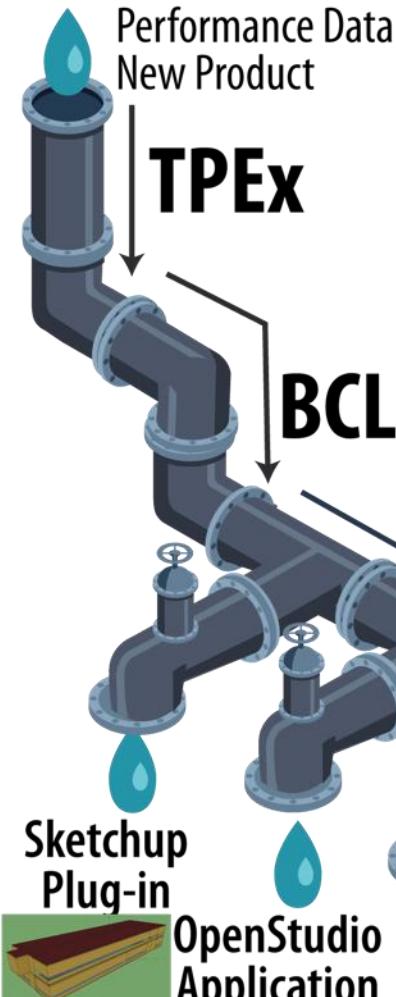
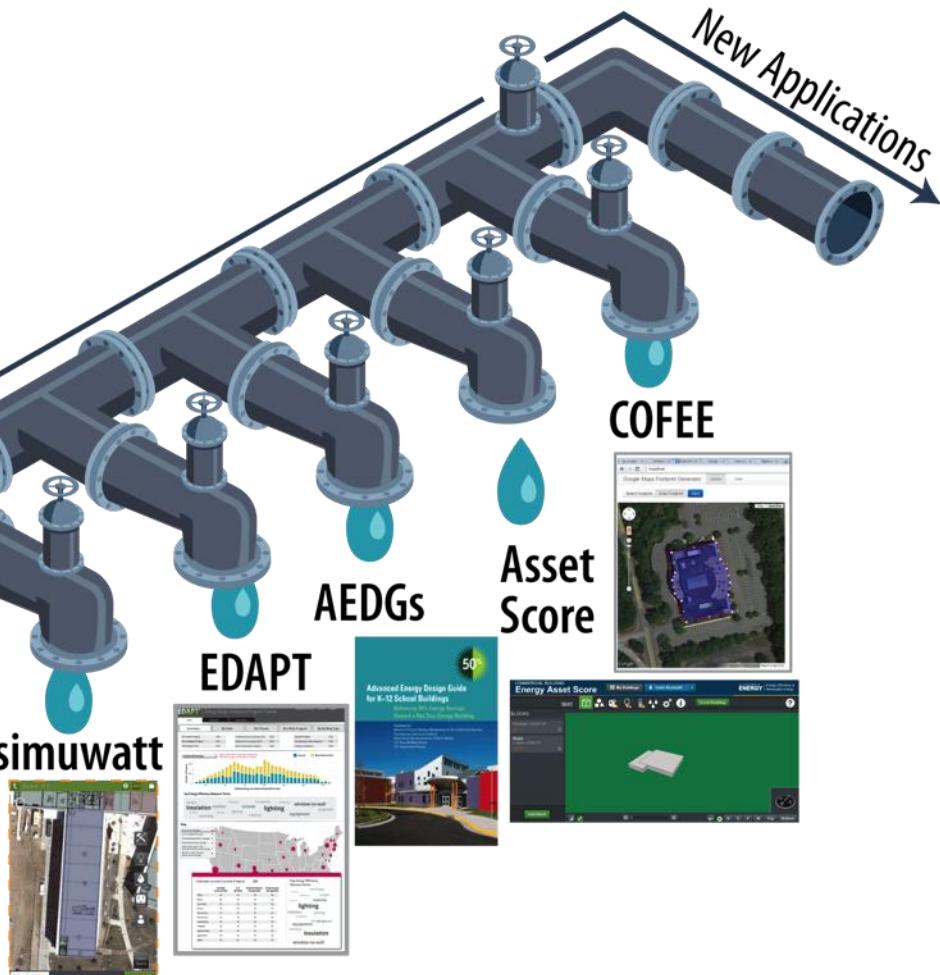


Performance Data on
New Product



OpenStudio Core

2014 Building Technologies Office Peer Review



U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

Dr. Larry Brackney, larry.brackney@nrel.gov
National Renewable Energy Laboratory
Oliver Davis, oliver@concept3d.com

concept3D Inc.

Project Summary

Timeline:

Start date: **Q1 FY10**

Planned end date: **Ongoing w/ Frequent Off-Ramping of Components**

Key Milestones:

1. V1.1 (Cloud) – 9/27/2013
2. V1.2 (Refrigeration) – 12/20/2013
3. V1.3 (HVAC/Refrigeration) – 3/28/2014

Budget:

Total DOE \$ to date: **\$7,655,000***

Total Cost Share to date: **\$4,691,000***

Total future DOE \$: **\$3,500,000***

Target Market/Audience:

Tool Developers, A&E Practitioners, Utilities, Researchers, and Students

Key Partners:

All BTO Labs	NRCan/NRC
CEC	concept3D Inc.
BPA	PSD Consulting
Xcel Energy	Multiple Universities
National Grid	Other Private Sector Companies

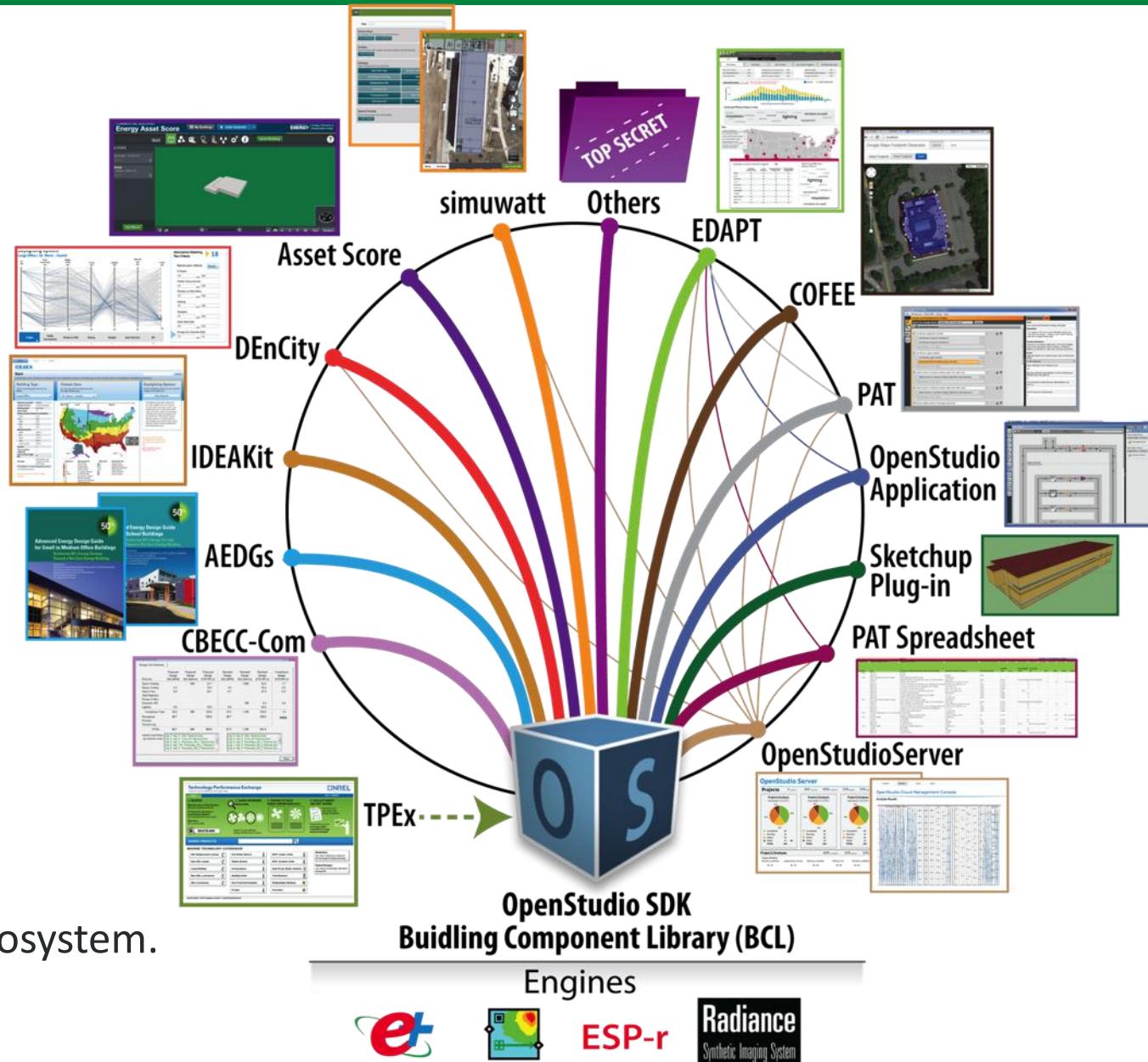
Project Goal:

Develop BTO's best-in-class building energy analysis ecosystem to enable rapid, low-cost development of new market facing tools produced by the National Laboratories, Universities, Private Sector, and other agencies.

Facilitate successful deployment of the software development kit across BTO performers, utilities, and private sector developers to drive real energy savings in new construction and retrofit projects.

Problem Statement

Q: What collection of software technologies will make energy modeling less costly, more accessible, increasingly reliable, and ubiquitous for the broad range of stakeholders who rely on analysis to make business decisions for their new construction and retrofit portfolios?

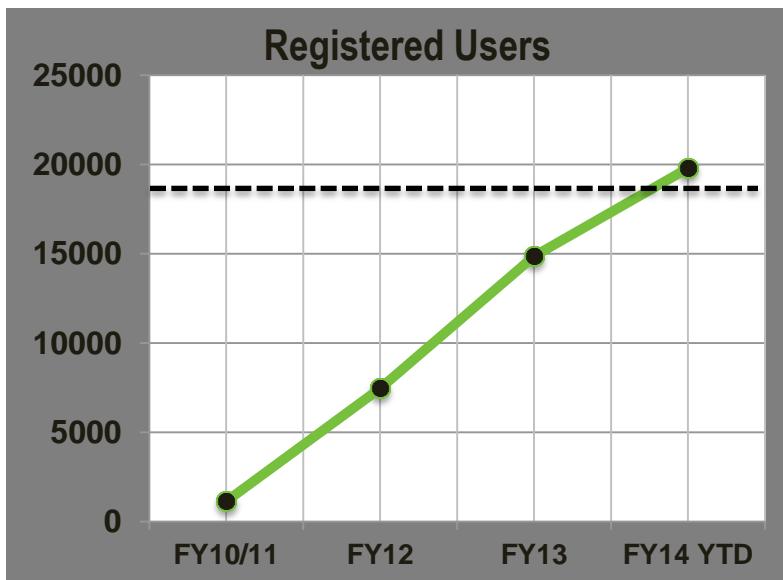


A: DOE's OpenStudio ecosystem.

Target Market and Audience

The market for OpenStudio is diverse and includes:

- Tool developers* that are able to quickly and cost-effectively bring new software innovations to market;
- A&E practitioners that use the example applications to reduce energy consumption for new construction and retrofit projects;
- Utilities that are trying to reduce the cost of incenting EE, realize greater EE savings, and assess technology potentials;
- Researchers who are trying to design and assess new technologies; and
- Students who are the next generation of building designers.



Partial List of Partners



nationalgrid

concept3D
Location. Web. 3D.

case
building + technology

+ wrightsoft®

SketchUp

Group 14
ENGINEERING

ARCHITECTURAL ENERGY
CORPORATION

NIST



GENABILITY

CARMEL
SOFTWARE

cbei
CONSORTIUM for
BUILDING ENERGY
INNOVATION



Natural Resources
Canada Ressources naturelles
Canada

Canada

BU

LD lab

GARD Analytics

Pacific
Northwest

BERKELEY LAB

OAK
RIDGE

Argonne
NATIONAL LABORATORY

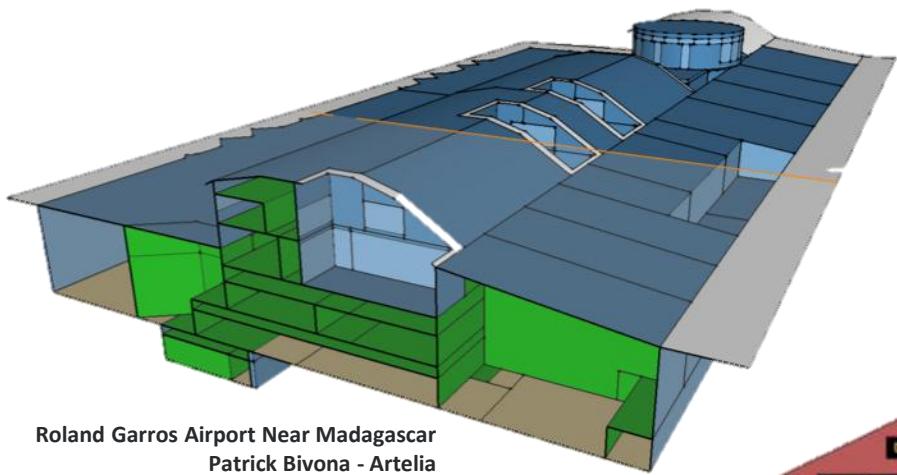


U.S. DEPARTMENT OF
ENERGY

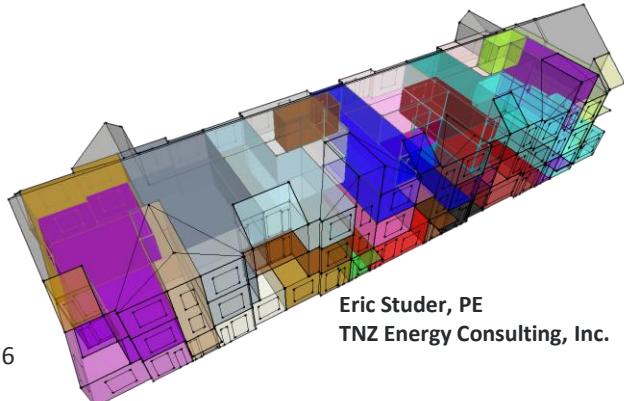
Energy Efficiency &
Renewable Energy

Real Market Adoption = Real Impact

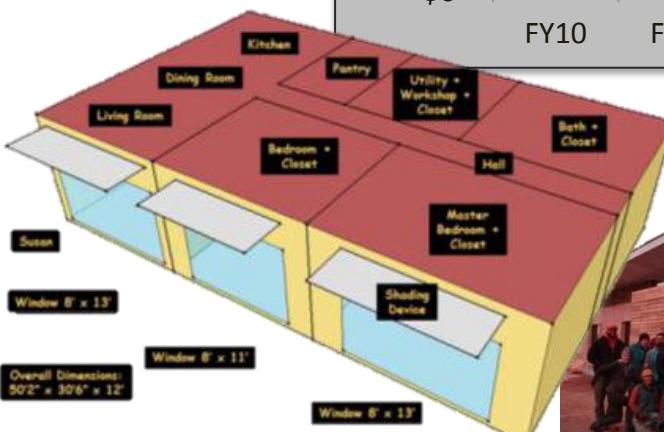
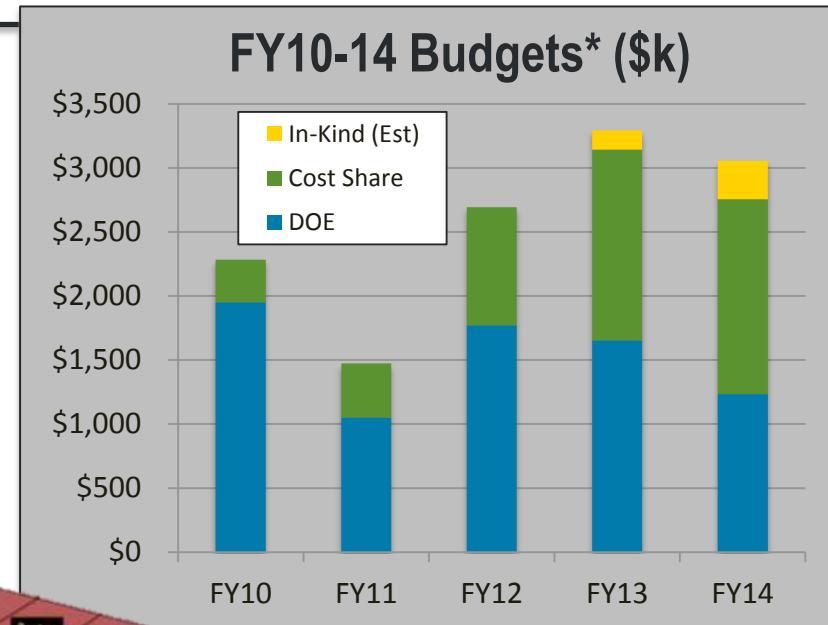
- For Xcel Energy's new construction program OpenStudio is directly contributing to its program savings goal of 40 GWH (up from 30 in 2013)
- Increasing cost-share from private sector —
- Example models from practitioners:



Roland Garros Airport Near Madagascar
Patrick Bivona - Artelia



Eric Studer, PE
TNZ Energy Consulting, Inc.



DesignBuildBluff
Southern Utah University and University of Colorado, Denver

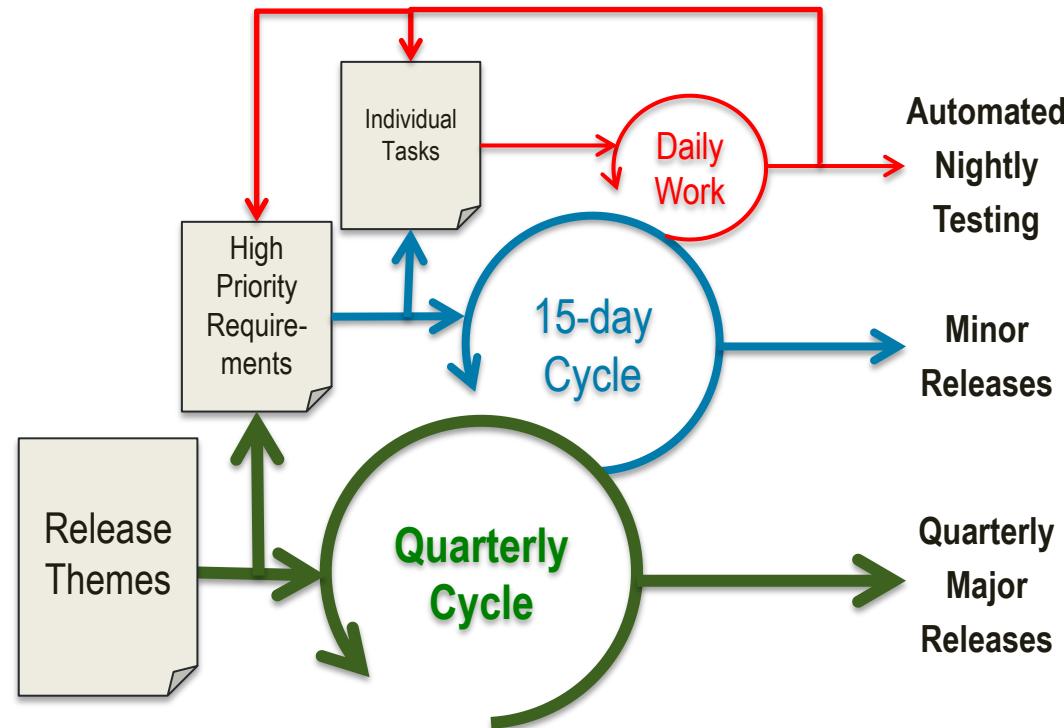
Approach to Development and Deployment

Approach:

- Development team uses an “agile” software development process
 - Formal task and bug tracking systems
 - Automated nightly software build, test, and dashboard system
 - Formal processes for design document and code reviews
- Frequent vetting of UI concepts and workflows with external stakeholders

Distinctive Characteristics:

- Flexibility to **quickly** produce new desktop, mobile, and web tools that are easily **integrated** with one another
- **Agile process** allows focus to change as new requirements emerge
- Rigorous approach to creating software for the marketplace - **not a research project**



Adapting to Changing Needs



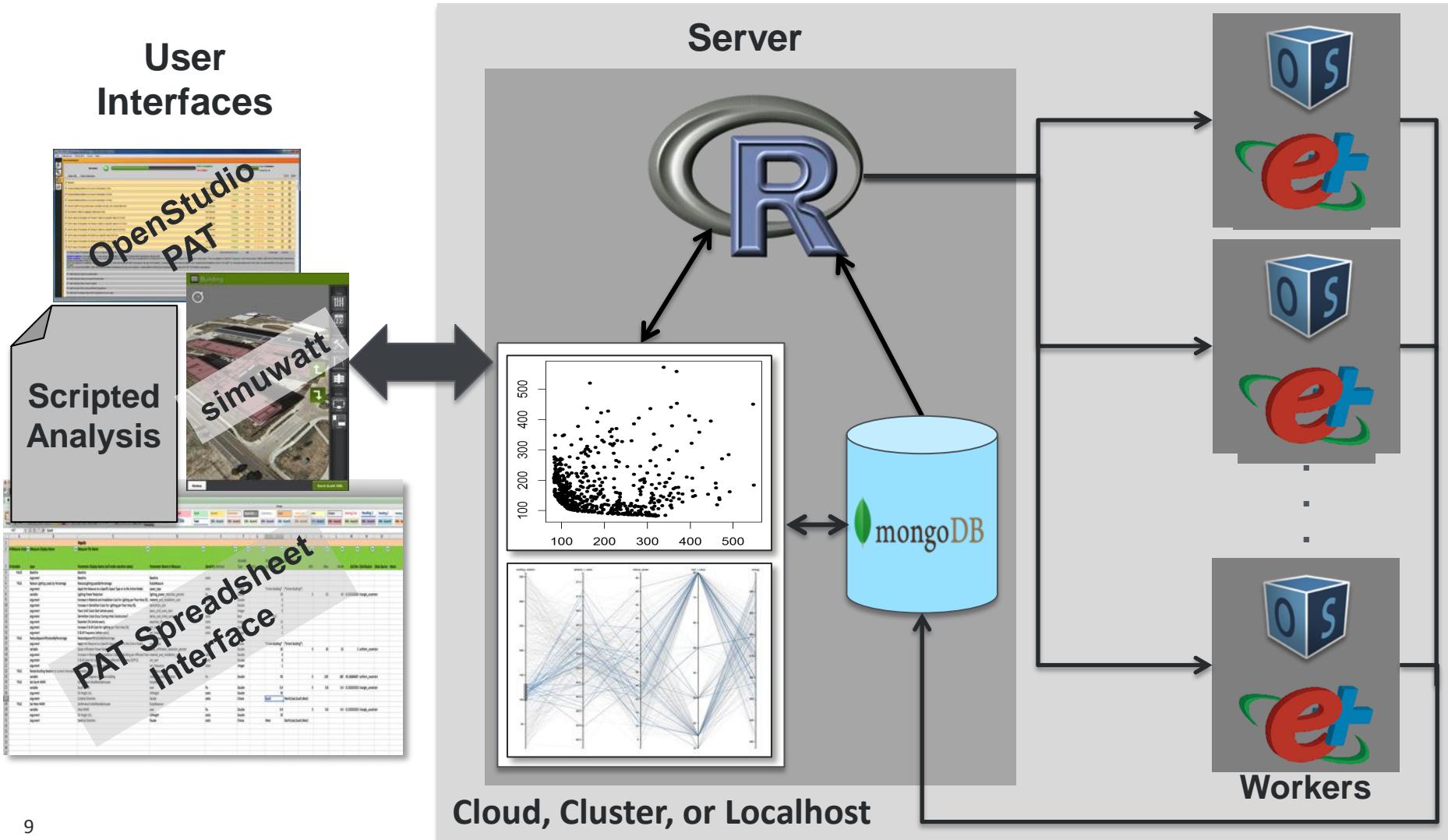
Increased Focus on Collaboration:

- Inclusion of non-NREL developers drove more process formalism
- New processes for better code sharing -> Canary in the coalmine for EnergyPlus
- Greater transparency of development plans on website
 - Key features
 - HVAC roadmap
 - Measures roadmap

Master OpenStudio HVAC Roadmap					Note:
Last Updated 4/1/14					When Adding an object make sure it has a unique ID in column A
151 objects are currently visible.					
HVAC SYSTEMS AND EQUIPMENT					Status
ID	OpenStudio Back End Support	OpenStudio GUI support	Planned Release	Priority	OpenStudio approach - E+
129	IP - NREL	IP - NREL	1.4 Jun 2014	1	ZoneMixing
153	No	No	1.4 Jun 2014	1	AirloopHVAC:UnitarySystem
22	No	No	1.4 Jun 2014	1	ZoneHVAC:OutdoorAirUnit
7	No	No	1.4 Jun 2014	1	AirTerminal:SingleDuct:Seri
24	No	No	1.4 Jun 2014	1	EvaporativeCooler:Indirect:
150	No	No	1.5 Sep 2014	1	SetpointManager:Outdoor?
90	No	No	1.5 Sep 2014	1	HeatExchanger:FluidToFluid
151	No	No	1.5 Sep 2014	1	SetpointManagerScheduled
147	No	No		1	How do we do this in E+?
132	No	No		1	Pipe:Indoor and Pipe:Outdo
152	No	No		1	Duct (E+ analog for pipe adi
110	No	No		1	DesignSpecification:ZoneAir
116	No	No		1	Need Water-to-Water Heat
125	No	No		1	SetpointManager:Warmest
130	No	No		1	How do we do this in E+?
131	No	No		1	How do we do this in E+?
12	No	No		2	
140	No	No		2	Look at SolarCollectorFlatPl
30	No	No		2	
59	No	No		2	
69	No	No		2	
71	No	No		2	Very common in NE in schoo
112	No	No		2	ZoneVentilation:DesignFlow
118	No	No		2	
133	No	No		2	How do we do this in E+?
134	No	No		2	ZoneHVAC:AirDistributionU
135	No	No		2	How do we do this in E+?
136	No	No		2	How do we do this in E+?
137	No	No		2	Is this already in the backen
141	No	No		2	Commonly used for retrofit
29	No	No		3	
47	No	No		3	Duplicate of row up further
48	No	No		3	PSD thinks that steam-fired
91	No	No		3	Perhaps add simple ventilat

Major Accomplishment – Cloud Support

Significance: Practitioners now have access to scalable computing resources on par with National Laboratories allowing them to consider more measures in less time.

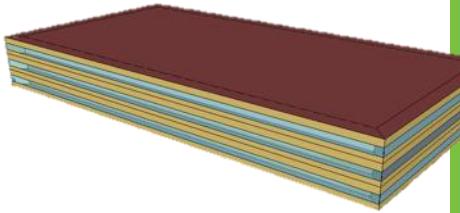


Major Accomplishment – Sensitivity Analysis for Asset Score

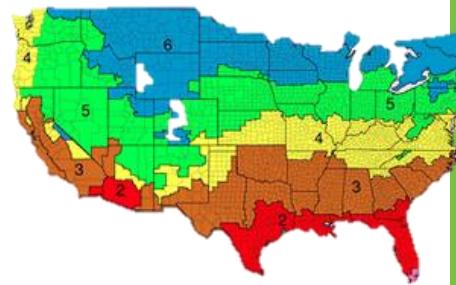
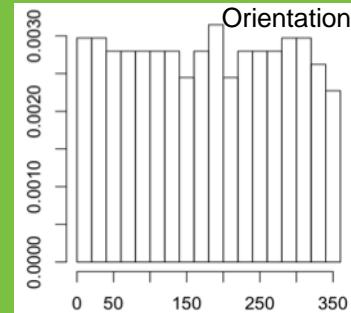
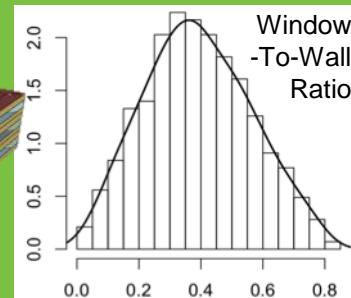
Significance: Practitioners and researchers can now easily assess the impact of uncertainty on energy efficiency for a broad range of parameters.



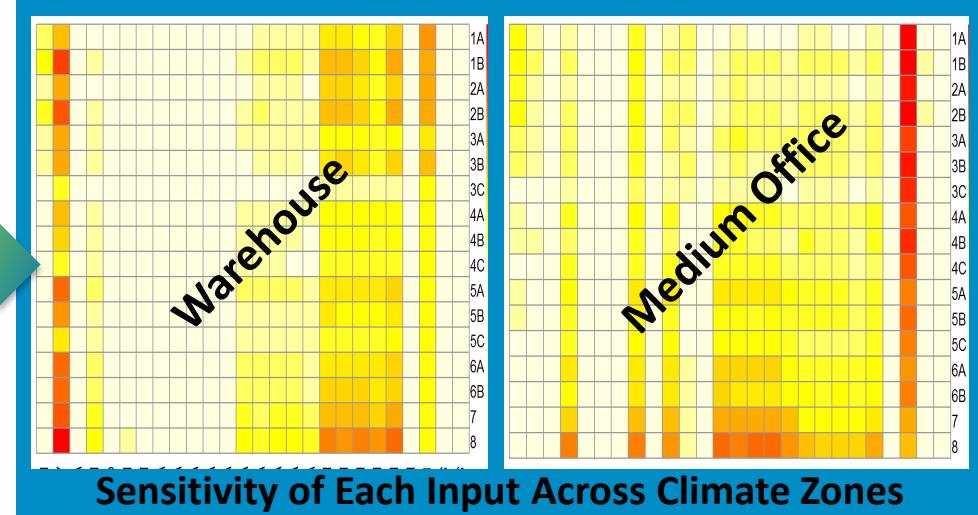
Baseline Models for Major Building Types



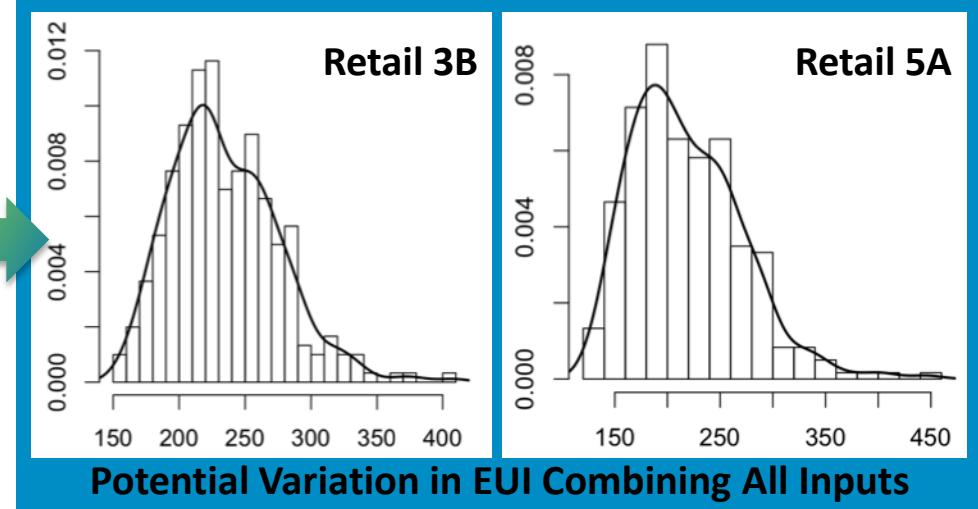
OpenStudio Measures for Major Sources of Variation



Climate Zones



Sensitivity of Each Input Across Climate Zones



Retail 3B

Retail 5A

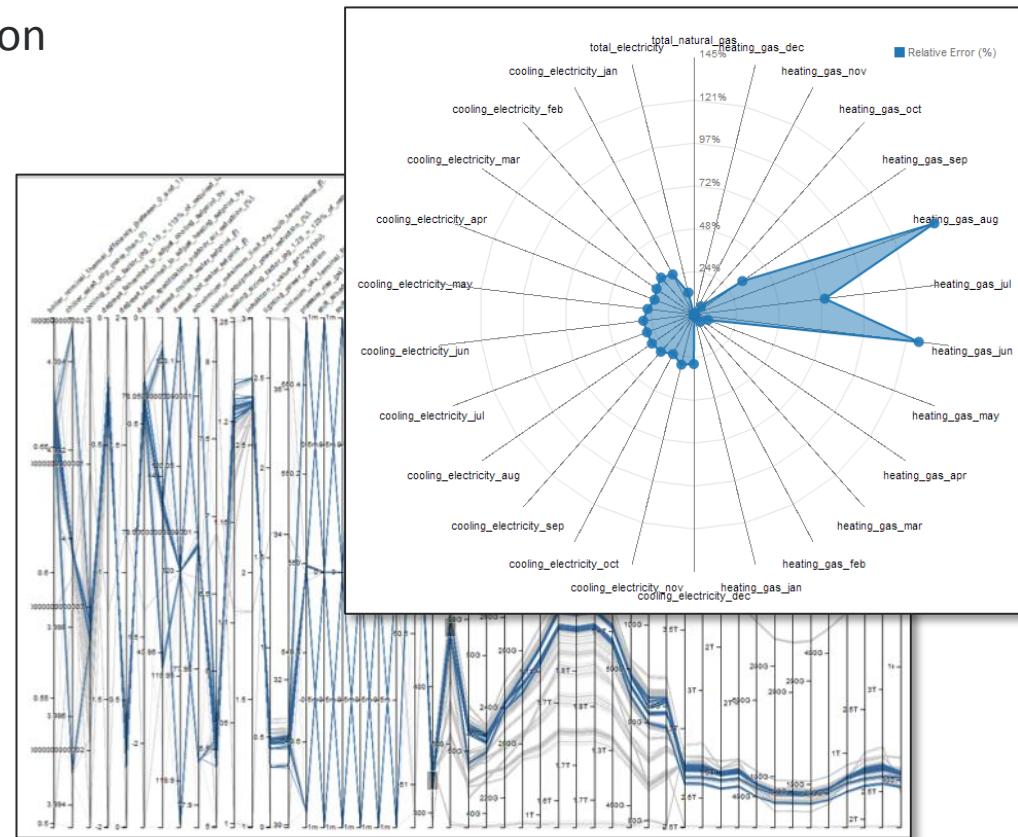
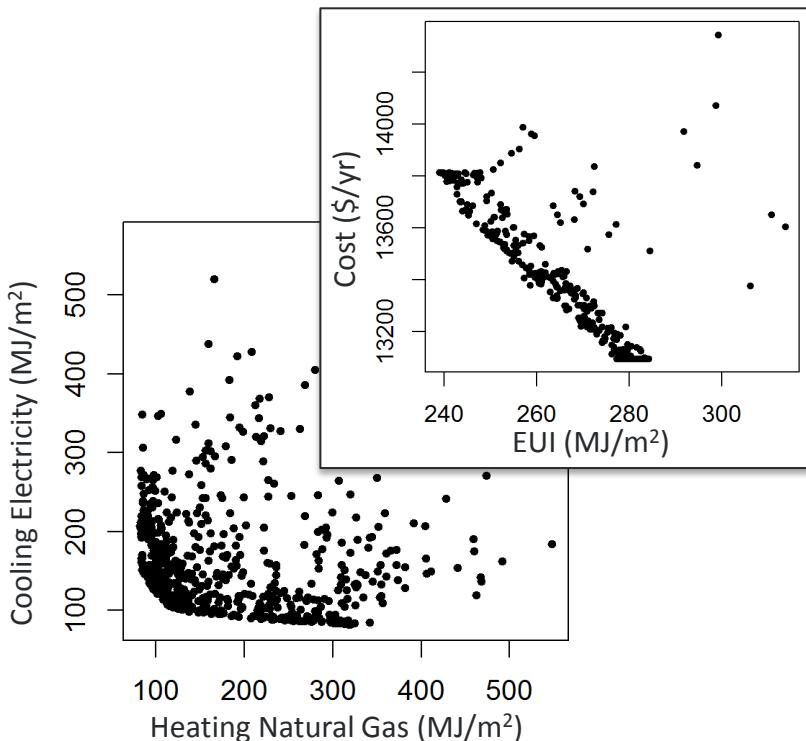
Potential Variation in EUI Combining All Inputs

Major Accomplishment – Optimization*

Significance: Practitioners and researchers can now easily optimize measures and associated parameters for design or to calibrate models.

- Multiple algorithms (easily extended via R)
- Supports discrete and continuous variables
- Customizable multi-objective optimization

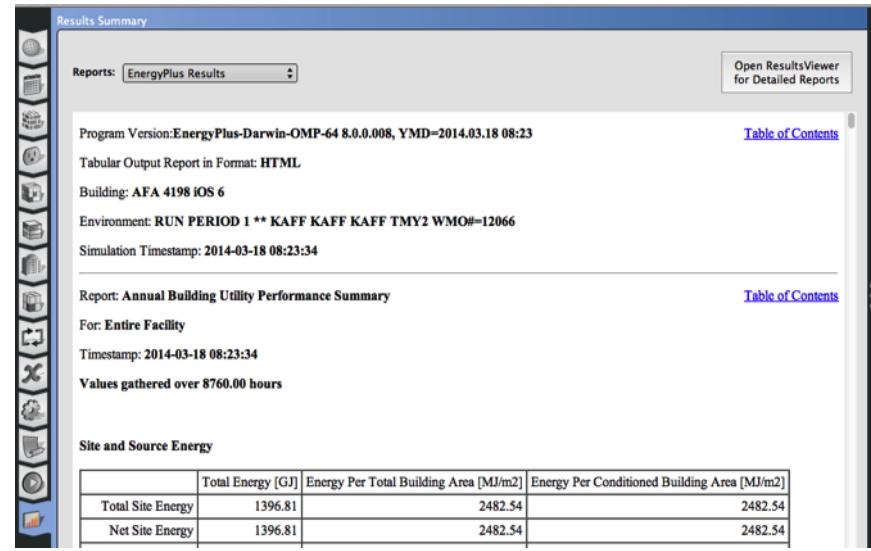
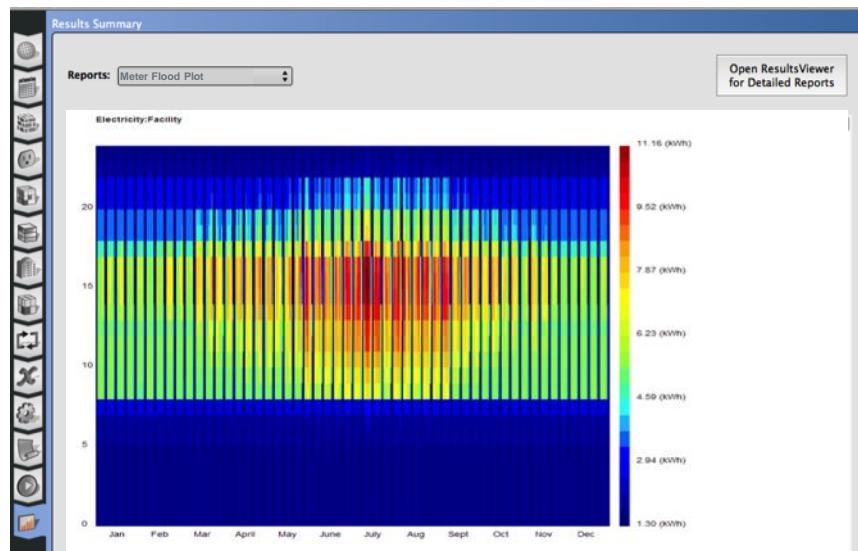
- Interactive visualization tools built into OS Server help explore large solutions spaces



* Not an AOP deliverable, but something the new analysis framework allowed us to deliver with little additional effort.

Major Accomplishment – Extensible Results Reporting

Significance: Practitioners can now easily extend the OpenStudio application with their own custom reports via reporting measures.



Major Accomplishment – Additional HVAC Systems

Significance: Much progress made on exposing the breadth of EnergyPlus' HVAC modeling capabilities as prioritized by project needs.

The screenshot displays the EnergyPlus HVAC Systems interface. On the left, there is a vertical toolbar with various icons representing different HVAC components. The main window shows two system configurations:

- Drop VRF System:** This section contains a sub-component labeled "Air Conditioner Variable Refrigerant Flow" which includes icons for a coil, a wavy line, a fan, and two terminal units, each associated with 3 zones.
- Air Conditioner Variable Refrigerant Flow 1:** This section includes icons for a coil, a wavy line, a fan, and two terminal units, each associated with 2 zones.

On the right, there is another HVAC Systems window titled "Packaged Rooftop VAV with Reheat". It displays a detailed piping and equipment diagram for a rooftop system, showing supply and demand equipment, ductwork, and multiple VAV boxes connected to a central reheat coil.

New systems include:

- Variable Refrigerant Flow
- Plenums
- Ground Source Heat Pumps (Vertical Well)
- Chilled Beams
- Exhaust Fans
- Radiant Slabs
- Baseboard Heating
- Demand Control Ventilation
- Many more complete or in process

Major Accomplishment – Commercial Refrigeration

Significance: Commercial refrigeration modeling is now “drag-and-drop” easy.

The screenshot displays the HVAC Systems software interface, specifically the Refrigeration module. On the left, a schematic diagram shows a refrigeration circuit with components like a compressor, condenser, and expansion valve. A 'Drag and Drop Compressor' icon is highlighted. Below the schematic, there are sections for 'Drag and Drop Cases' (containing 4 display cases) and 'Walk Ins' (containing 0 walk ins). On the right, a library panel lists various components: Fan Constant Volume, Fan Variable Volume, Heat Exchanger Air To Air Sensible and Latent, Pipes, Pump Variable Speed, Pump Constant Speed, Refrigeration Case, and Refrigeration Case. The main workspace shows a 'Display Cases' table with the following data:

Name	Case Anti Sweat Heater Power per Unit Length	Anti Sweat Heater Control Type	Minimum Anti Sweat Heater Energy per Unit Length	Humidity at Zero Anti Sweat Heater Energy	Fraction of Anti Sweat Heater Energy to Case
Refrigeration Case	0.000000 W/m	None	0.000000 W/m	-10.000000	1.000000
Refrigeration Case 1	0.000000 W/m	None	0.000000 W/m	-10.000000	1.000000
Refrigeration Case 2	0.000000 W/m	None	0.000000 W/m	-10.000000	1.000000
Refrigeration Case 3	0.000000 W/m	None	0.000000 W/m	-10.000000	1.000000
Refrigeration Case 4	0.000000 W/m	None	0.000000 W/m	-10.000000	1.000000
Refrigeration Case 5	0.000000 W/m	None	0.000000 W/m	-10.000000	1.000000
Refrigeration Case 6	0.000000 W/m	None	0.000000 W/m	-10.000000	1.000000

Below this, a 'Walk Ins' table shows two entries, both named 'Refrigeration Walk In' and 'Refrigeration Walk In 1', each associated with 'Refrigeration System 1'. The right side of the interface shows a vertical library panel with categories like Pipes, Pump Variable Speed, Pump Constant Speed, Refrigeration Case, and Refrigeration Subcooler Liquid Suction, among others.



Major Accomplishment – CEC Title 24 Compliance Tool

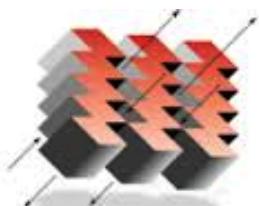
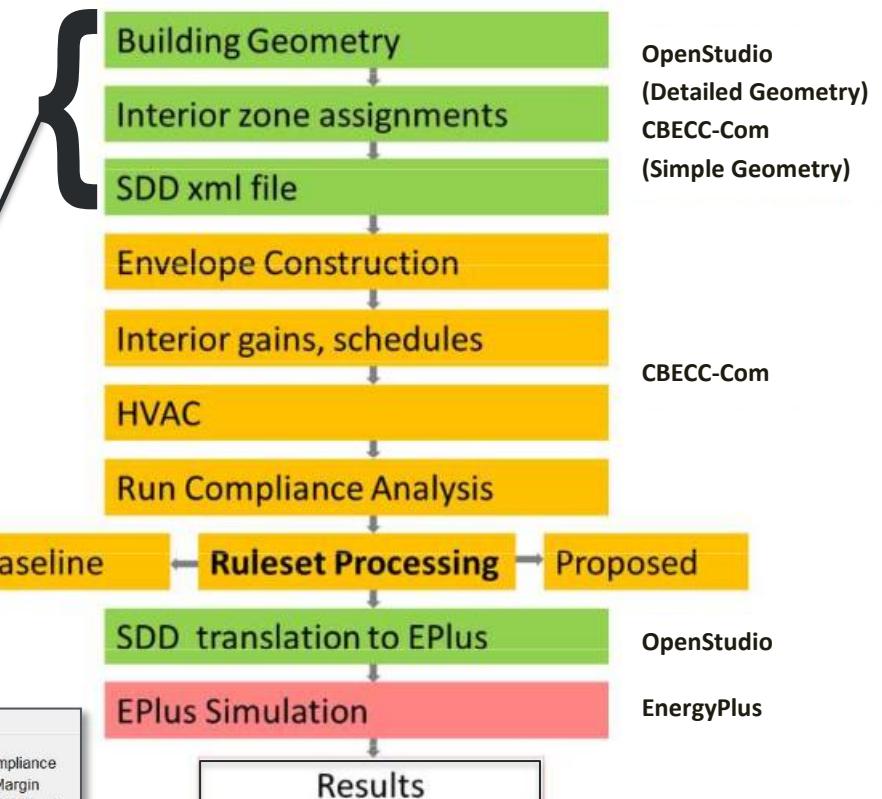
- Version 1 of CBECC-Com certified 9/2013
- Certification for version 2 expected 4/2014

The screenshot shows the OpenStudio software interface. On the left is a 3D sketchup-style view of a building model. On the right is a table titled "Energy Use Summary". The table compares proposed design values with standard design values across various end uses. A red arrow points from the "Export SDD Model" option in the OpenStudio menu to the "SDD xml file" step in the flowchart.

End Use	Proposed Design Site (MWh)	Proposed Design Site (therms)	Proposed Design (kTDV/ft ² -yr)	Standard Design Site (MWh)	Standard Design Site (therms)	Standard Design (kTDV/ft ² -yr)	Compliance Margin (kTDV/ft ² -yr)
Space Heating			292		292	10.0	
Space Cooling	9.9			9.9		71.6	0.1
Indoor Fans	19.6			19.6		81.0	
Heat Rejection							
Pumps & Misc.							
Domestic HW			169		169	5.0	
Lighting	7.9			7.9		35.8	
Compliance Total	37.4	461	203.5	37.4	461	203.6	0.2
Receptacle	23.6			23.6		109.8	
Process							
Process Ltg							
TOTAL	80.9	461	313.3	61.0	461	313.4	

Unmet Load Hours: (by thermal zone)
 clg: 0 htg: 0 'Attic Thermal Zone'
 clg: 0 htg: 0 'Core_ZN Thermal Zone'
 clg: 0 htg: 0 'Perimeter_ZN_1 Thermal Zone'
 clg: 0 htg: 0 'Perimeter_ZN_2 Thermal Zone'
 clg: 0 htg: 0 'Perimeter_ZN_3 Thermal Zone'

clg: 0 htg: 0 'Attic Thermal Zone'
 clg: 0 htg: 0 'Core_ZN Thermal Zone'
 clg: 0 htg: 0 'Perimeter_ZN_1 Thermal Zone'
 clg: 0 htg: 0 'Perimeter_ZN_2 Thermal Zone'
 clg: 0 htg: 0 'Perimeter_ZN_3 Thermal Zone'



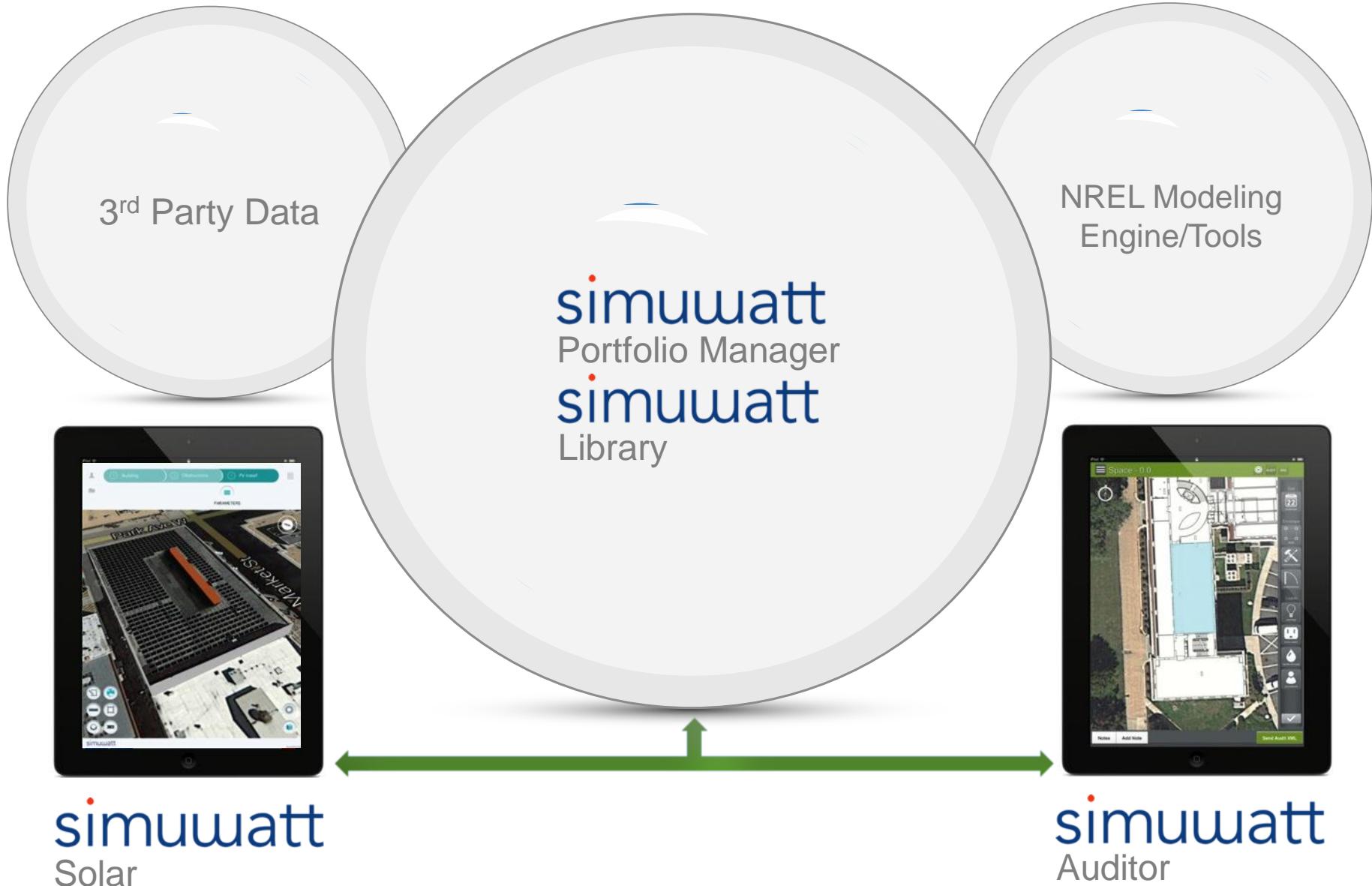
concept3D Inc. and simuwatt Energy Auditor



Benefits

- Streamlined, high quality commercial energy audits (Level II, III)
- Lower the cost of energy audits by 35-75%
- Consistent, standardized and reusable data format
- Access data from the cloud and share projects
- Custom reporting and output
- Asset tracking and building lifecycle tracking
- Opportunity for benchmarking and portfolio tracking

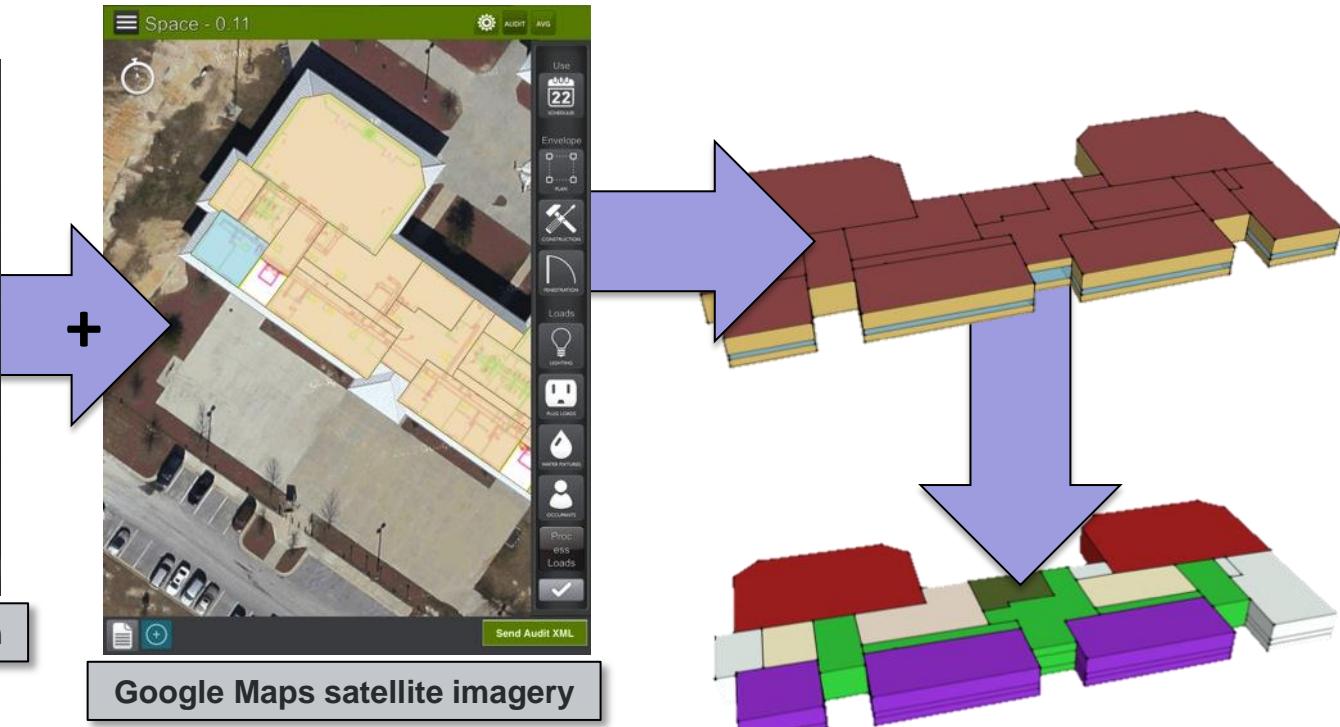
simuwatt Cloud and Applications



simuwatt Energy Auditor Workflow Overview



Photo of on-site evacuation plan

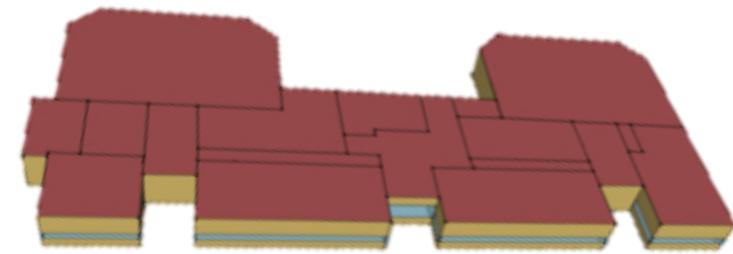


- OpenStudio automatically generates a detailed energy model ready for simulation



Ft. Jackson Bldg 10400

simuwatt Energy Auditor Workflow Overview



Baseline Model

Building Component Library

Welcome, Guest! Login | Register

Enter the terms you wish to search for:

Search

1 Search for a component or energy conservation measure
2 Filter results and download specific file or files you need.
3 Add component data to your energy model.
4 Run simulation and review results.

Components Total Components: 28,652

The components are designed to provide data to the energy auditor during the process of gathering inputs. The range of components goes from whole buildings to detailed files, like duct sealing components.

Energy Conservation Measures Total Measures: 1

Energy saving measures are packages that have been created for one or a package of energy saving measures to your model. An example would be a measure that adds overhangs to all your windows.

Developer Access

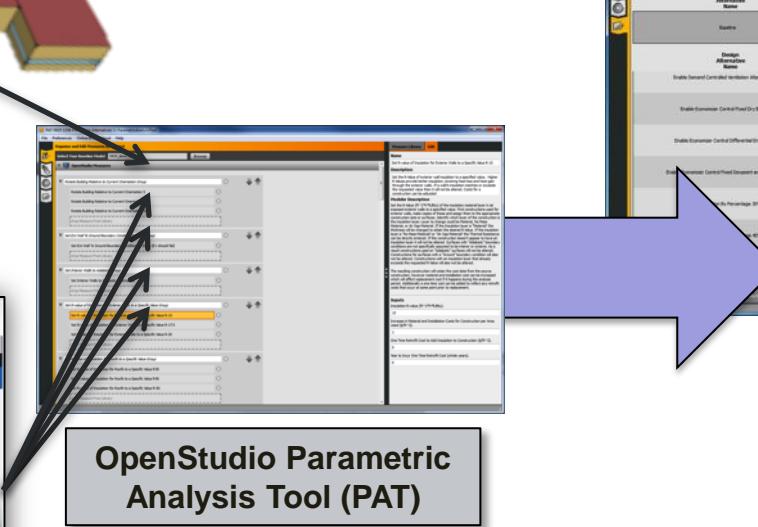
News view all Initial Component Upload Complete

[Browse Components](#) [Search](#) [Browse Energy Conservation Measures](#) [Search](#)

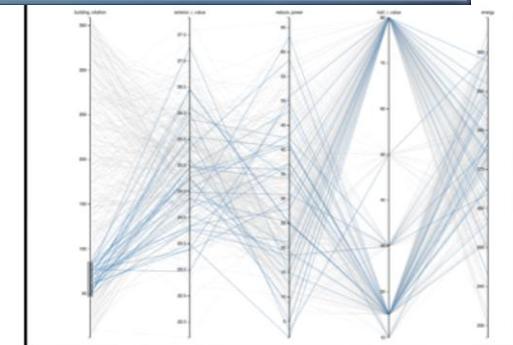
Building Component Library:
Online Database of Measures



Ft. Jackson Bldg 10400

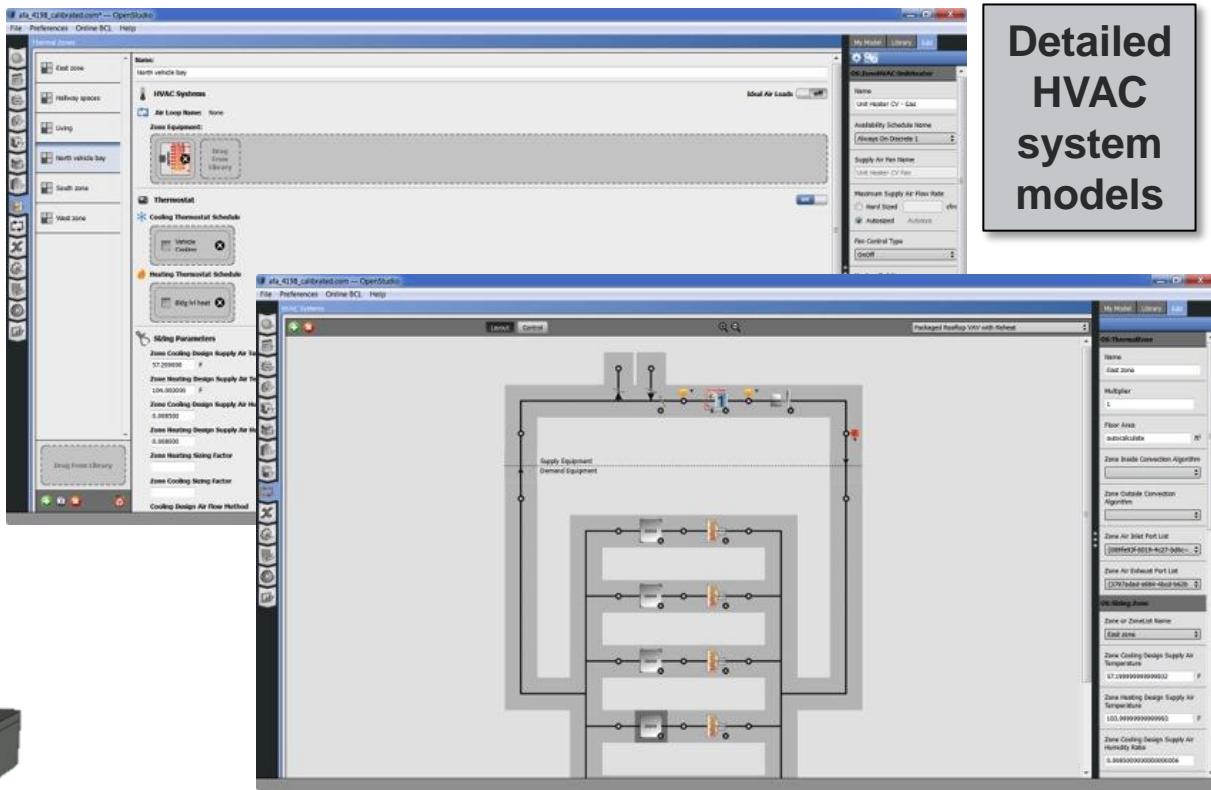
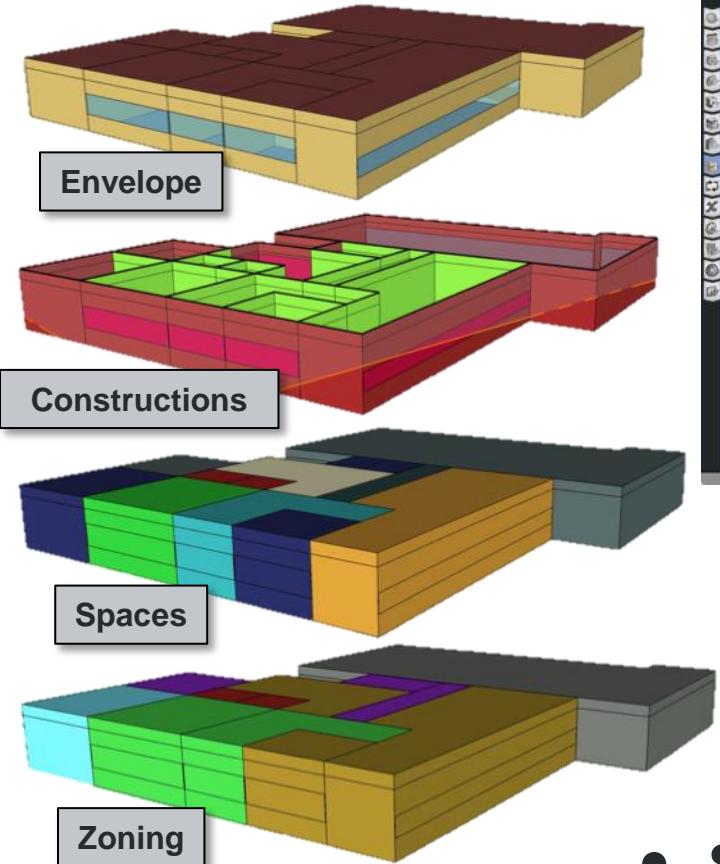


Design Option Name	Design Alternative Name	Energy Use (MMBtu/yr)	Peak Electric Demand (kW)	Electricity Consumption (MMBtu/yr)	Natural Gas Consumption (MMBtu/yr)	District Cooling Consumption (MMBtu/yr)	District Heating Consumption (MMBtu/yr)	First Year Capital Cost (\$)	Annual Utility Cost (\$)	Annual Maintenance Cost (\$)	Total LCC (\$)
Baseline	Baseline	223	30	95.588	1,000	0	0	1,000,000	95,588	0	1,095,588
Enable Demand Controlled Ventilation Alternative Only	Enable Demand Controlled Ventilation Alternative Only	20	30	94,712	0	0	0	0	3,720	0	94,712
Enable Economic Control (Preset Dry/Sub Only)	Enable Economic Control (Preset Dry/Sub Only)	0	30	95,142	0	0	0	0	3,720	0	95,142
Enable Economic Control Differential Embodiment Only	Enable Economic Control Differential Embodiment Only	0	30	95,142	0	0	0	0	3,720	0	95,142
Enable Economic Control Preset (Dry/Sub Only)	Enable Economic Control Preset (Dry/Sub Only)	0	30	95,142	0	0	0	0	3,720	0	95,142
Enable Economic Control Preset (5% Only)	Enable Economic Control Preset (5% Only)	0	30	95,142	0	0	0	0	3,720	0	95,142
Enable Economic Control Preset (5% Only)	Enable Economic Control Preset (5% Only)	0	30	95,142	0	0	0	0	3,720	0	95,142



- Life cycle analysis identifies most cost-effective measures

simuwatt Energy Auditor Case Study



Detailed
HVAC
system
models

- simuwatt and OpenStudio produce the complete model needed for rigorous energy analysis



AFA Bldg 4198

simuwatt Energy Auditor Case Study

Calibration Method

ASHRAE 14-2002

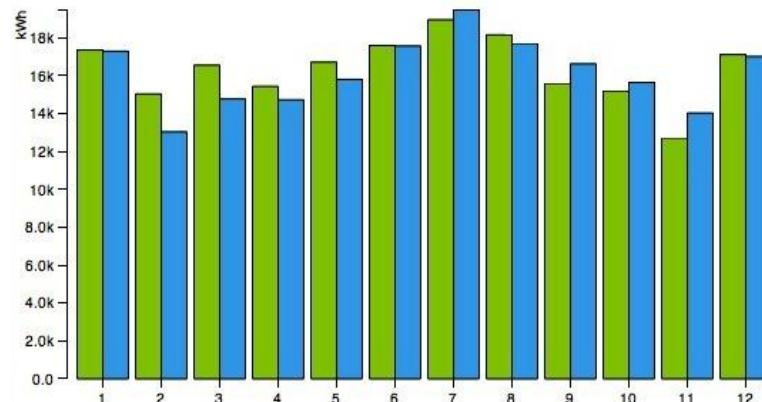
NBME of 5% or less and CV(RMSE) of 15% relative to monthly data.

Must contain all utility data for one year and real weather data. Check the guideline for additional requirements.

Electricity Consumption (kWh)

CV(RMSE) = 6.37

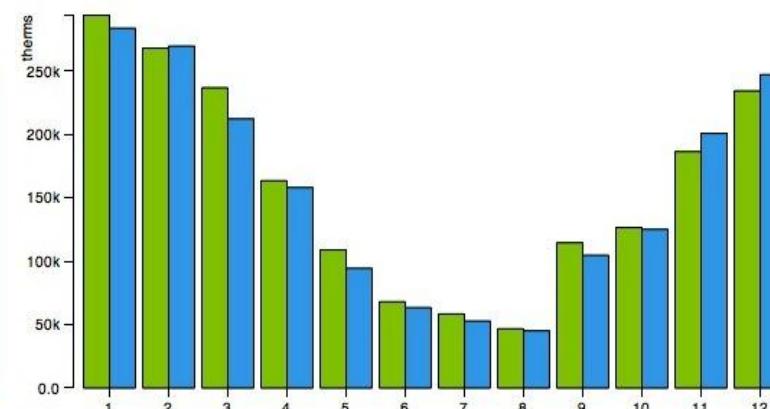
NMBE = 1.53



Natural Gas Consumption (therms)

CV(RMSE) = 7.28

NMBE = 2.79



	1	2	3	4	5	6	7	8	9	10	11	12
Start	1/1	2/1	3/1	4/1	5/1	6/1	7/1	8/1	9/1	10/1	11/1	12/1
End	1/31	2/28	3/31	4/30	5/31	6/30	7/31	8/31	9/30	10/31	11/30	12/31
Actual	17,360	15,040	16,560	15,440	16,720	17,600	18,960	18,160	15,600	15,200	12,720	17,120
Model	17,297	13,041	14,778	14,730	15,810	17,572	19,471	17,705	16,631	15,645	14,033	17,019
NMBE	-0.36%	-13.29%	-10.76%	-4.6%	-5.44%	-0.16%	2.7%	-2.51%	6.61%	2.93%	10.33%	-0.59%



AFA Bldg 4198

- OpenStudio assists with rapid model calibration

simuwatt Energy Auditor Case Study

Create and View Reports

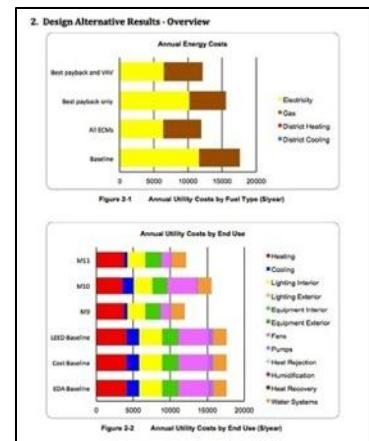
View: Standard Calibration

Design Alternative Name	Energy Use Intensity (kBtu/ft ² -yr)	Peak Electric Demand (kW)	Electricity Consumption (kWh)	Natural Gas Consumption (Million Btu)	District Cooling Consumption (Million Btu)	District Heating Consumption (Million Btu)	First Year Capital Cost (\$)	Annual Utility Cost (\$)	Total LCC (\$)	
Baseline	263	36	193,678	1,913	0	0	0	17,627	311,140	
Design Alternative Name	Energy Use Intensity Reduction (kBtu/ft ² -yr)	Peak Electric Demand Reduction (kW)	Electricity Savings (kWh)	Natural Gas Savings (Million Btu)	District Cooling Savings (Million Btu)	District Heating Savings (Million Btu)	First Year Capital Cost Increase (\$)	Annual Utility Cost Savings (\$)	Simple Payback (years)	Total LCC Savings (\$)
Implement setbacks at night Only	24 9%	0 0%	3,097 2%	227 12%	0 --	0 --	120 --	897 5%	0	16,008 5%
High efficiency motors in AHU Only	0 0%	0 0%	0 0%	0 0%	0 --	0 --	1,116 --	0 0%	--	(1,084) (0%)
Install cogged v-belts Only	0 0%	0 0%	0 0%	0 0%	0 --	0 --	240 --	0 0%	--	(233) (0%)
CAV with Reheat to VAV with Reheat Air Handler Only	17 6%	11 32%	64,439 33%	(56) (3%)	0 --	0 --	70,944 --	3,692 21%	19	(4,709) (2%)
Constant Speed to Variable Speed Pump Alternative Only	0 0%	0 1%	6,467 3%	(18) (1%)	0 --	0 --	400 --	332 2%	1	5,350 2%
					0 --	0 --	4,650 --	709 4%	7	7,764 2%
					0 --	0 --	31,500 --	171 1%	185	(27,620) (9%)

- **Simulation results compare:**

- EUI and peak demand savings
- Gas and district heating/cooling impacts if appropriate
- Capital cost increases
- Annual utility cost savings
- Simple payback
- Total life cycle cost savings

- **Auto-generated report creates standard plots, text, etc. to save even more time**



High Demand Across Products – 300+

Energy Services/
Construction/Real
Estate



NORESCO
Honeywell



AMERESCO
Green • Clean • Sustainable

SIEMENS

Mckinstry
For The Life Of Your Building

Mortenson
construction

**JONES LANG
LA SALLE®**

WYNDHAM®
Hotels and Resorts

Solar



CIVIC SOLAR™

**STANDARD
SOLAR**

UMCpower
Simplifying Energy

Johnson
Controls

Honeywell

Chevron
Energy Solutions

**REC
SOLAR**

Utilities

Xcel Energy™

nationalgrid

**SOUTHERN CALIFORNIA
EDISON**

An EDISON INTERNATIONAL® Company

EPRI
Electric Power Research Institute

ComEd®

An Exelon Company

State/Local/Feder
al/non-profit

NREL
NATIONAL RENEWABLE ENERGY LABORATORY



**ROCKY
MOUNTAIN
INSTITUTE®**

SF Environment
Our home. Our city. Our planet.

Project Integration and Collaboration

Project Integration: OpenStudio platform directly enables the development of other National Laboratory products and private sector applications identified on previous slides. OpenStudio is also a critical component for CEC, NRCan, and multiple utility initiatives.

Communications:

- Active communication via:
 - <http://openstudio.nrel.gov> website and forums
 - OpenStudio YouTube channel with over 100 tutorial videos
- Multiple training opportunities offered by private sector performers
- Presentations at Fall eSource Forum and follow up scheduled for June
- Upcoming workshop at eSim in Ottawa Canada
- Papers presented at IBPSA SimBuild 2013
- Upcoming publications at:
 - eSim in Ottawa Canada
 - ACEEE Summer Study
 - IBPSA SimBuild 2014

Next Steps and Future Plans

1. Increased alignment (process and technology) with EnergyPlus 8.2
2. Ensure successful development, deployment, and adoption of platform-based tools
3. Expanded capability for rapid baseline modeling
4. Improve linkages between TPEx and BCL and the modeling ecosystem to enable assessment and adoption of ET
5. Leverage distributed analysis framework to support creation of large pre-computed simulation database (DEnCity)
6. Expand available measures (ECM, reporting, QA/QC) in BCL to further drive down the cost of modeling
7. Continue to increase cost-share and off ramp as value propositions expand for other agencies and utilities

Thank You!



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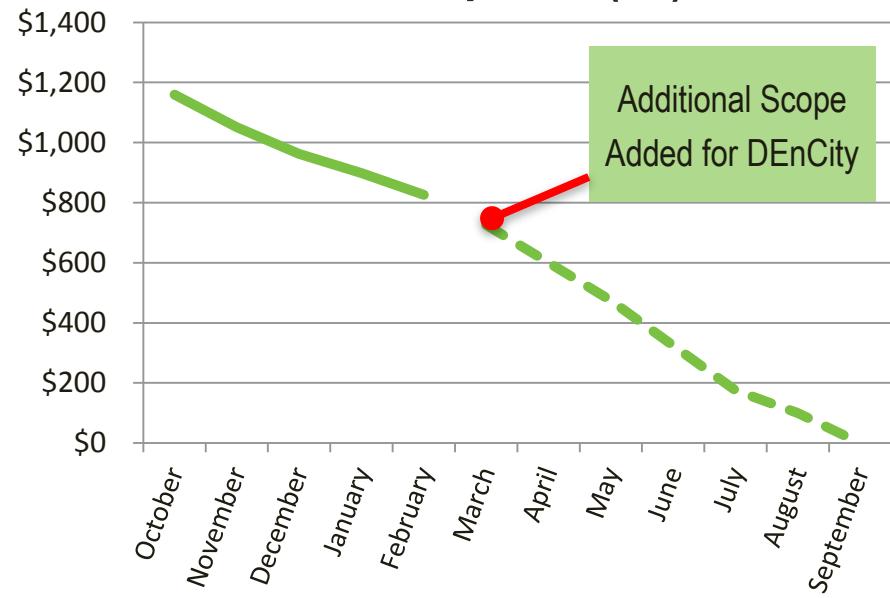


Phylroy Lopez
(NRCan)

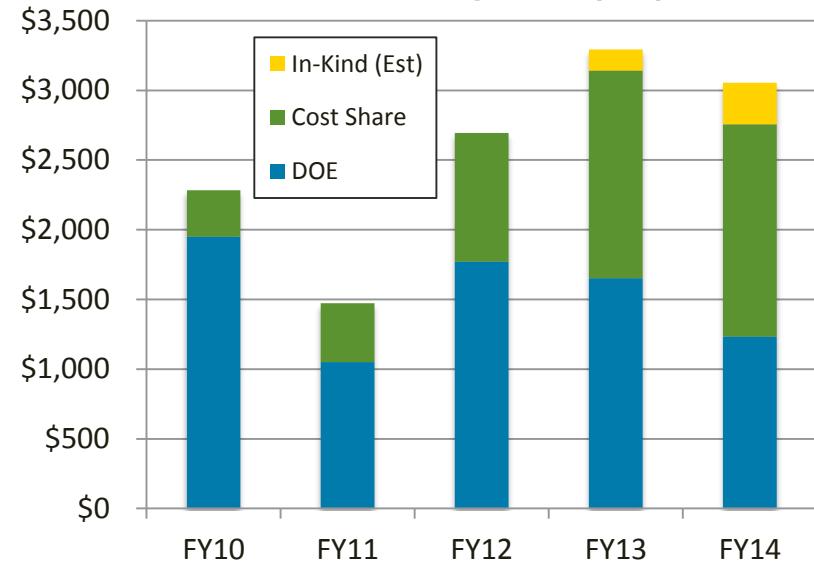
REFERENCE SLIDES

Project Budget

FY14 Spend* (\$k)



FY10-14 Budgets* (\$k)



Additional Funding Sources:



- * FY14 Spend and Budget Includes OpenStudio Core, Refrigeration GUI, and Asset Score CBI Budgets

Project Plan and Schedule

Project Initiation Date:	Q1/FY10
Planned Completion Date:	Ongoing with Frequent Off-Ramping of Components (e.g. training transitioned to private sector in Q1 FY14)
Release Schedule:	Bi-weekly (Agile) Minor Releases Quarterly Major Releases with DOE-Prescribed Focus Areas

