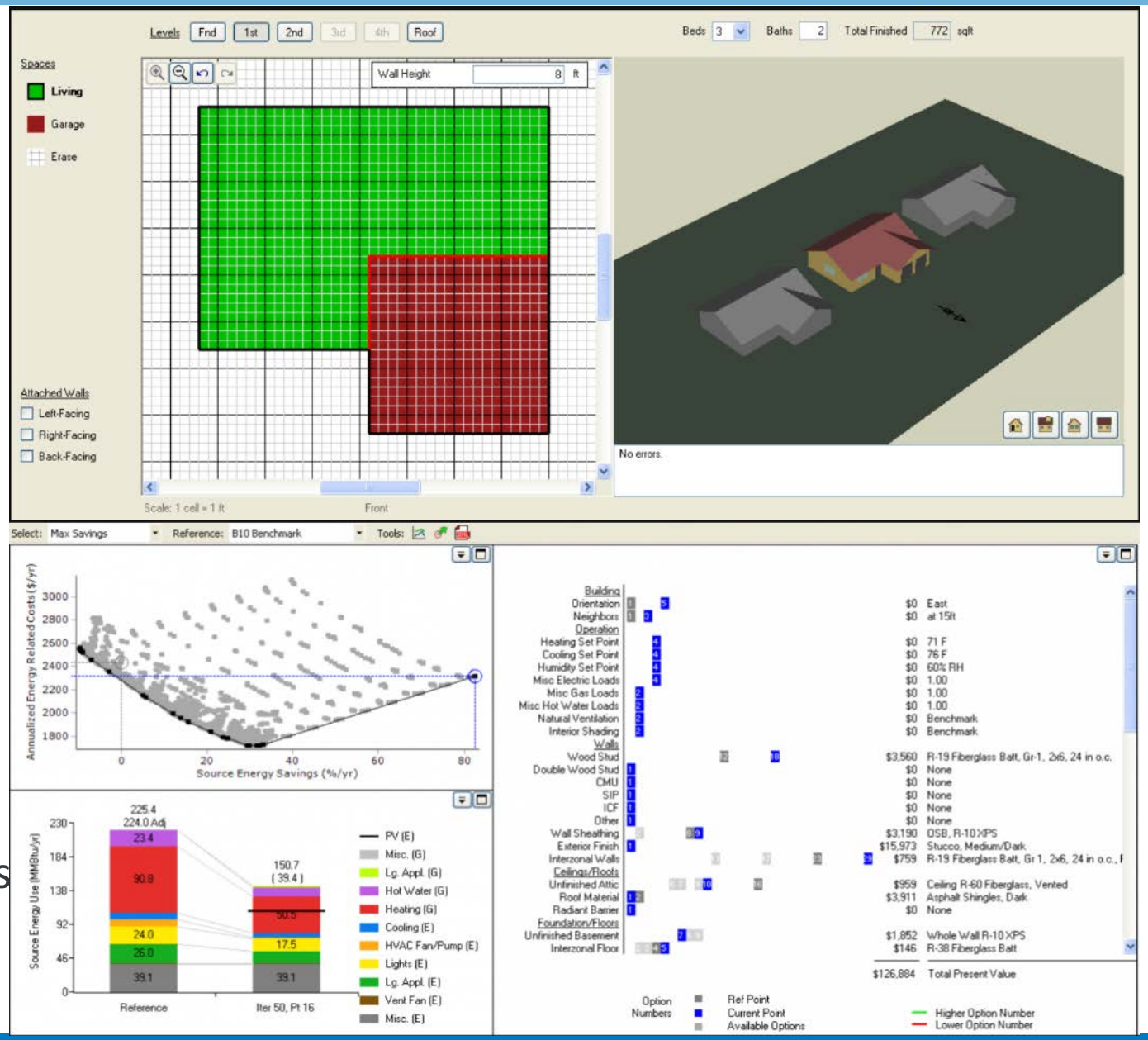
Building Energy Modeling Tools

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](https://beopt.nrel.gov/home)



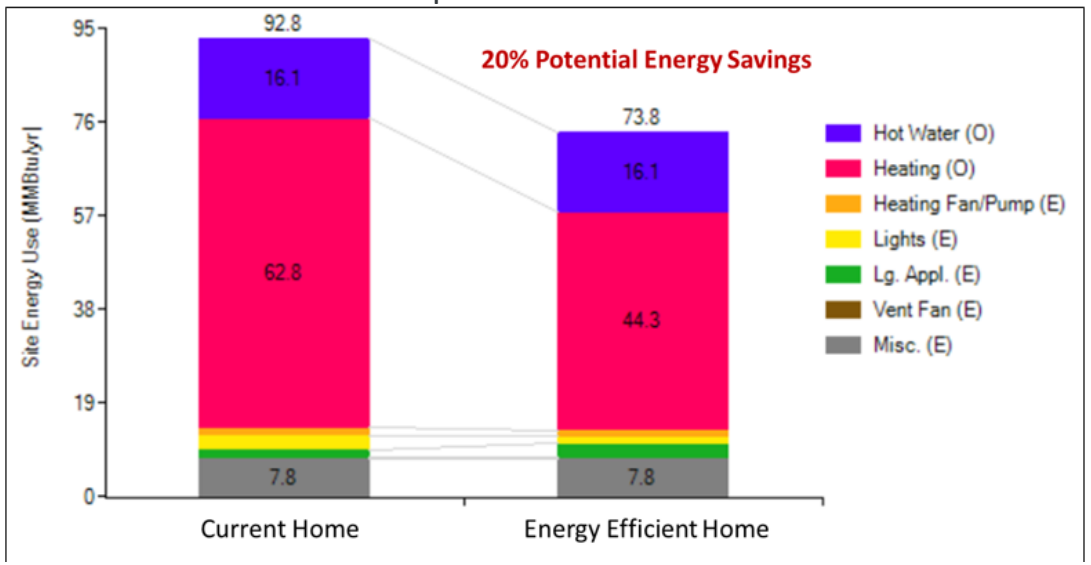
Case Study: Kwethluk, AK

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

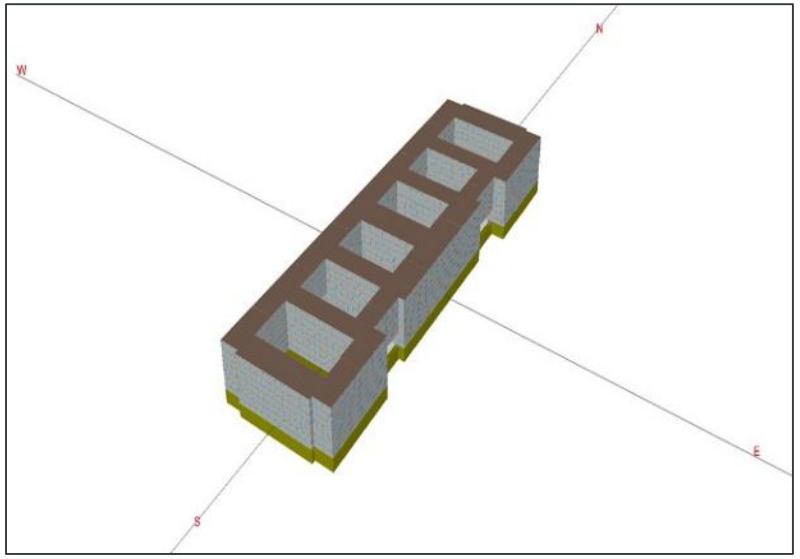


Building Simulation Output

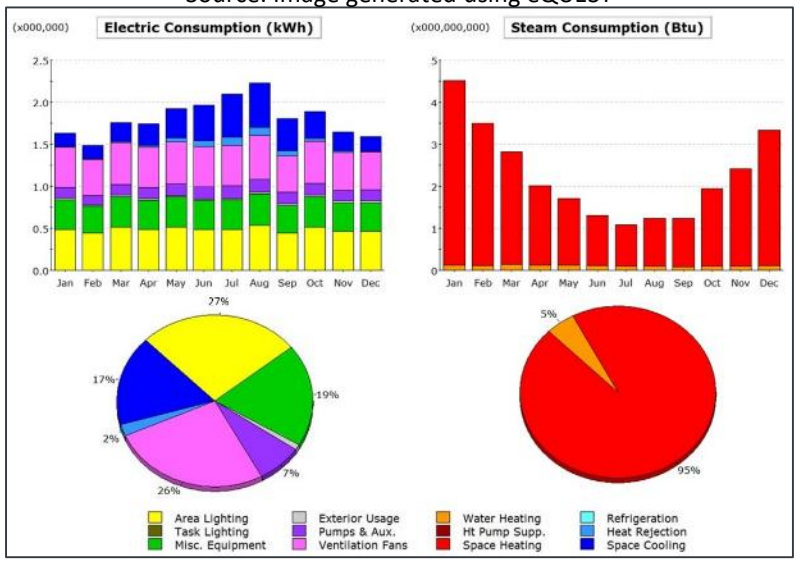
eQuest: Commercial Building Energy Modeling Tools

- 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



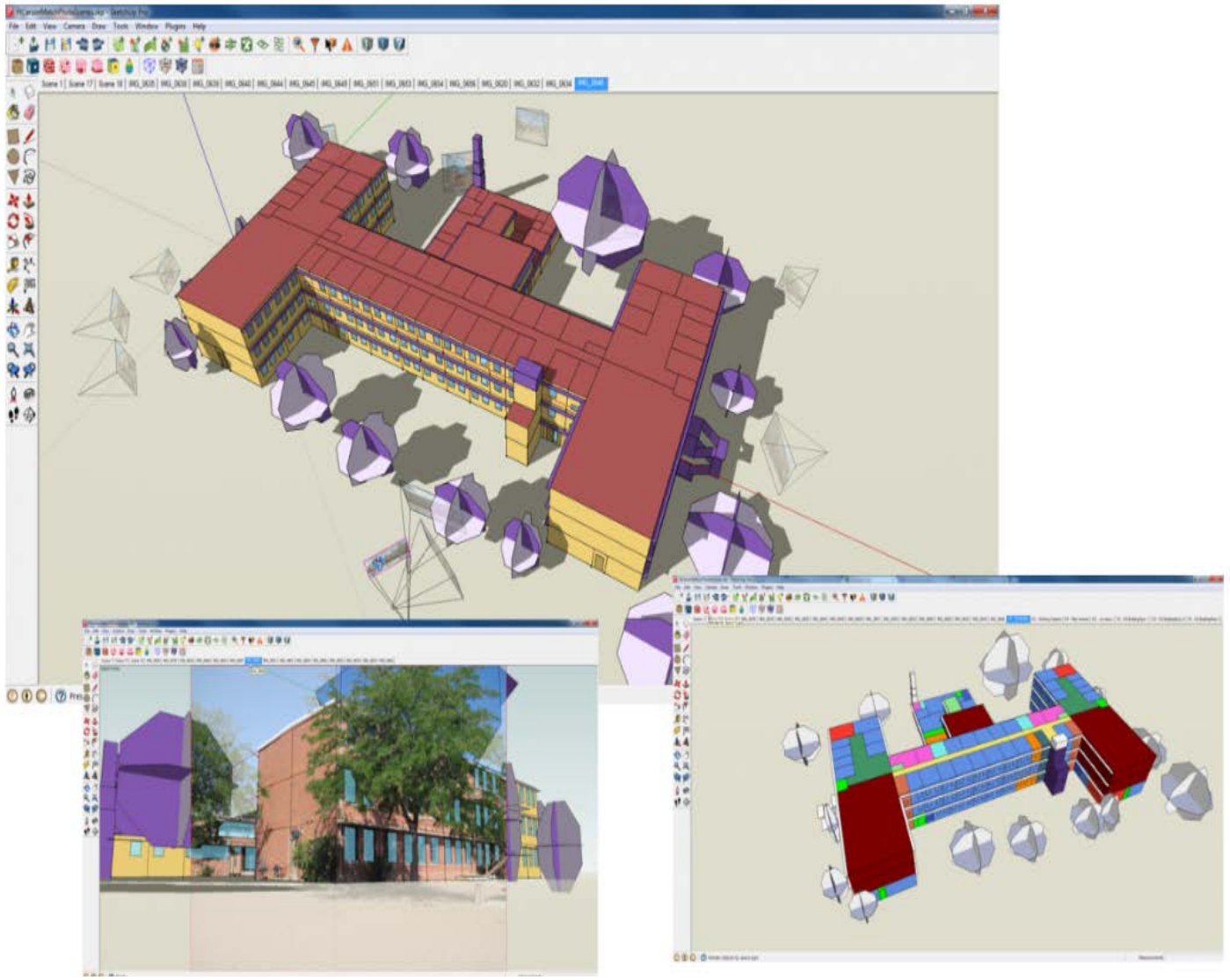
eQUEST calibrated baseline energy use estimates
Source: Figures generated using eQUEST

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

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

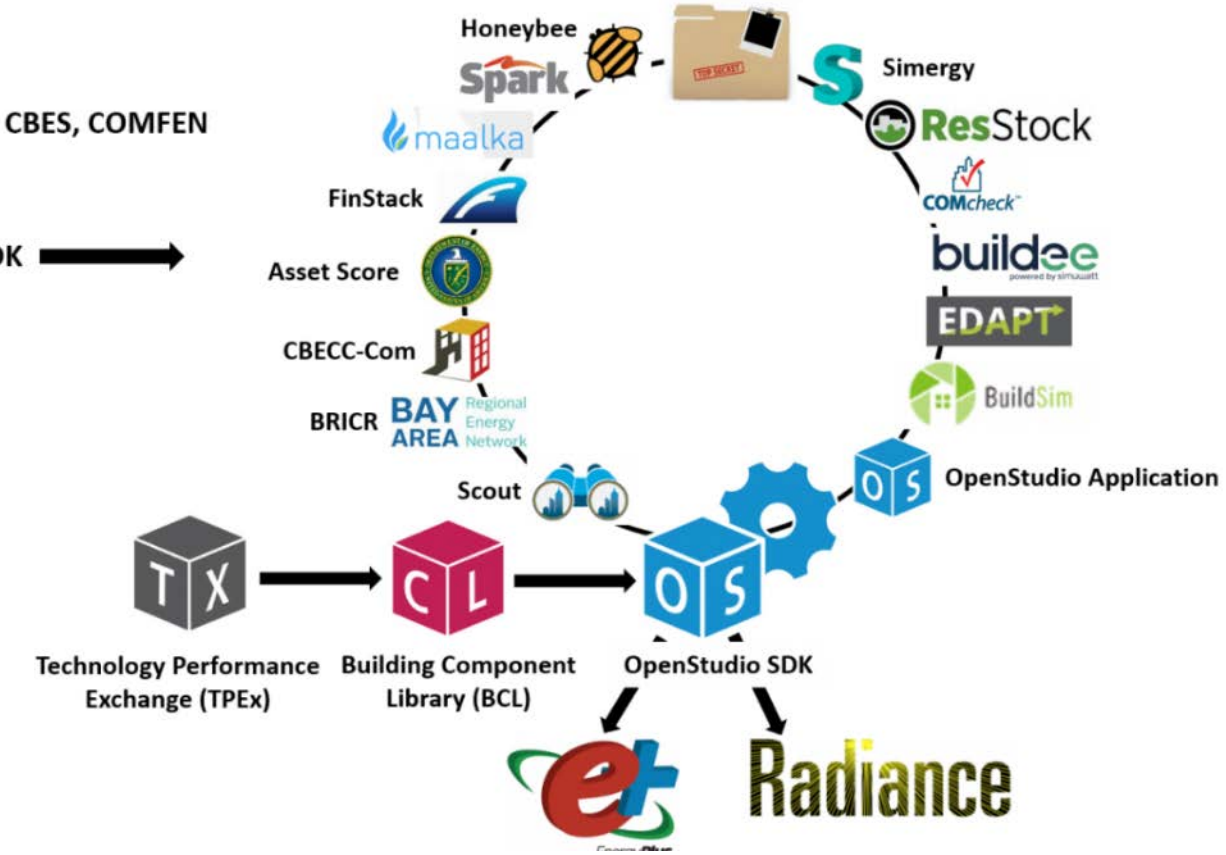
OpenStudio: Commercial Building Energy Modeling Tool

- 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

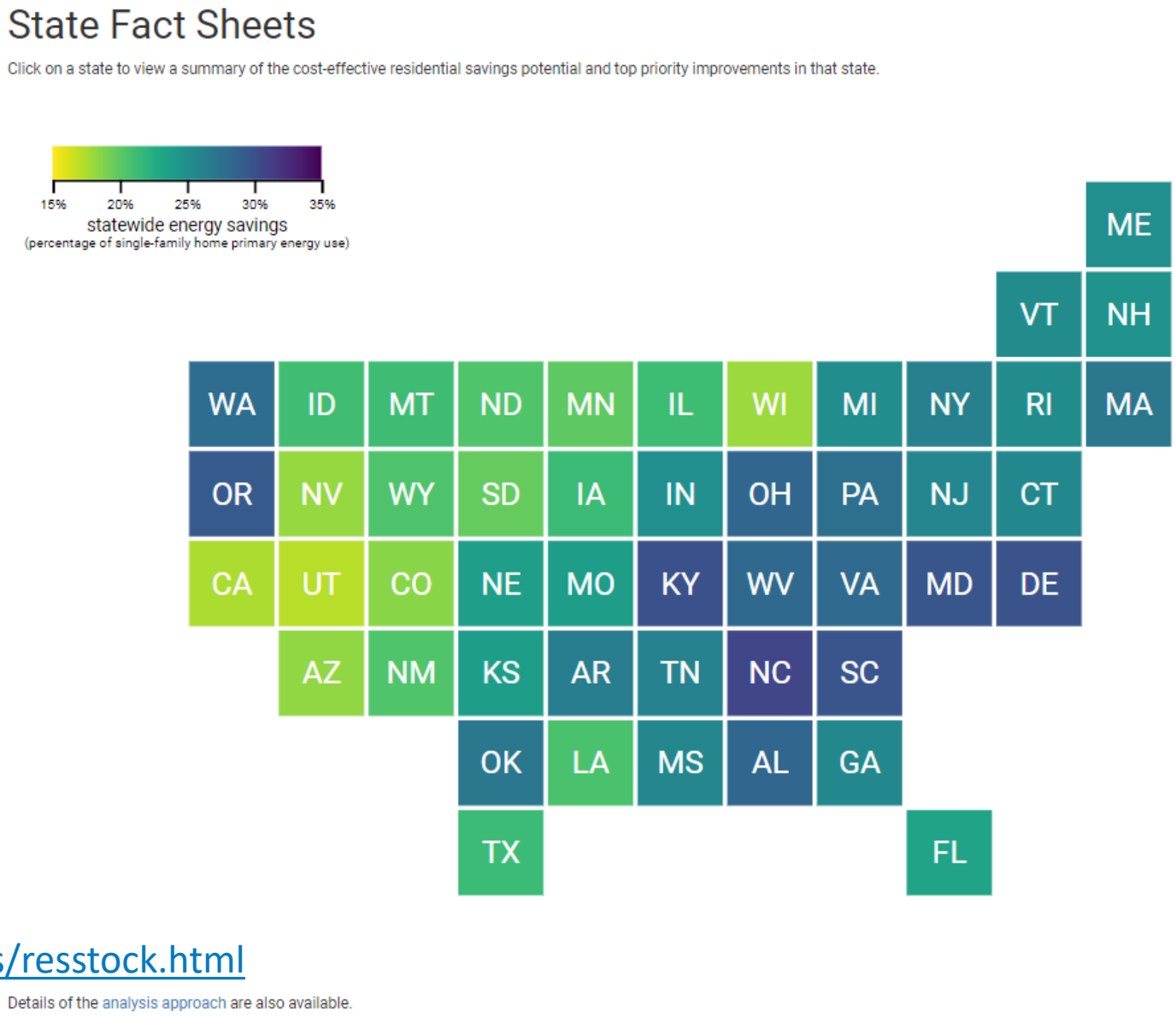


- EnergyPlus directly supports several public and private sector tools and services. It supports additional applications and services via the OpenStudio Platform

ResStock :Residential Stock Modeling Tool

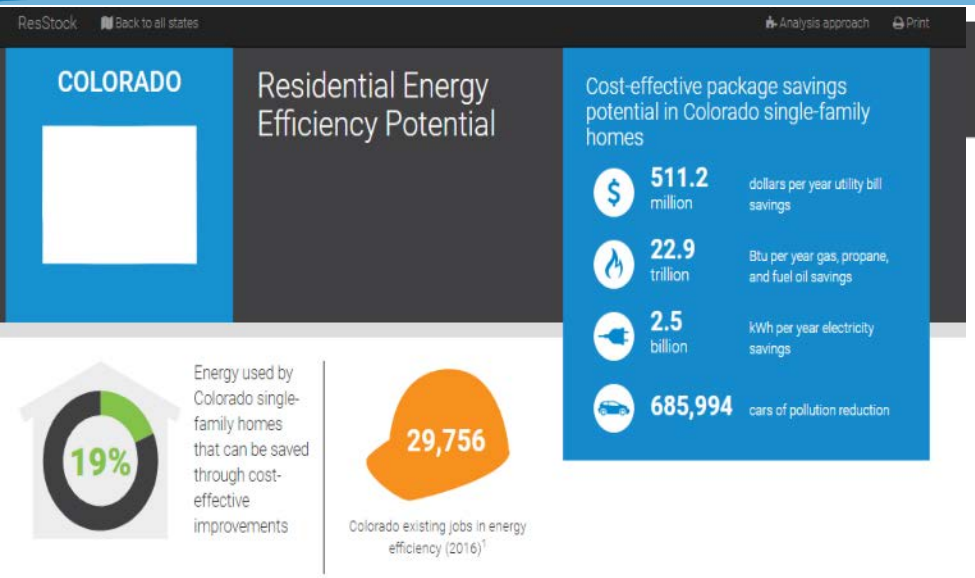
- The ResStock analysis tool is helping states, municipalities, utilities, and manufacturers identify which home improvements save the most energy and money

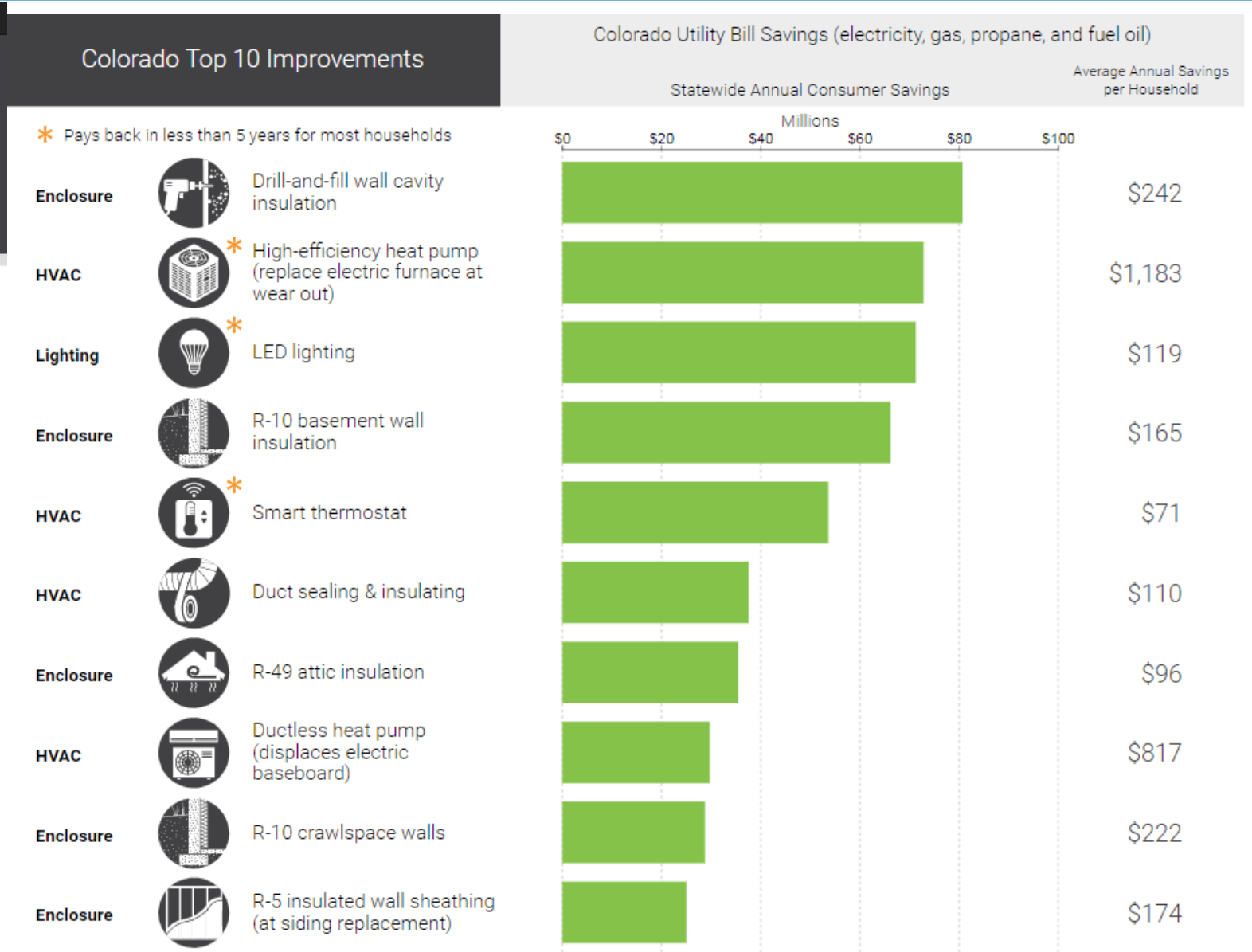
- The ResStock software is offered at no cost, leveraging the U.S. Department of Energy's (DOE's) open-source building energy modeling ecosystem of OpenStudio® and EnergyPlus™.



Free Downlaod: https://www.nrel.gov/buildings/resstock.html

ResStock: Residential Stock Modeling Tool





https://resstock.nrel.gov/factsheets/CO

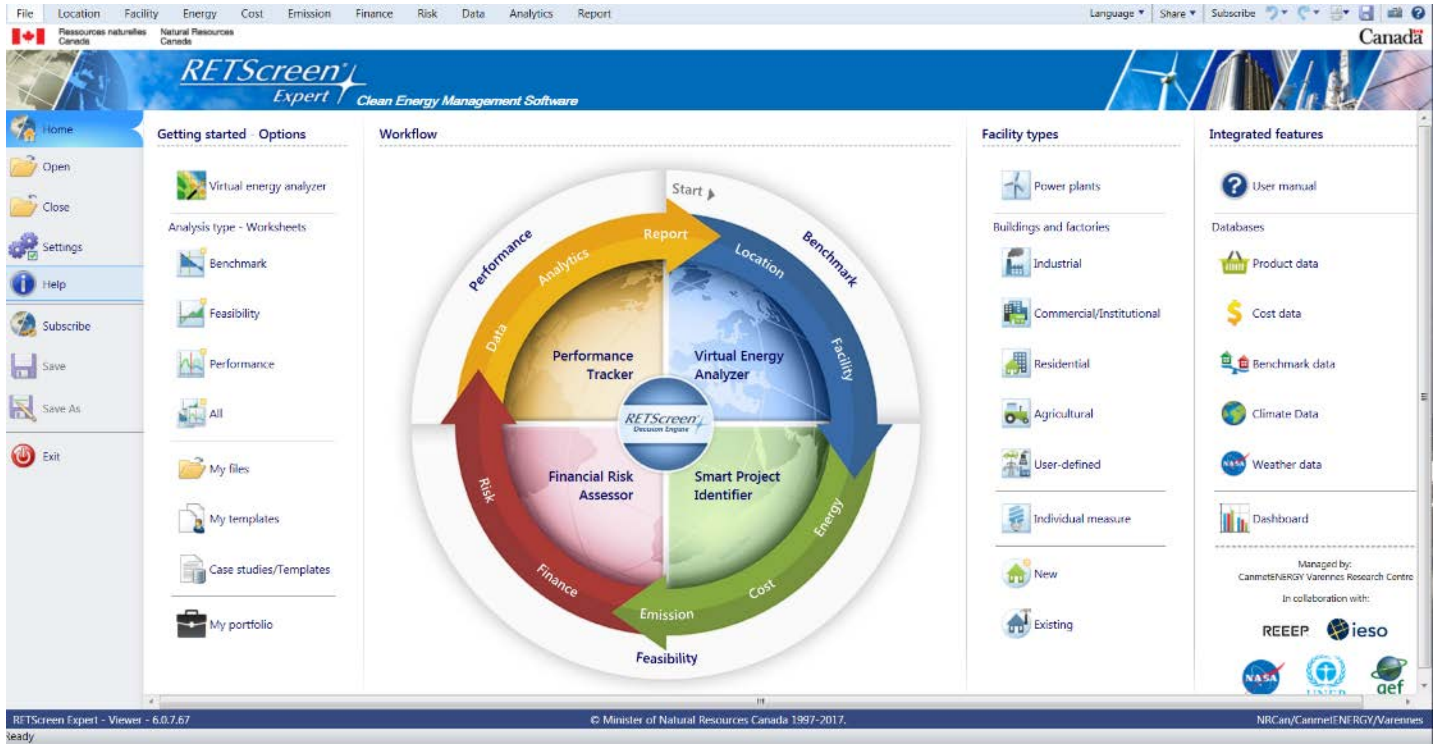
RETScreen Renewable Energy Modeling Tool

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



- Free web download
  - http://www.nrcan.gc.ca/energy/software-tools/7465

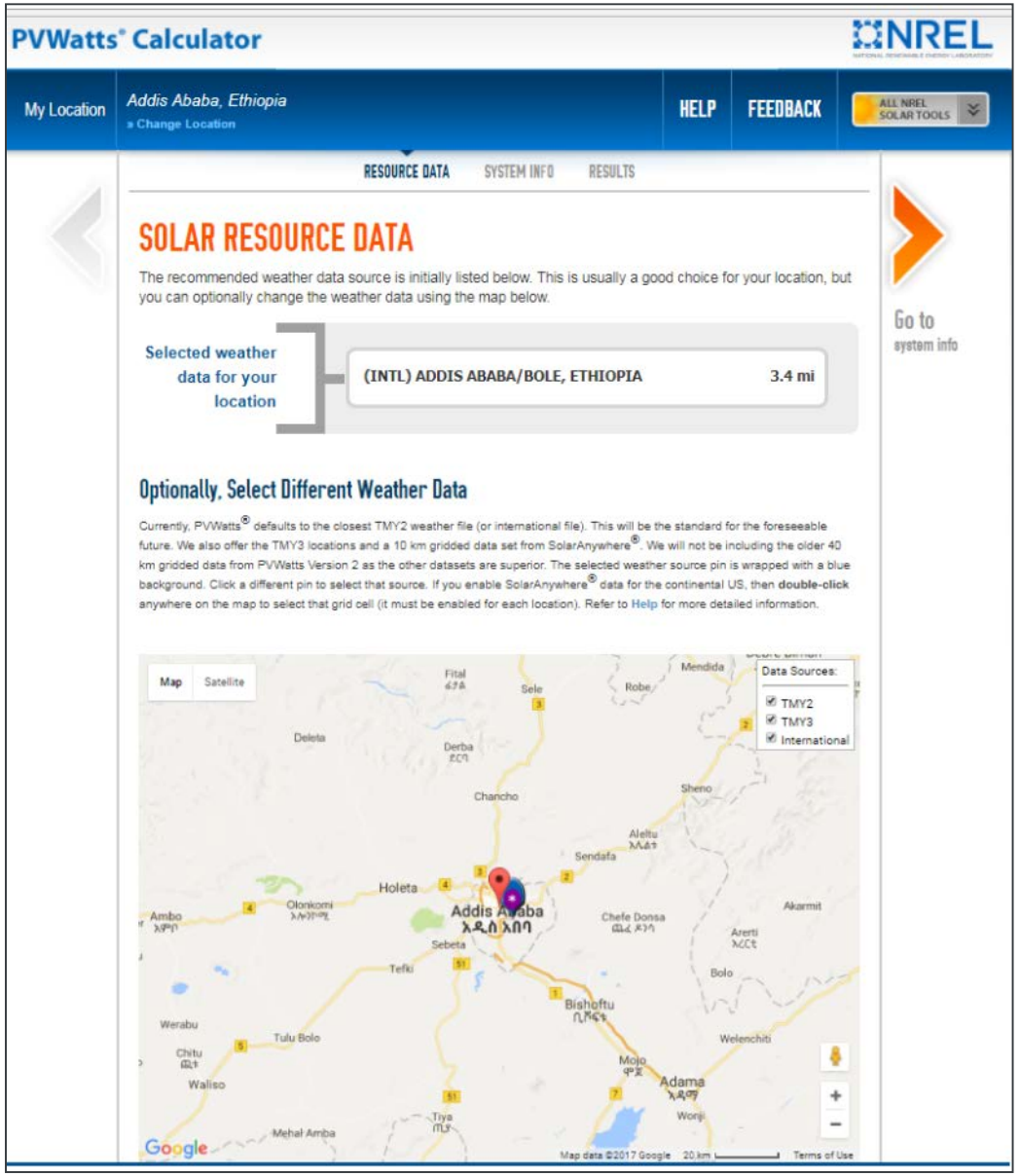
Related (Non-Building) Energy Modeling Tools

PVWatts Solar PV Modeling Tool

- Estimates the energy production and cost of energy of grid-connected photovoltaic (PV) energy systems throughout the world

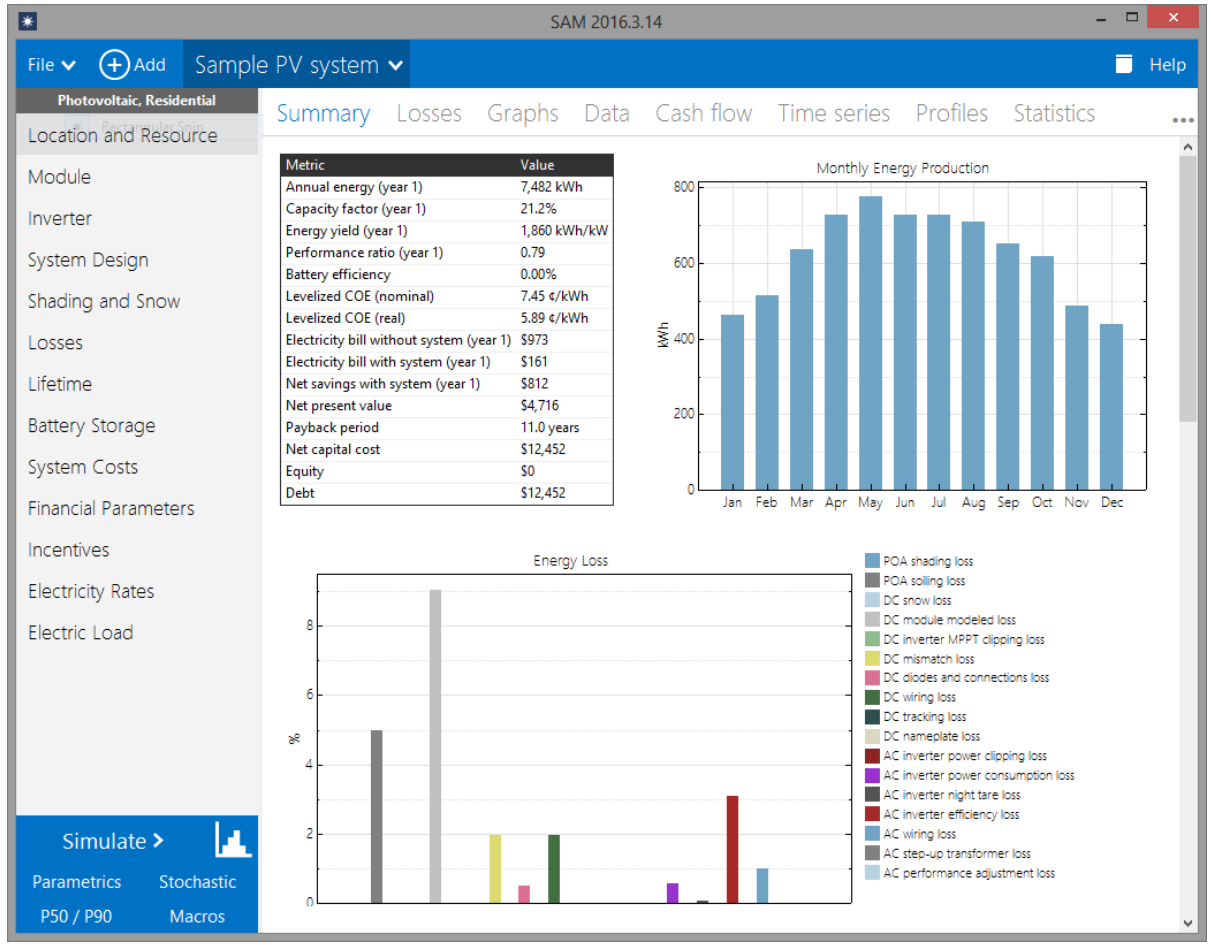
- It allows homeowners, small building owners, installers and manufacturers to easily develop estimates of the performance of potential PV installations

- Free web-based tool
  - http://pvwatts.nrel.gov/pvwatts.php



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



http://sam.nrel.gov/download

Technologies

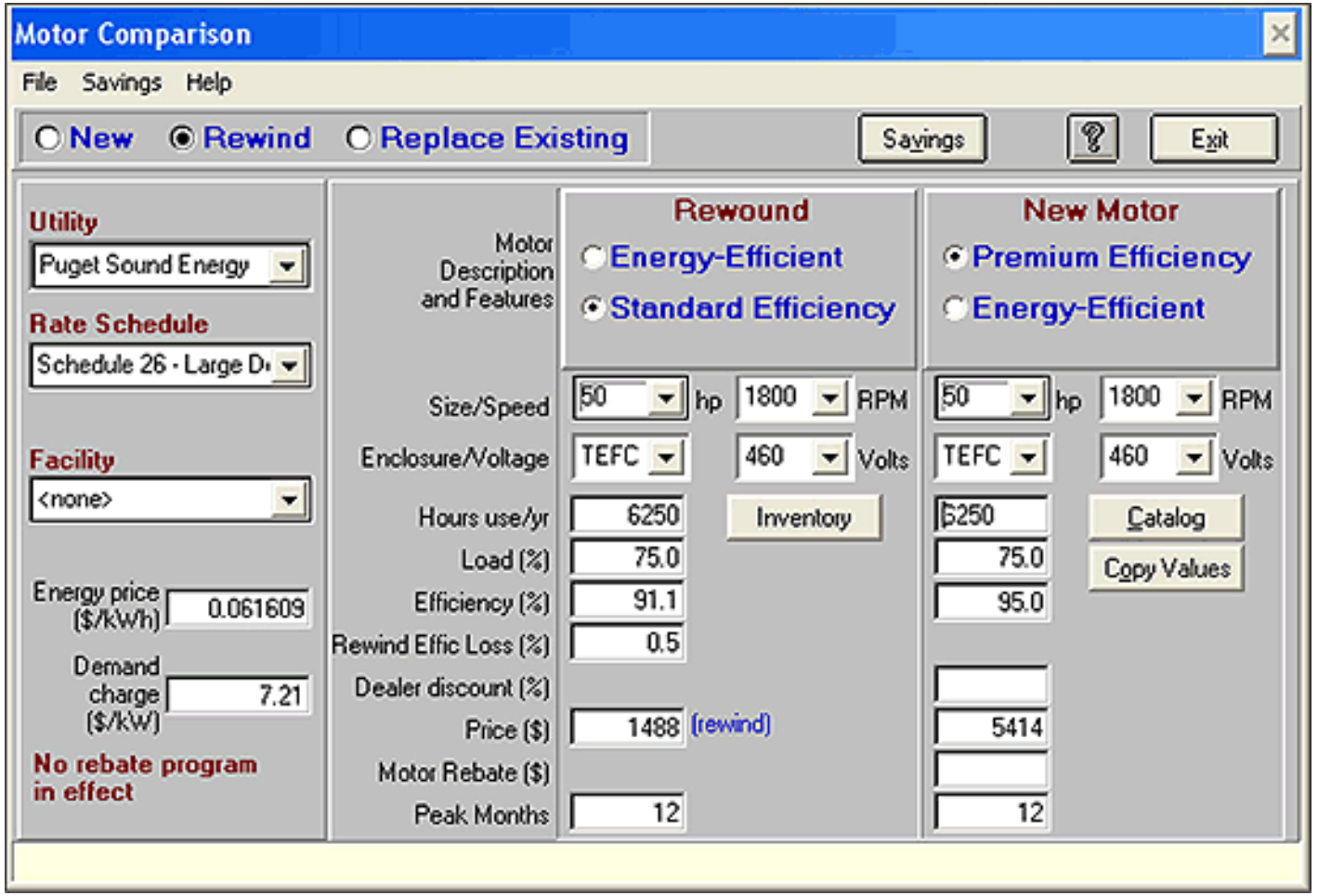
- Photovoltaics, detailed & PVWatts
- Battery storage
- Concentrating solar power
- Wind
- Geothermal
- Biomass
- Solar water heating

Financials

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

MotorMaster

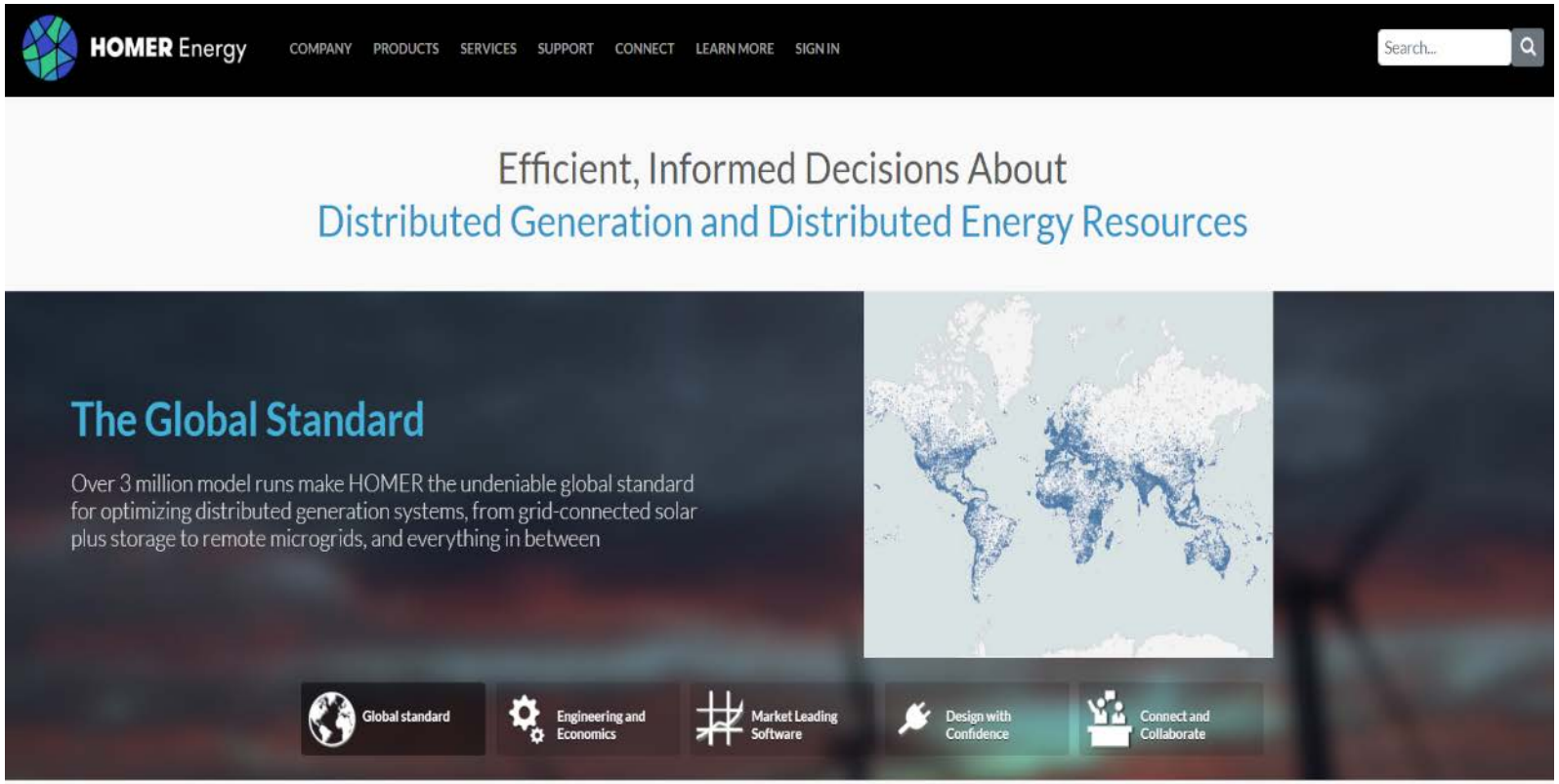
- Models motor energy use
- Extensive database of available motors
- Free web download
  - http://www1.eere.energy.gov/manufacturing/downloads/MMIntl14Setup.exe



HOMER Energy Microgrid Energy Modeling

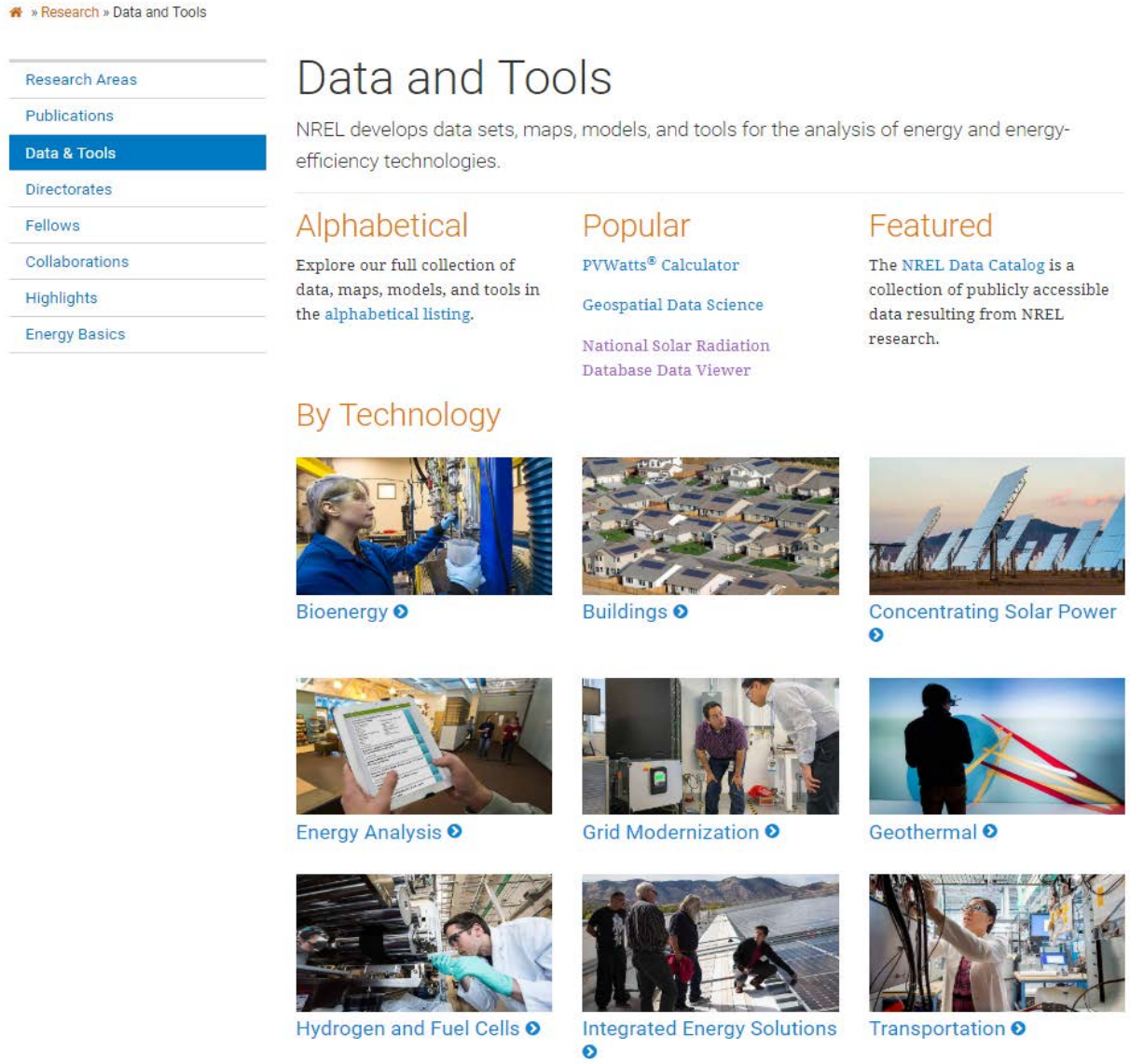
- HOMER (Hybrid Optimization Model for Multiple Energy Resources) is used to model and optimize conventional electrical generation microgrids with a high penetration of renewable energy

- Free and pay versions available http://www.homerenergy.com/HOMER_pro.html



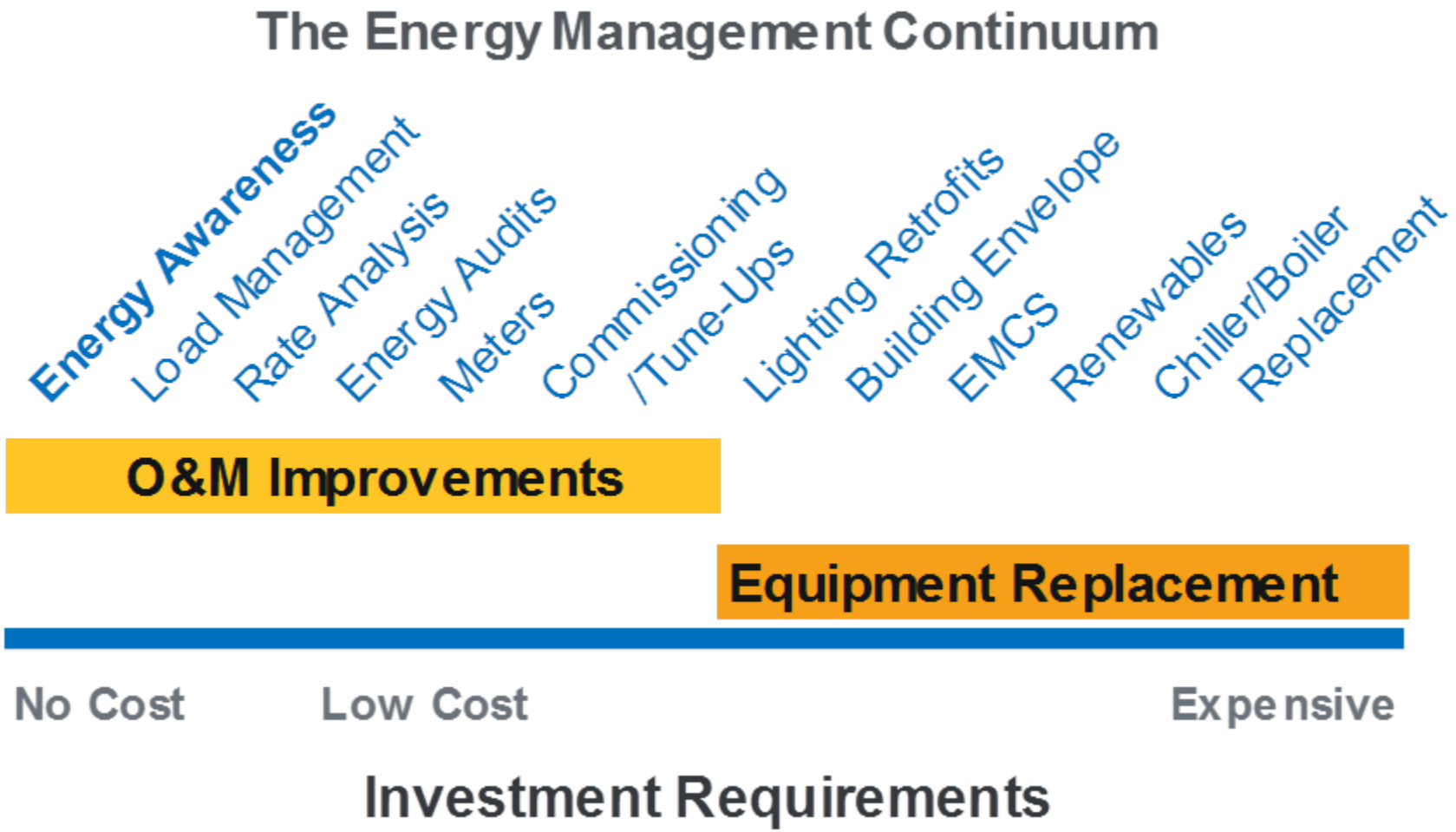
Many Free Software Tools Available from NREL

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



Common Energy, Water, and Renewable Measures

Energy Conservation Measures

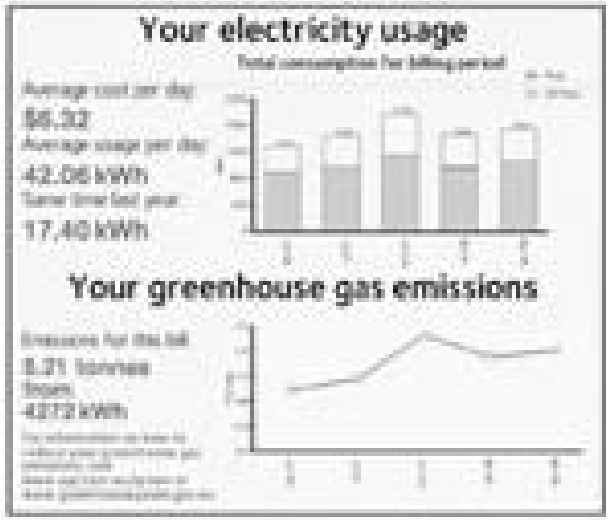


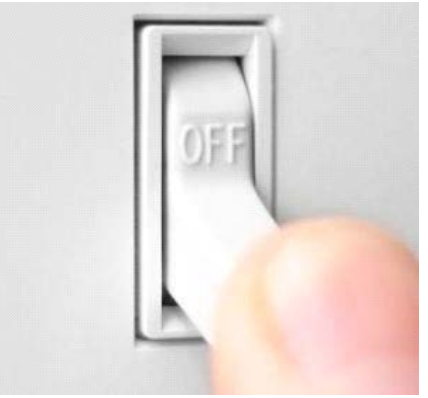
Typical Measures Considered

- **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

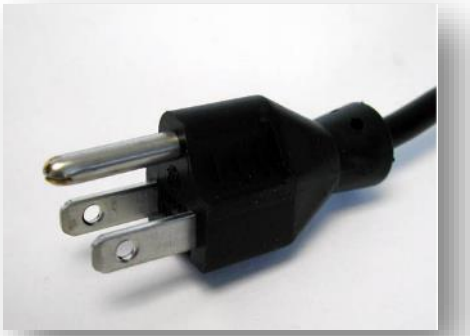
- **HVAC**
  - Install programmable thermostats for all zones and HVAC equipment.
  - Install high coefficient of performance (COP) cooling system.
  - Replace regular fan and motor belts with cogged V-belts.
  - Regularly replace HVAC filters.
  - Convert constant air volume (CAV) system to variable 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

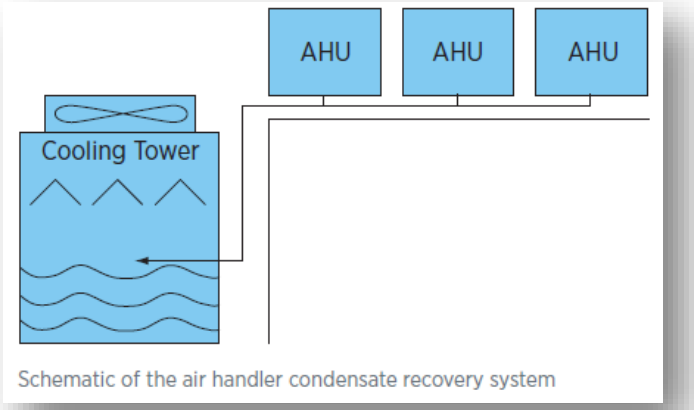
- **Building Envelope**
  - Roofs
    - Increase the amount of roof insulation
    - Retrofit existing roof with green roof
    - Retrofit existing roof with cool roof
  - Walls
    - Install additional insulation in exterior walls
    - Seal off all the infiltration points in exterior wall
  - Windows
    - 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



Schematic of the air handler condensate recovery 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

NREL
NATIONAL RENEWABLE ENERGY LABORATORY