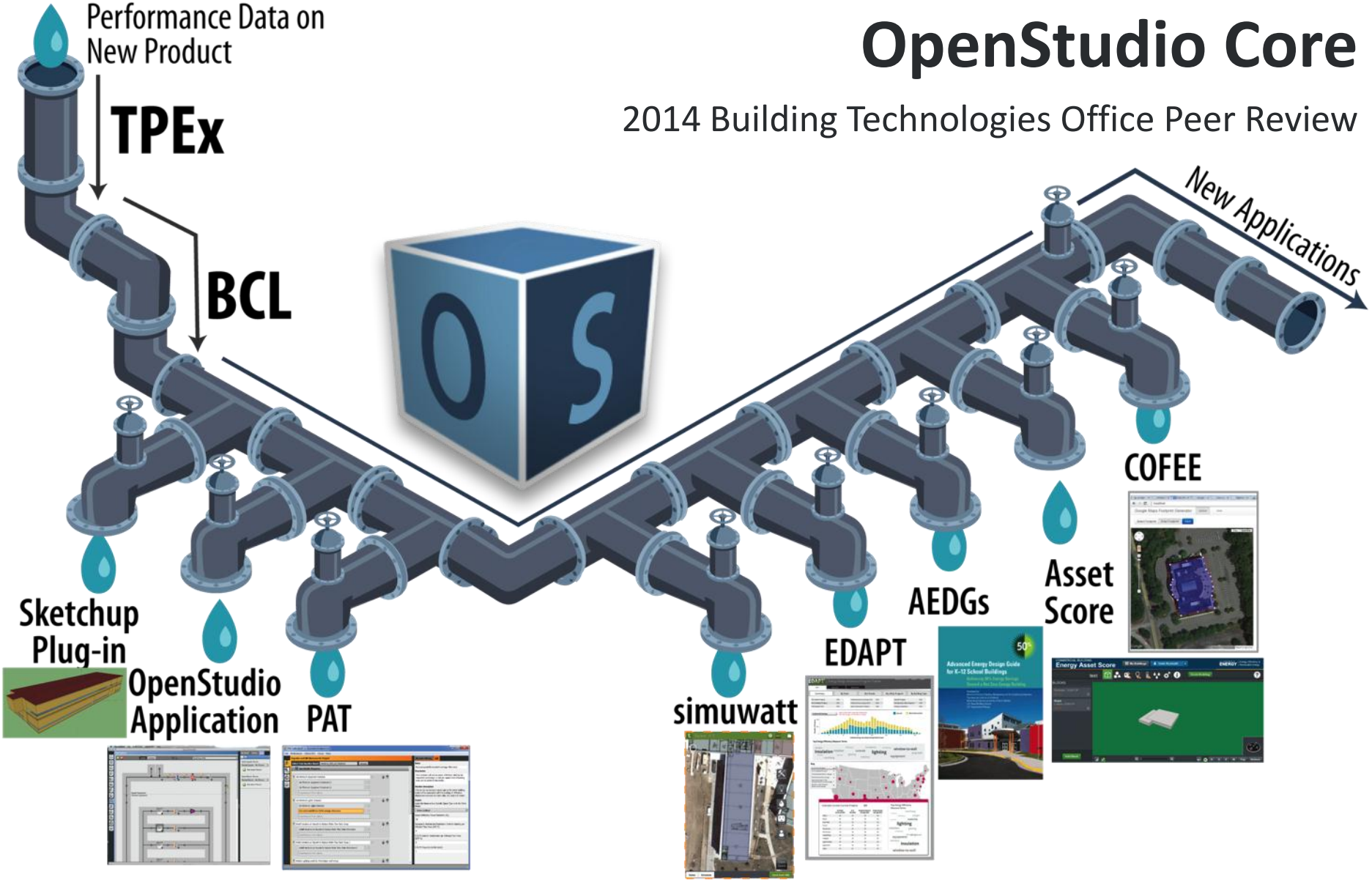
OpenStudio Core

2014 Building Technologies Office Peer Review



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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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:

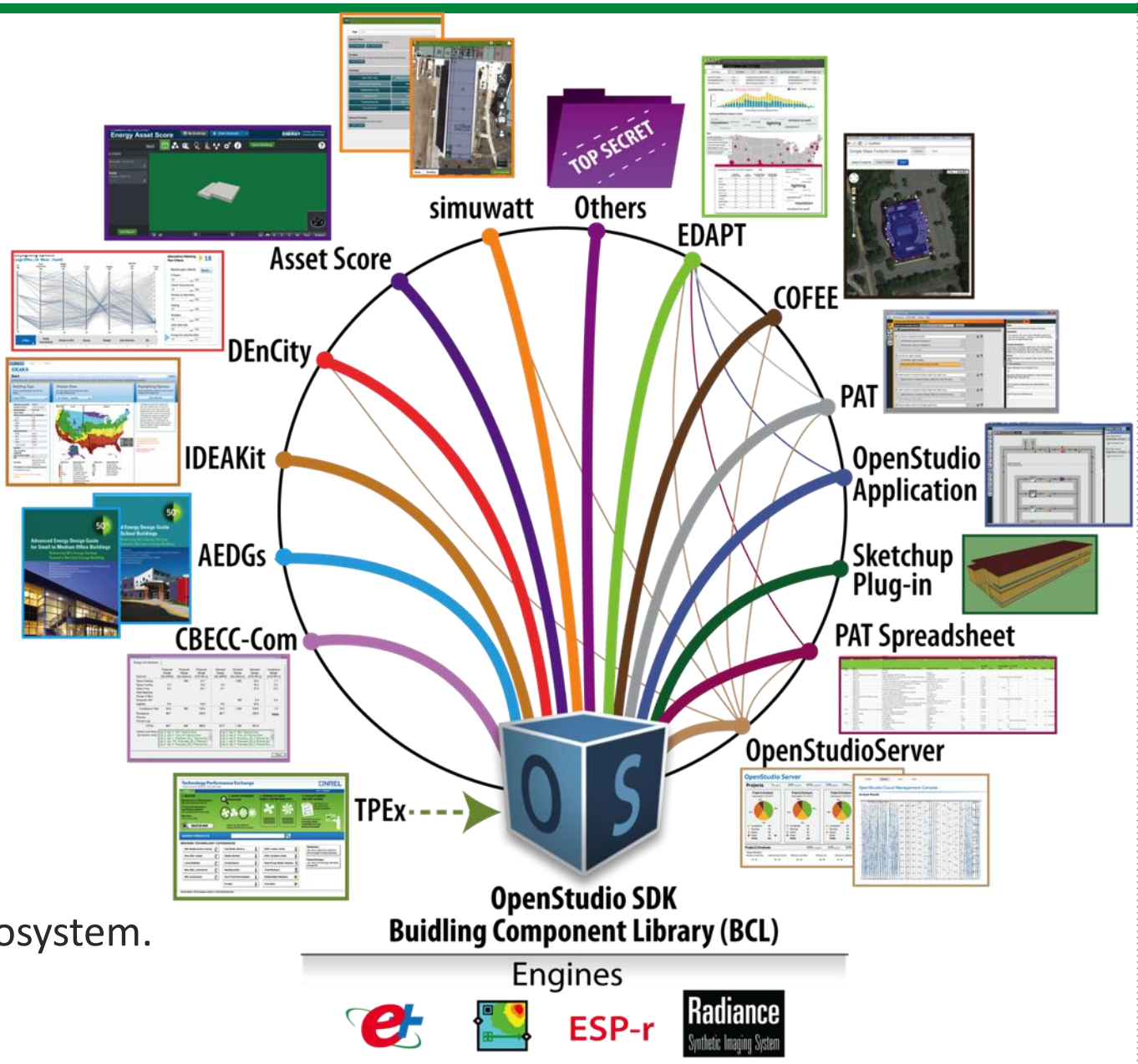
Develop BTO's best-in-class building energy analysis ecosystem to enable rapid, low-cost development of new market facing tools produced by the National Laboratories, Universities, Private Sector, and other agencies.

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.

* Includes OpenStudio Core, Asset Score, and related OS 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?

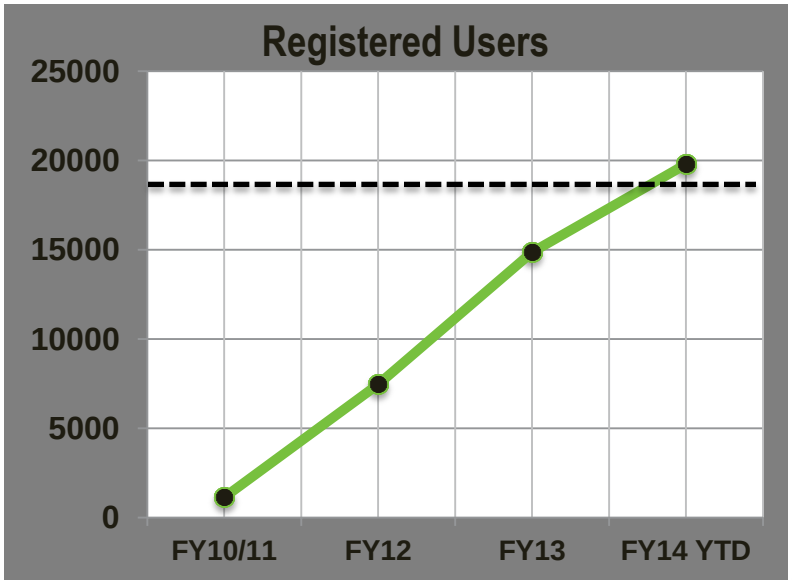


A: DOE's OpenStudio ecosystem.

Target Market and Audience

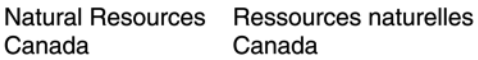
The market for OpenStudio is diverse and includes:

- 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.



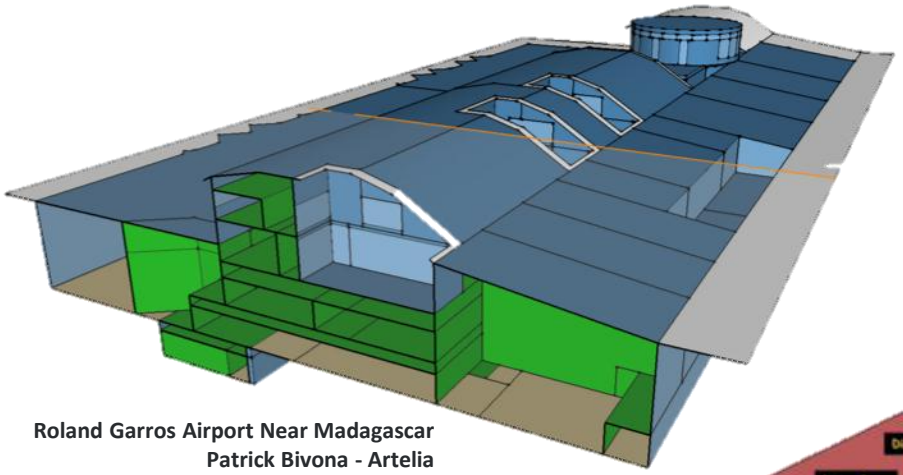
* This is OpenStudio's biggest growth area in FY13/14

Partial List of Partners

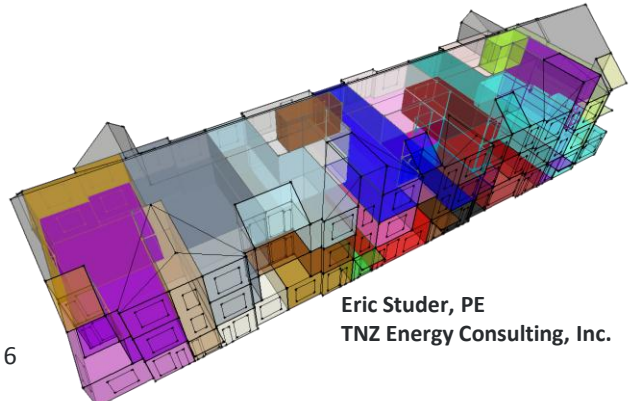


Real Market Adoption = Real Impact

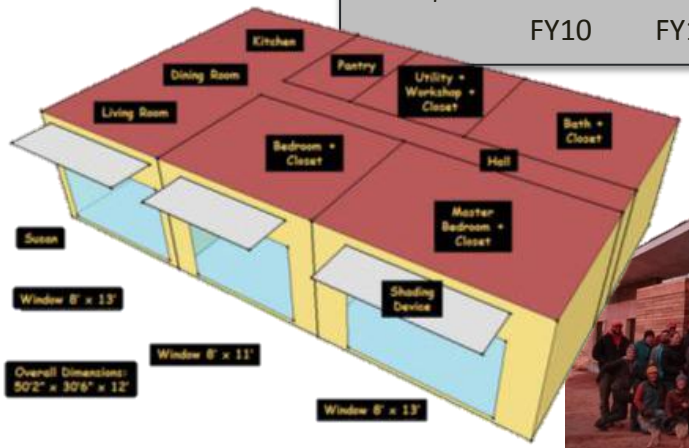
- For Xcel Energy's new construction program OpenStudio is directly contributing to its program savings goal of 40 GWH (up from 30 in 2013)
- Increasing cost-share from private sector
- Example models from practitioners:

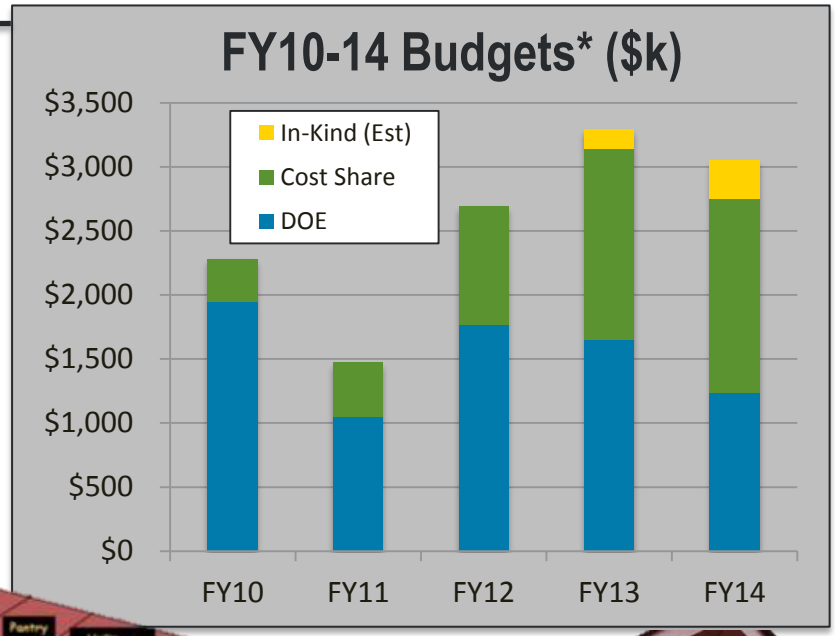


Roland Garros Airport Near Madagascar
Patrick Bivona - Artelia



Eric Studer, PE
TNZ Energy Consulting, Inc.





DesignBuildBluff
Southern Utah University and University of Colorado, Denver

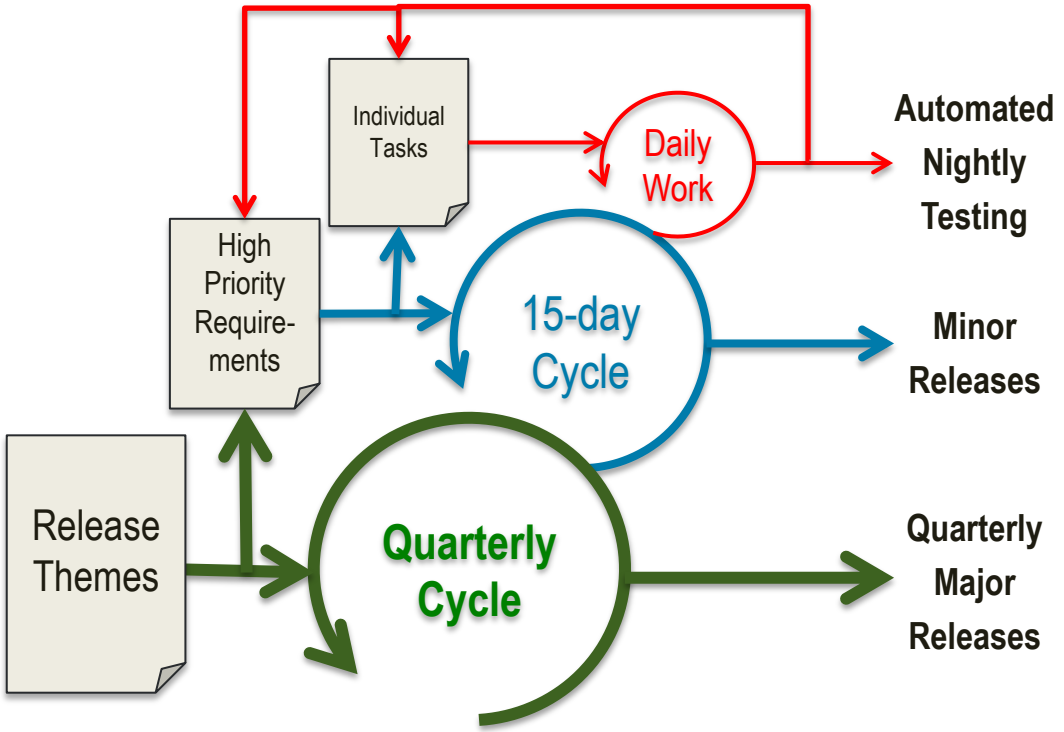
Approach to Development and Deployment

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

Embracing Agile:

- HVAC coverage initiatives driven by CEC, Xcel, and other market actors
- New software technologies have enabled a more extensible, scalable OpenStudio analysis framework that works well in the cloud
- Solution is enabling us to deliver optimization capability along with our AOP objectives for parametric uncertainty analysis

Master OpenStudio HVAC Roadmap

Last Updated 4/1/14

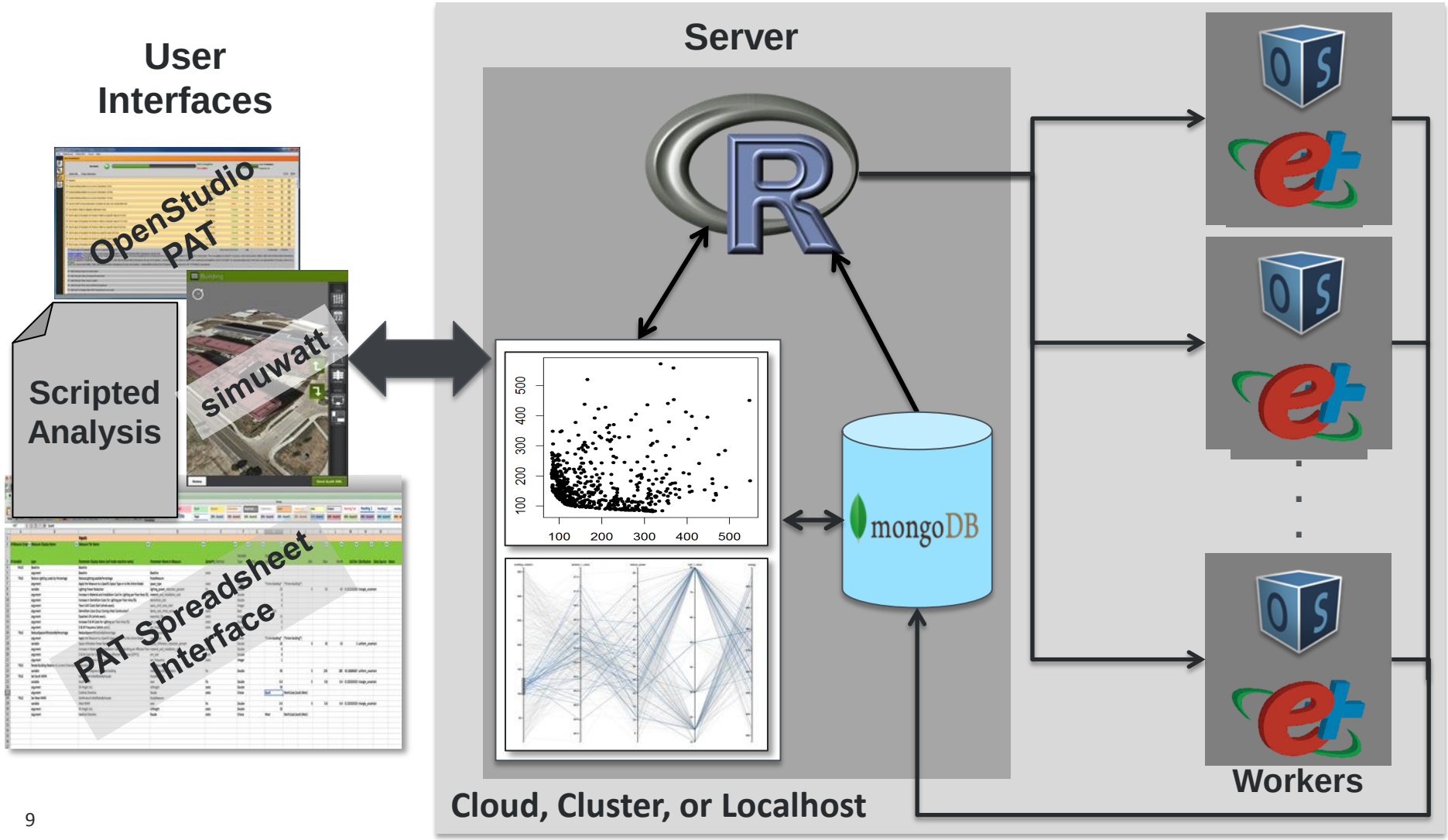
151 objects are currently visible.

Note: When Adding an object make sure it has a unique ID in column A

		Status				
ID	HVAC SYSTEMS AND EQUIPMENT	OpenStudio Back End Support	OpenStudio GUI support	Planned Release	Priority	OpenStudio approach - E+
129	Inter-Zone Air Transfer	IP - NREL	IP - NREL	1.4 Jun 2014	1	ZoneMixing
153	Unitary HVAC Equipment	No	No	1.4 Jun 2014	1	AirloopHVAC:UnitarySystem
22	Unit Ventilator - Makeup Air Unit	No	No	1.4 Jun 2014	1	ZoneHVAC:OutdoorAirUnit
7	Series Fan Power Boxes	No	No	1.4 Jun 2014	1	AirTerminal:SingleDuct:Seri
24	Evaporative Cooler Systems - Indirect	No	No	1.4 Jun 2014	1	EvaporativeCooler:Indirect:
150	OA Pre-treat Setpoint Manager	No	No	1.5 Sep 2014	1	SetpointManager:OutdoorA
90	Water-side economizer	No	No	1.5 Sep 2014	1	HeatExchanger:FluidToFluic
151	Setpoint Manager Scheduled Dual Setpoint	No	No	1.5 Sep 2014	1	SetpointManagerScheduled
147	Duct Heat Loss	No	No		1	How do we do this in E+?
132	Indoor and Outdoor Pipes (for modeling steam and hw losses)	No	No		1	Pipe:Indoor and Pipe:Outdo
152	Air System Bypass (For modeling CAV AHU with VAV terminals)	No	No		1	Duct (E+ analog for pipe adi
110	Air Distribution System - Underfloor air distribution	No	No		1	DesignSpecification:ZoneAir
116	Chilled water loop - Primary and secondary	No	No		1	Need Water-to-Water Heat
125	HVAC Controls - AHU Static Pressure Reset	No	No		1	SetpointManager:Warmest
130	Heat Pipe (wraparound heat pipe coil)	No	No		1	How do we do this in E+?
131	Packaged Water-cooled DX coupled with Zone hw heating coil	No	No		1	How do we do this in E+?
12	Dual Duct Sytems	No	No		2	
140	Solar Thermal	No	No		2	Look at SolarCollectorFlatPl
30	Adiabatic humidification	No	No		2	
59	Ground Source Heat Pump - Horizontal Loops (straight tube/slinky tube)	No	No		2	
69	Thermal Storage - Chilled Water Storage	No	No		2	
71	Thermal Storage - Ice Storage	No	No		2	Very common in NE in schoo
112	Air Distribution System - Displacement ventilation	No	No		2	ZoneVentilation:DesignFlow
118	Condenser Heat Recovery	No	No		2	
133	Wastewater heat reclaim	No	No		2	How do we do this in E+?
134	Duct Leakage	No	No		2	ZoneHVAC:AirDistributionU
135	Induction air systems - high pressure airloop w/ induction terminals	No	No		2	How do we do this in E+?
136	Water-cooled server racks	No	No		2	How do we do this in E+?
137	Hot water tank heated by a heat exchanger from another HW loop	No	No		2	Is this already in the backen
141	Runaround loop heat recovery	No	No		2	Commonly used for retrofit
29	Dessicant Cooling - Solid Dessicant Dehumidification	No	No		3	
47	Chiller - Electric Centrifugal with heat recovery	No	No		3	Duplicate of row up further
48	Chiller - Absorption Chiller with water-cooled condensor (single stage/two st	No	No		3	PSD thinks that steam-fired
91	Natural Ventilation	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.

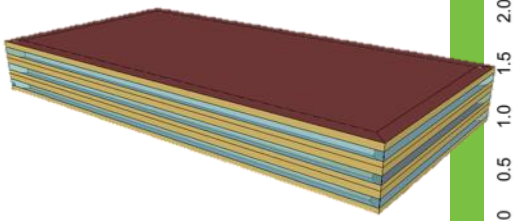


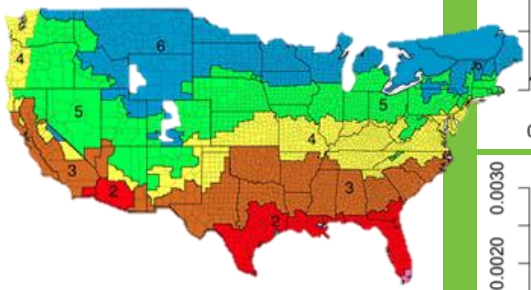
Major Accomplishment – Sensitivity Analysis for Asset Score

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

Pacific Northwest

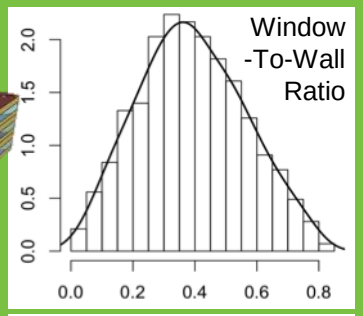
Baseline Models for Major Building Types

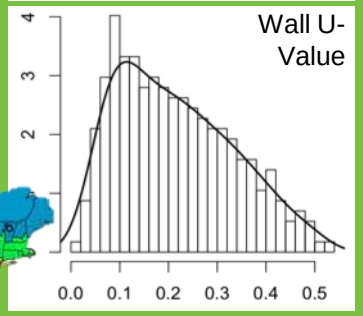


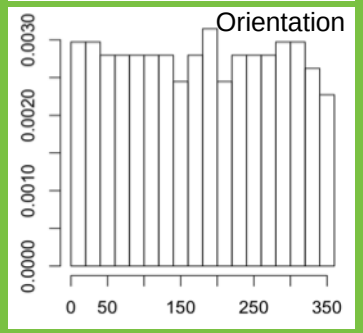


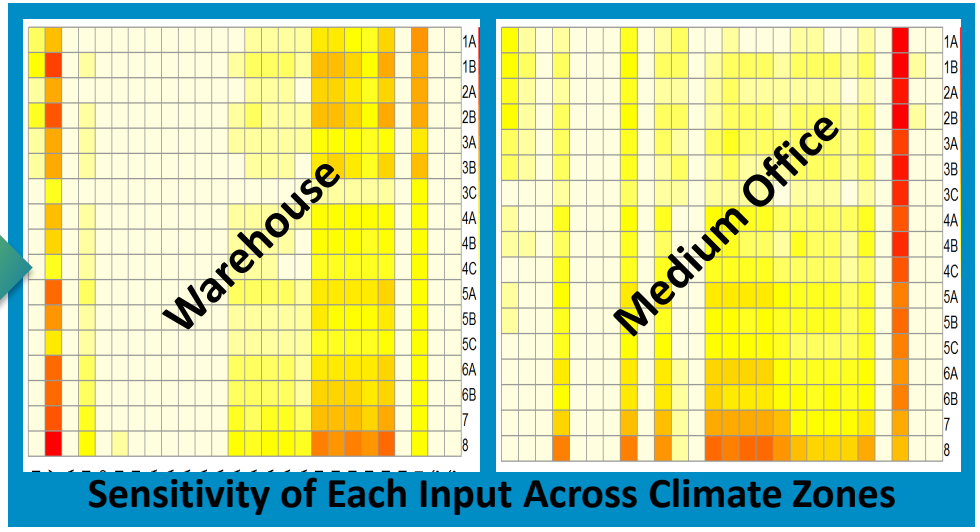
Climate Zones

OpenStudio Measures for Major Sources of Variation

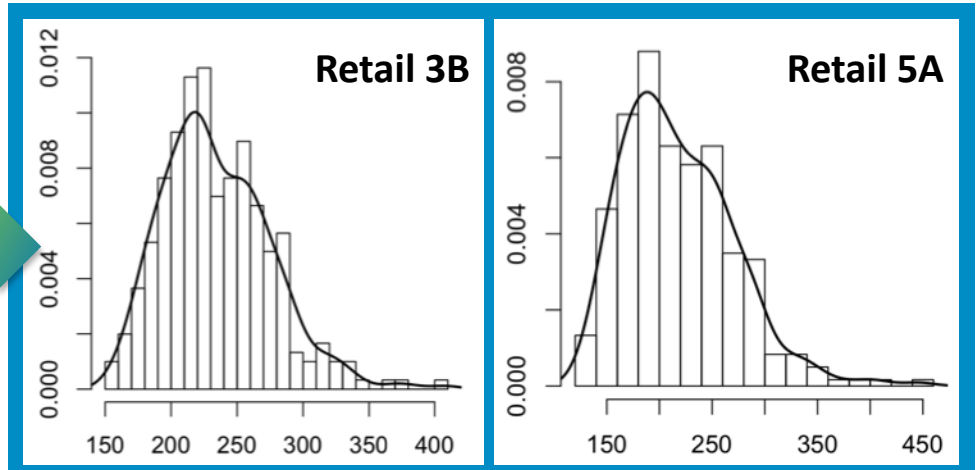








Sensitivity of Each Input Across Climate Zones



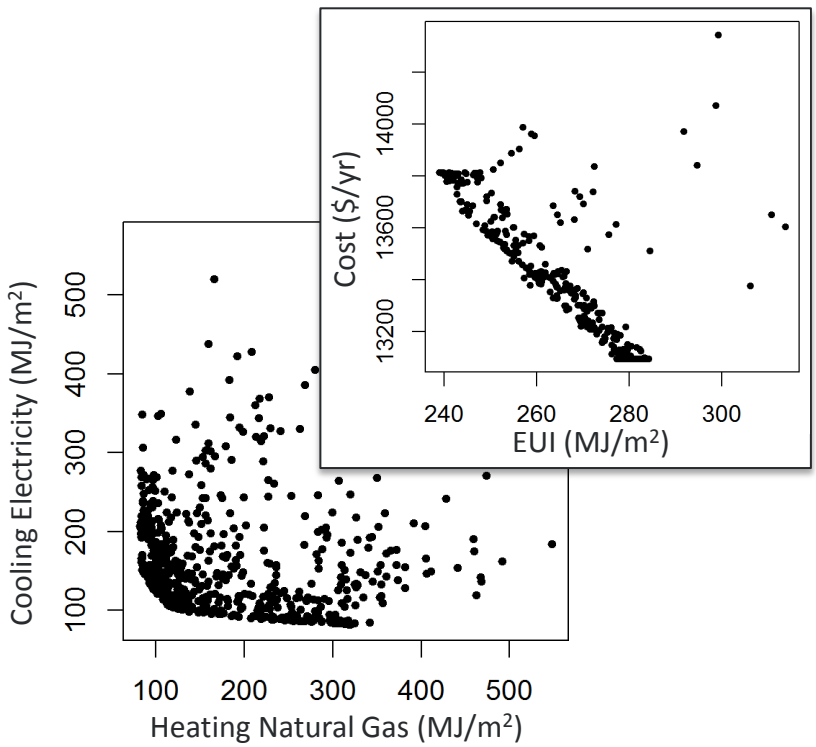
Potential Variation in EUI Combining All Inputs

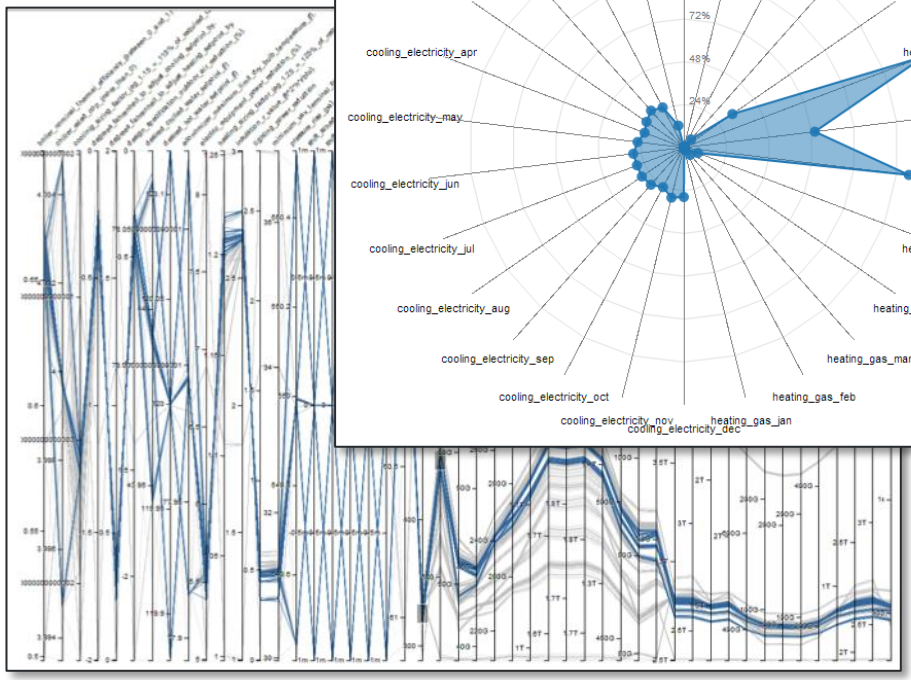
Major Accomplishment – Optimization*

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

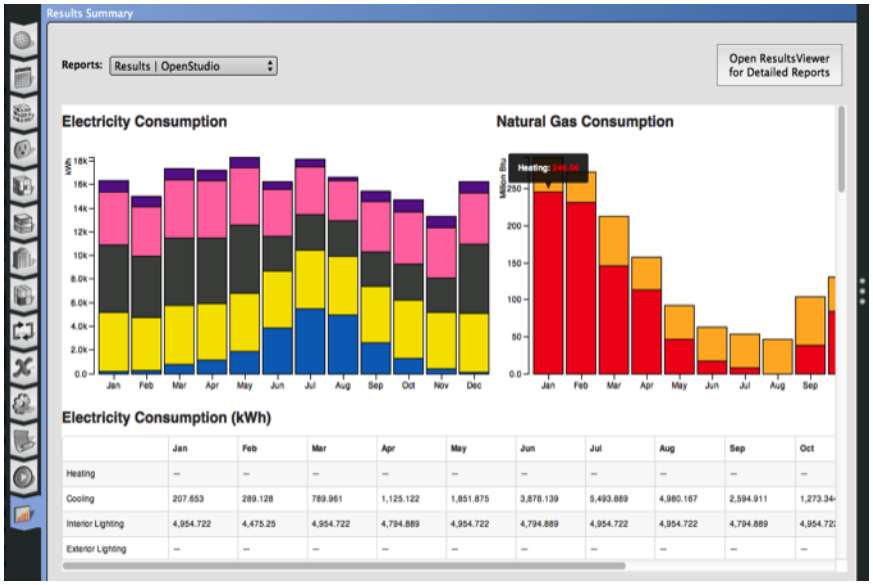


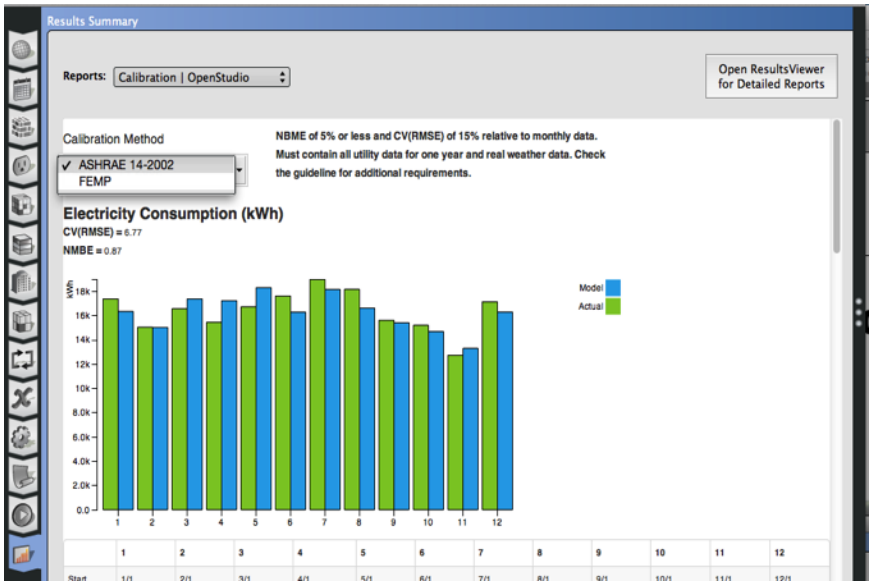


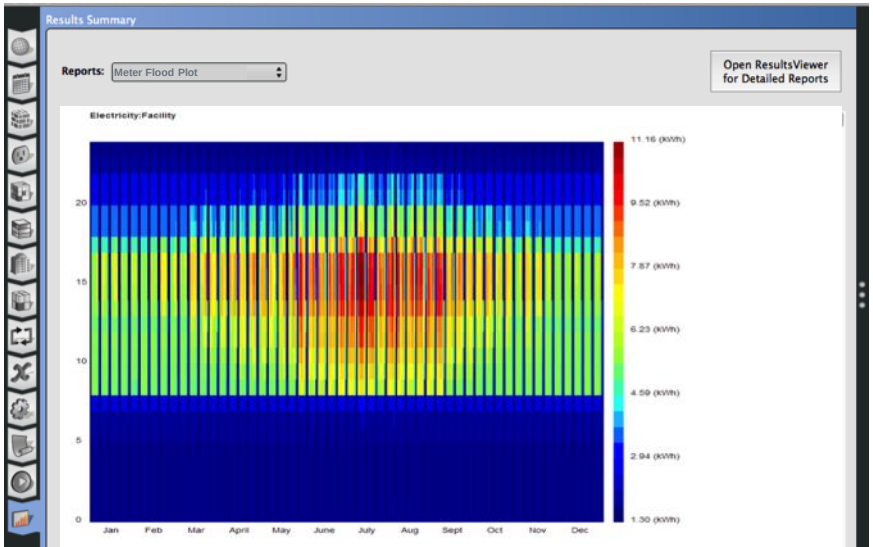
* Not an AOP deliverable, but something the new analysis framework allowed us to deliver with little additional effort.

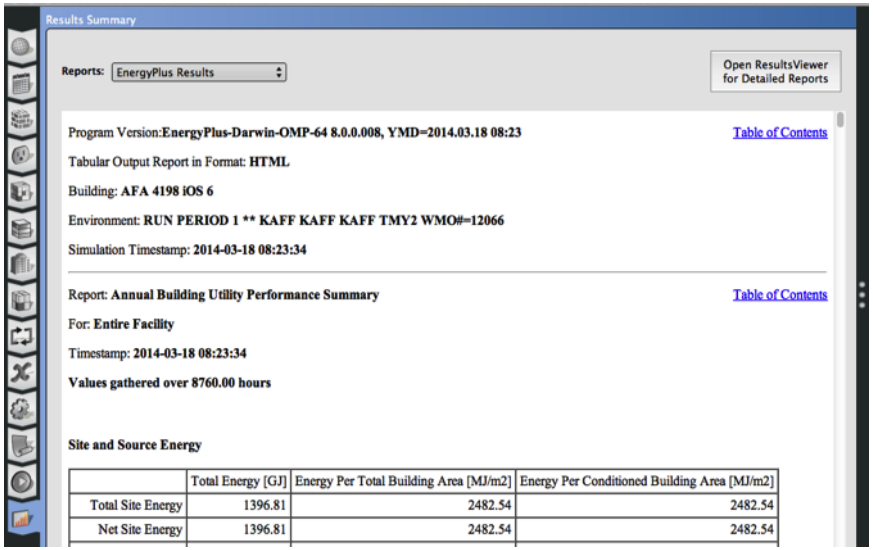
Major Accomplishment – Extensible Results Reporting

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



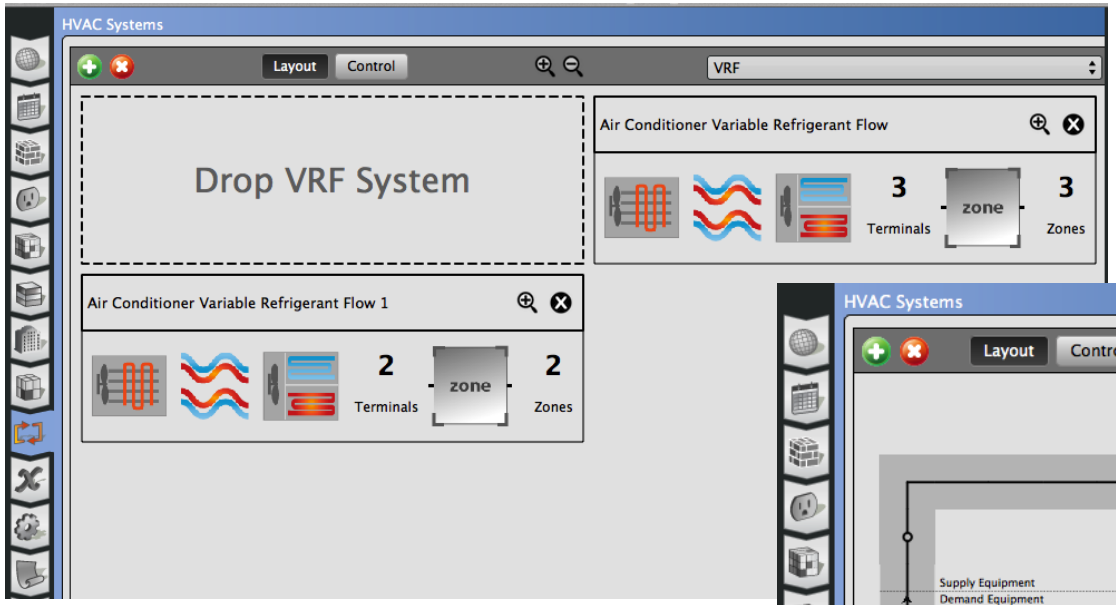


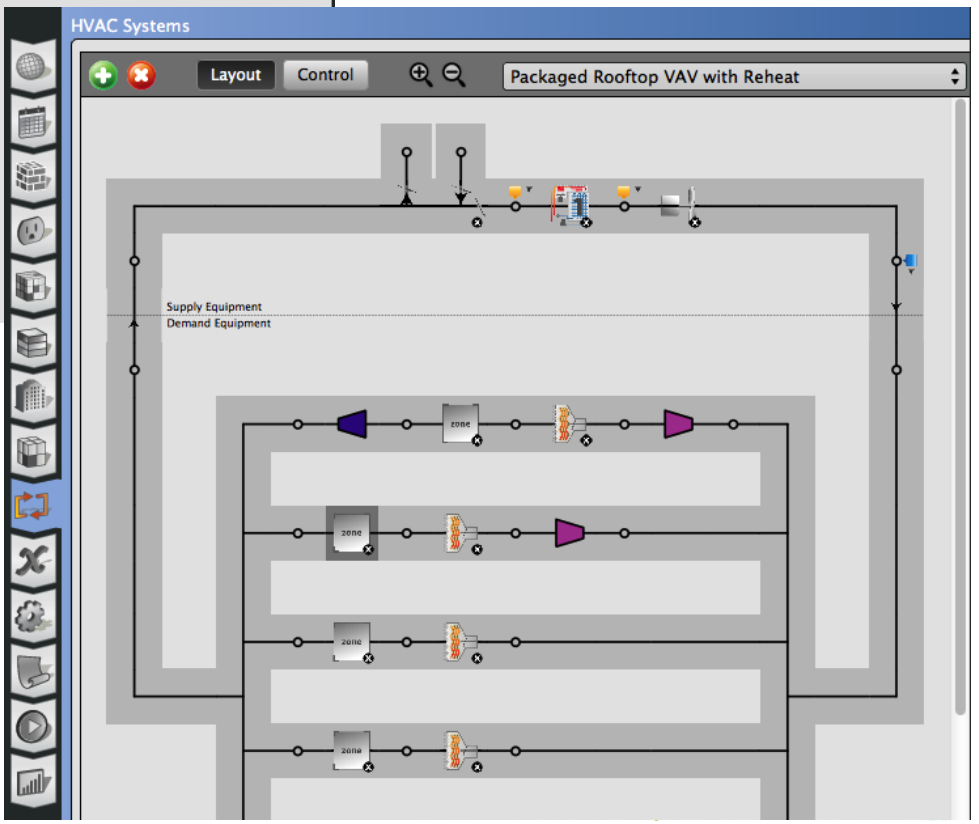




Major Accomplishment – Additional HVAC Systems

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



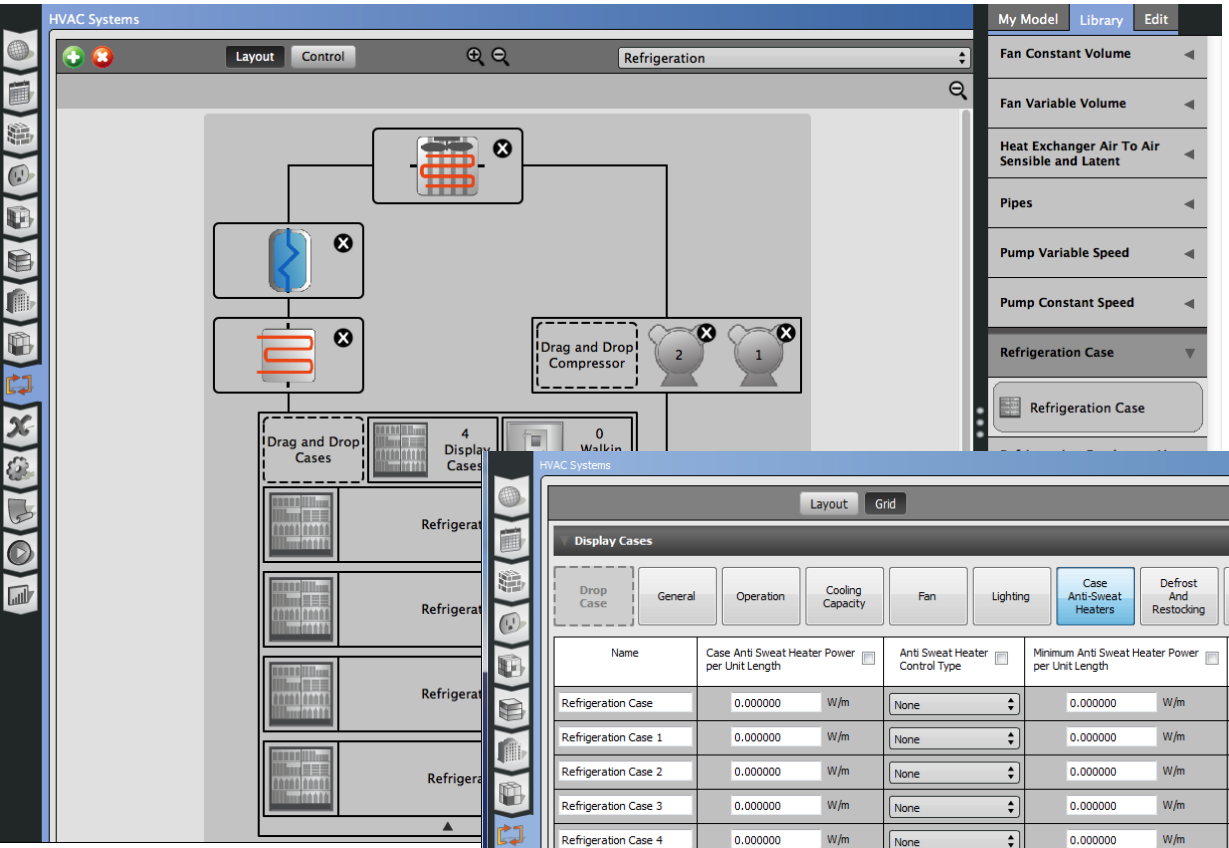


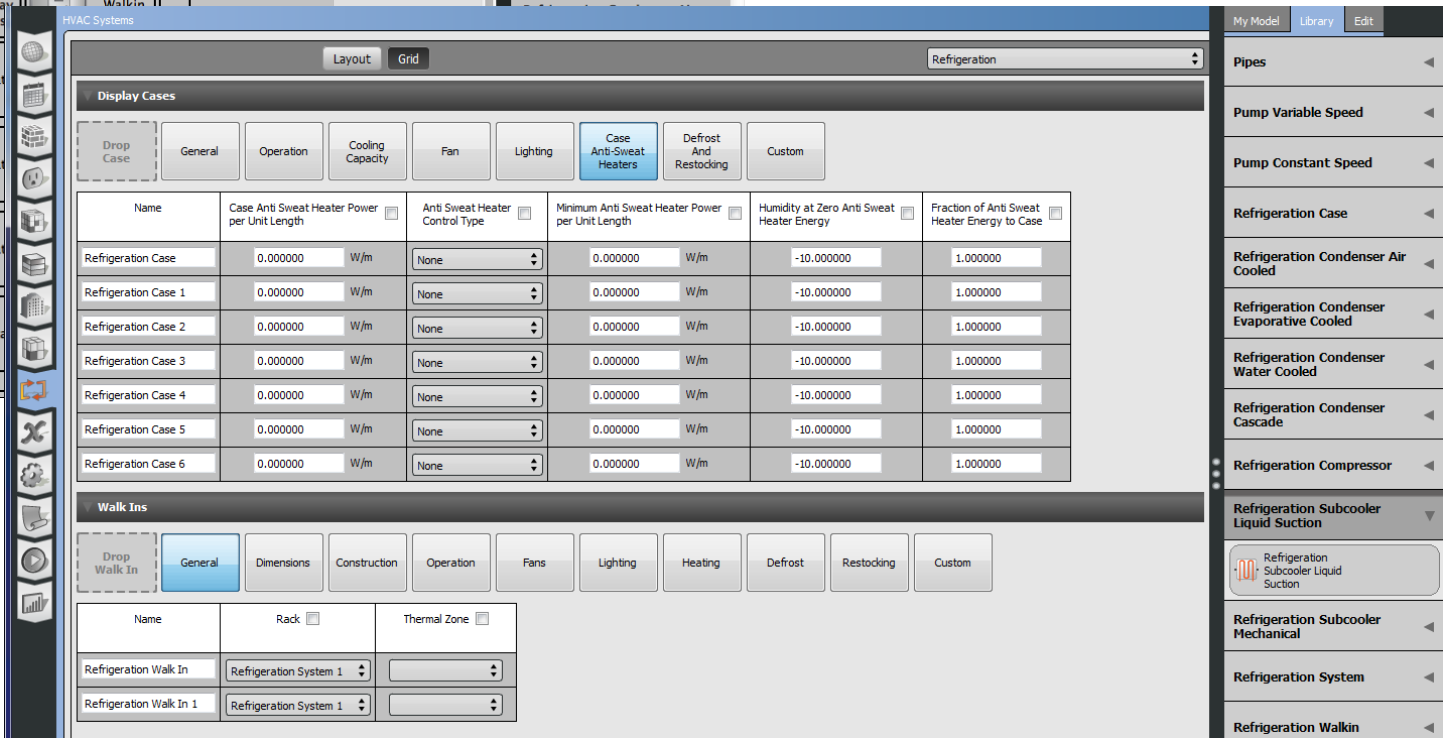
New systems include:

- 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.

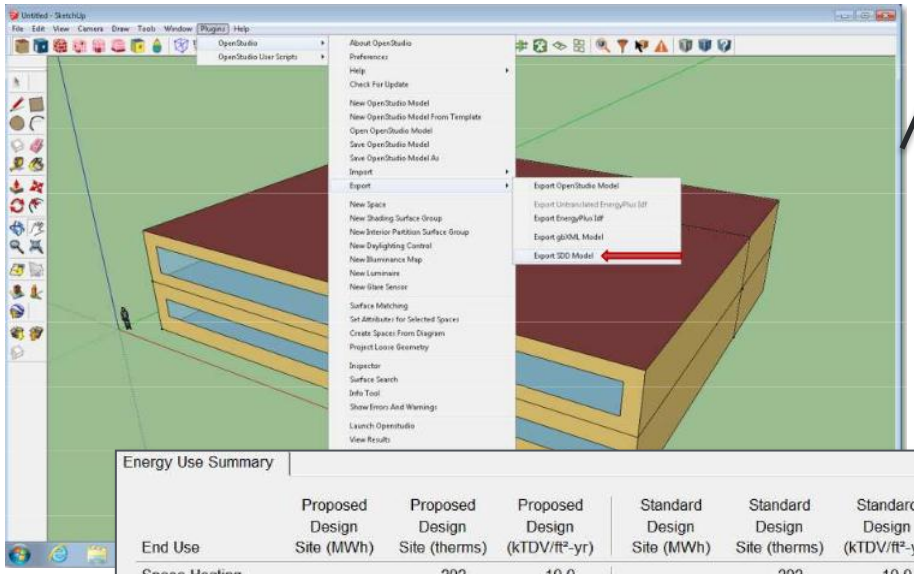


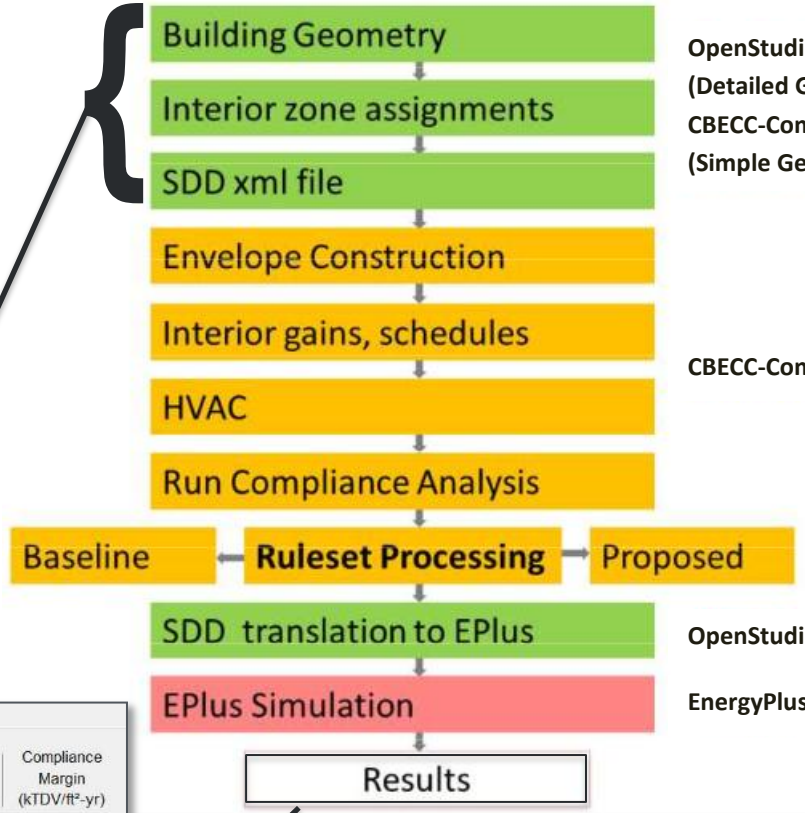


OAK RIDGE

Major Accomplishment – CEC Title 24 Compliance Tool

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





Energy Use Summary

End Use	Proposed Design Site (MWh)	Proposed Design Site (therms)	Proposed Design (kTDV/ft²-yr)	Standard Design Site (MWh)	Standard Design Site (therms)	Standard Design (kTDV/ft²-yr)	Compliance Margin (kTDV/ft²-yr)
Space Heating		292	10.0		292	10.0	
Space Cooling	9.9		71.6	9.9		71.7	0.1
Indoor Fans	19.6		81.0	19.6		81.0	
Heat Rejection							
Pumps & Misc.							
Domestic HW		169	5.0		169	5.0	
Lighting	7.9		35.8	7.9		35.8	
Compliance Total	37.4	461	203.5	37.4	461	203.6	0.2
Receptacle	23.6		109.8	23.6		109.8	Result:
Process							PASS
Process Ltg							
TOTAL	60.9	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

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ARCHITECTURAL ENERGY CORPORATION

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

concept3D Inc. and simuwatt Energy Auditor

concept3D Location. Web. 3D.

NREL NATIONAL RENEWABLE ENERGY LABORATORY

ESTCP

simuwatt Energy Auditor

Building Component Library (BCL)

CRADA

Go to Market Summer 2014

Benefits

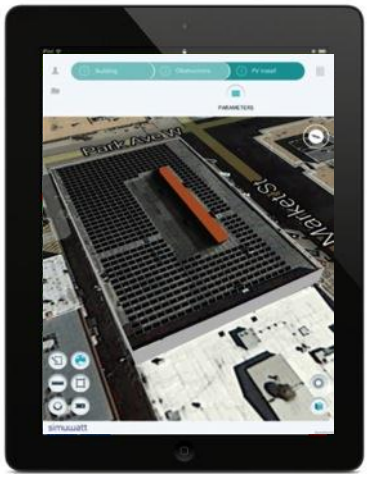
- Streamlined, high quality commercial energy audits (Level II, III)
- Lower the cost of energy audits by 35-75%
- Consistent, standardized and reusable data format
- Access data from the cloud and share projects
- Custom reporting and output
- Asset tracking and building lifecycle tracking
- Opportunity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

simuwatt Cloud and Applications

3rd Party Data

simuwatt
Portfolio Manager
simuwatt
Library

NREL Modeling Engine/Tools



simuwatt
Solar

simuwatt
Auditor

simuwatt Energy Auditor Workflow Overview

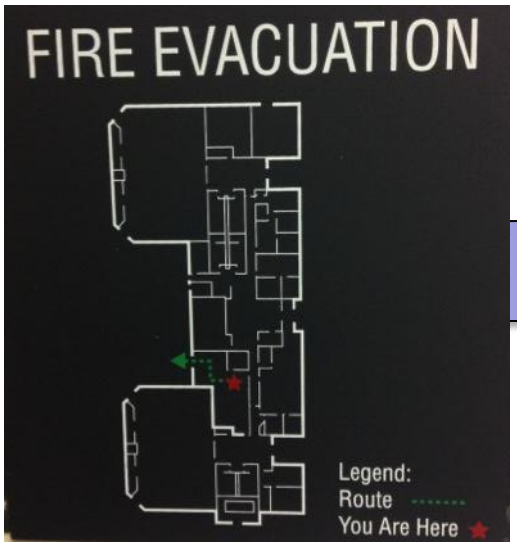


Photo of on-site evacuation plan

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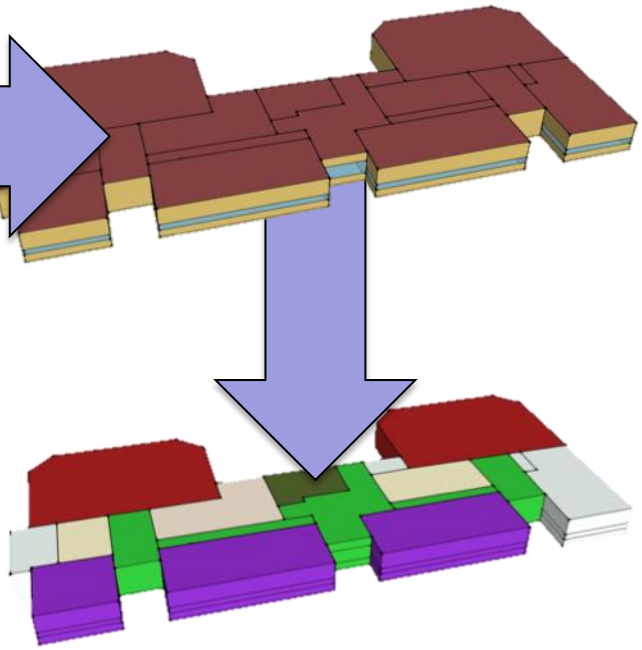
Google Maps satellite imagery

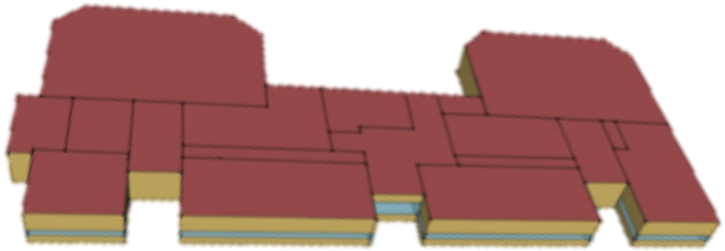


- **OpenStudio automatically generates a detailed energy model ready for simulation**

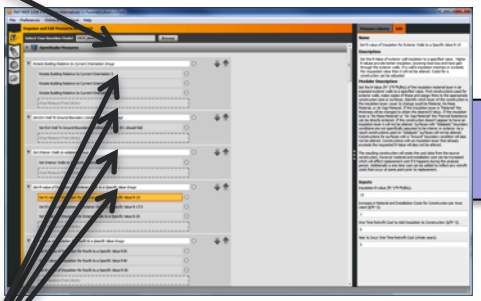
Ft. Jackson Bldg 10400

simuwatt

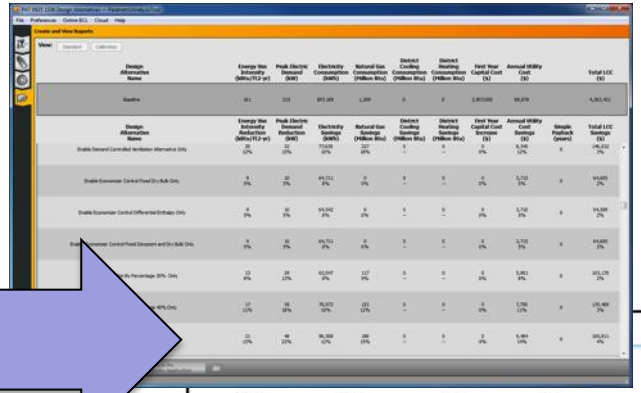
simuwatt Energy Auditor Workflow Overview

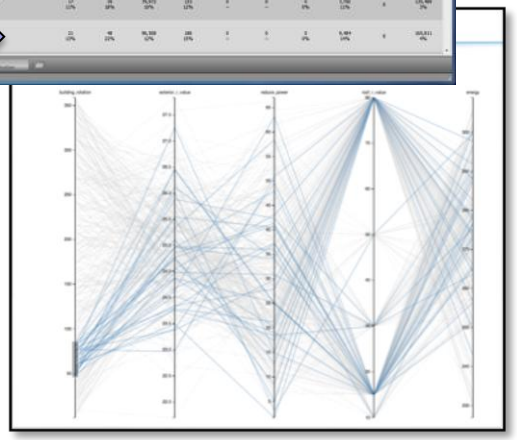


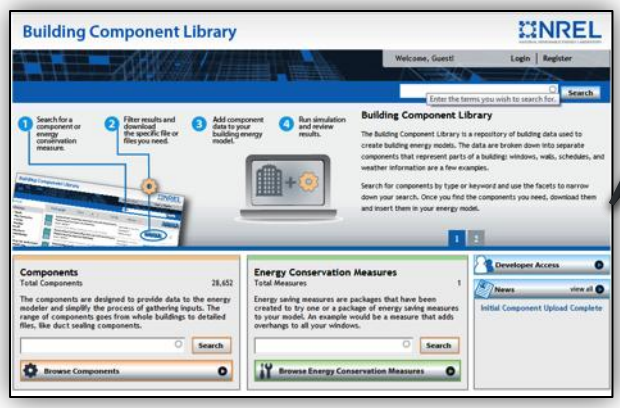
Baseline Model



OpenStudio Parametric Analysis Tool (PAT)







Building Component Library: Online Database of Measures

- **Life cycle analysis identifies most cost-effective measures**

Ft. Jackson Bldg 10400

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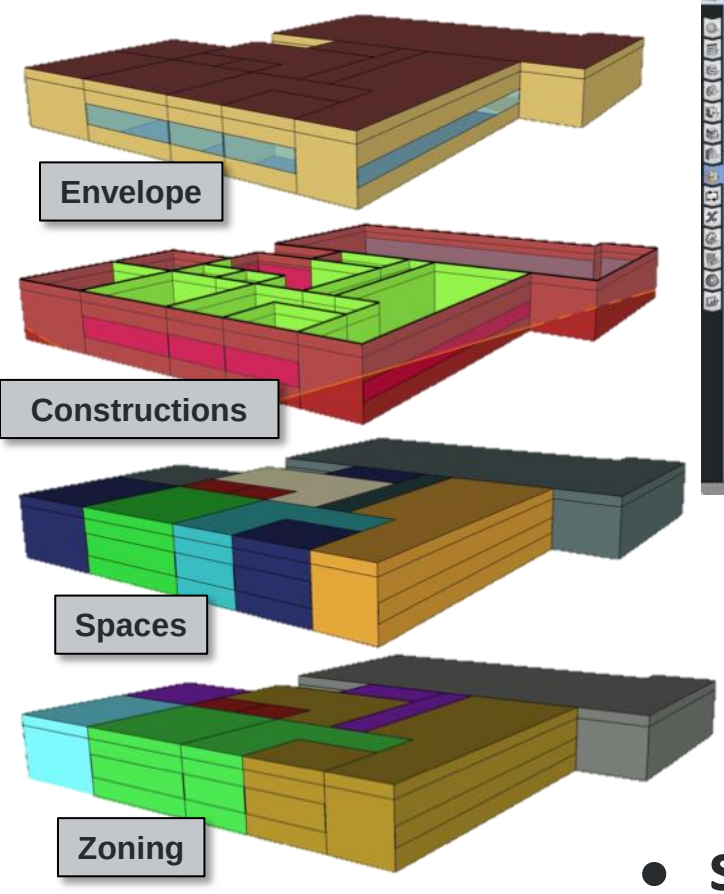

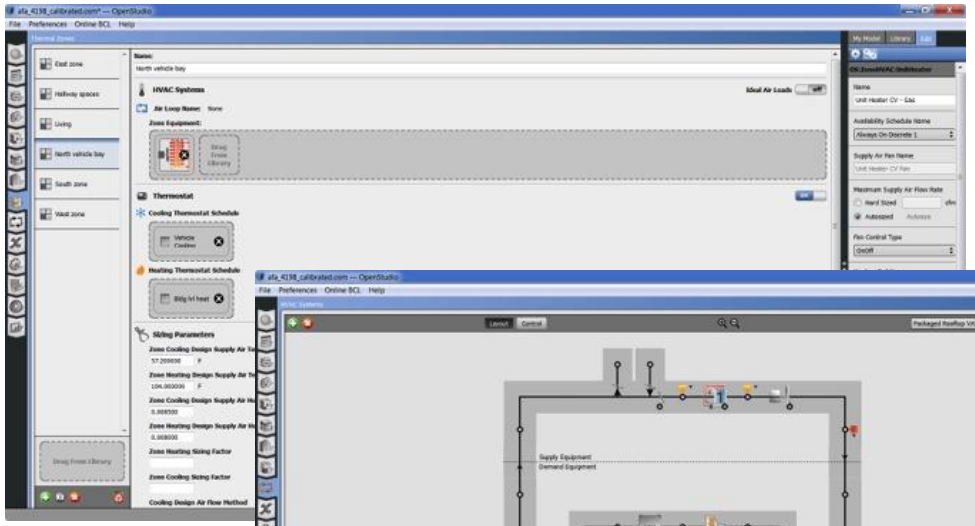

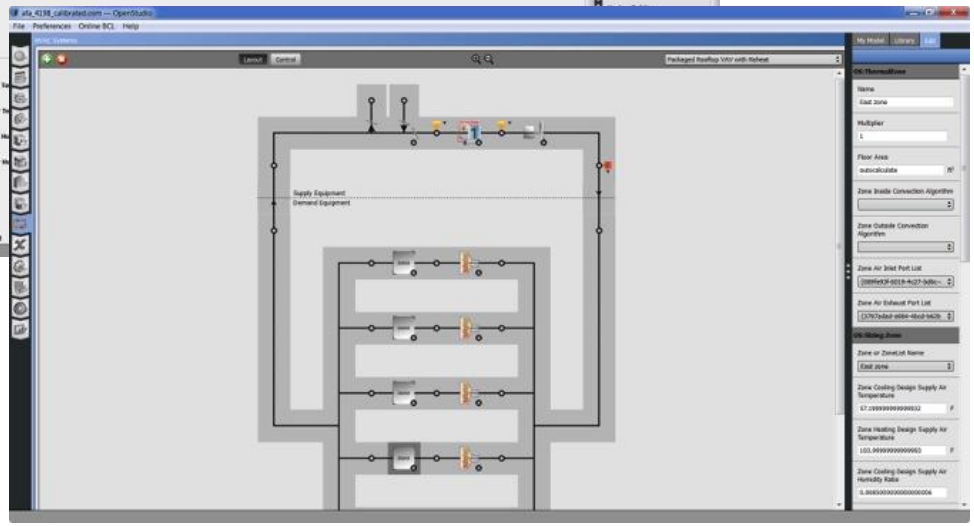

Detailed HVAC system models

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


AFA Bldg 4198

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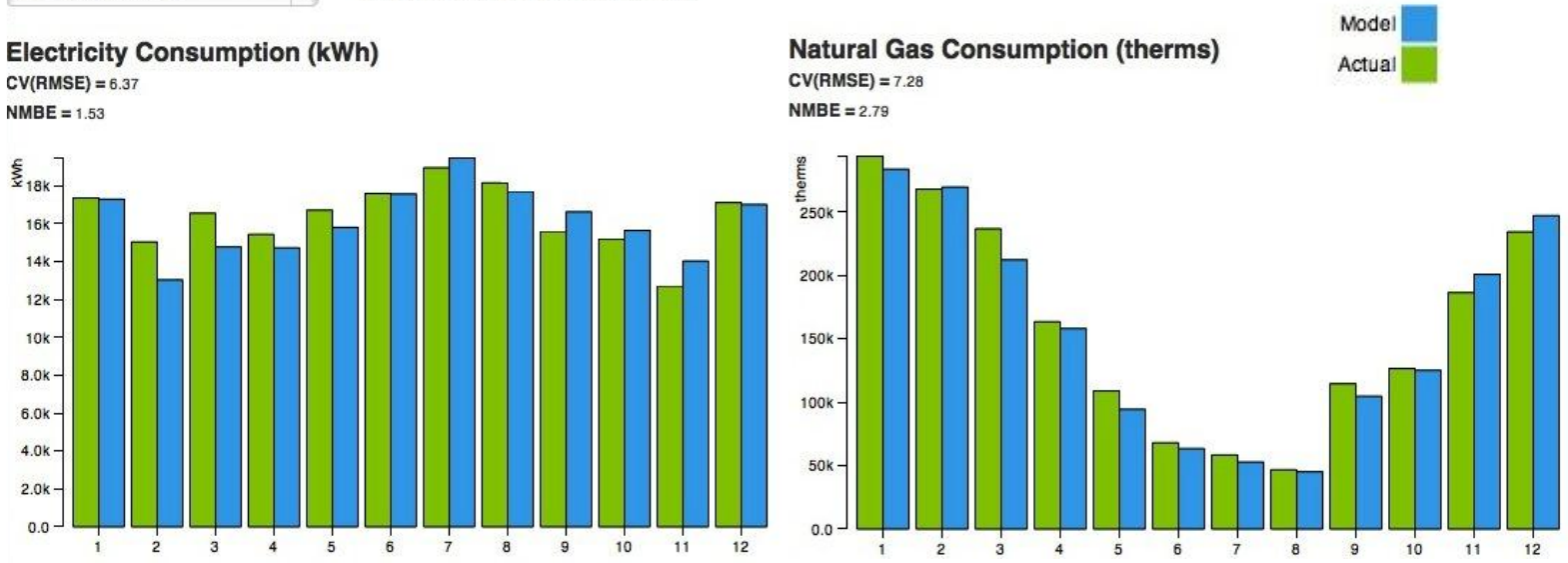
Calibration Method

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)

	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%

- **OpenStudio assists with rapid model calibration**

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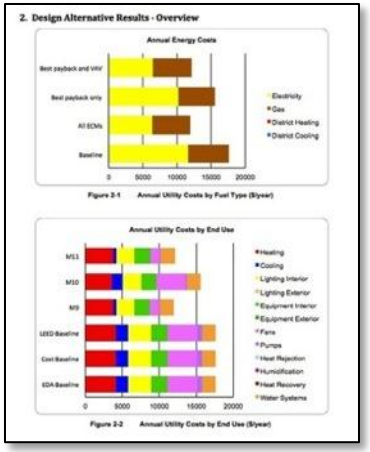
Create and View Reports

View: Standard | Calibration

Design Alternative Name	Energy Use Intensity (kBtu/ft2-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/ft2-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**



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High Demand Across Products – 300+

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Energy Services/ Construction/Real Estate	Solar	Utilities	State/Local/Federal/non-profit

Johnson Controls
NORESCO
Honeywell
TRANE
AMERESCO
Green • Clean • Sustainable
SIEMENS
McKinstry
For The Life Of Your Building
Mortenson construction
Jones Lang LaSalle
WYNDHAM Hotels and Resorts

SolarCity
CIVICSOLAR
STANDARD SOLAR
UMCpower
Simplifying Energy
Johnson Controls
Honeywell
Chevron Energy Solutions
REC SOLAR

Xcel Energy
nationalgrid
Southern California Edison
An EDISON INTERNATIONAL Company
EPRI
Electric Power Research Institute
ComEd
An Exelon Company

NREL
National Renewable Energy Laboratory
Department of Defense
Department of Energy
Public Utilities Commission, Eureka, State of California
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!

Dr. Brian Ball (NREL)

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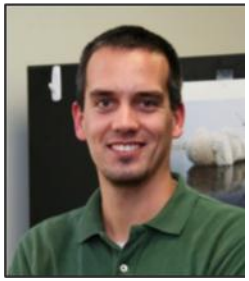
Andrew Parker (NREL)

Marjorie Schott (NREL)

Alex Swindler (NREL)

Evan Weaver (NREL)

Jason Turner (Empty Crate Software)



Mark Adams (ORNL)

Xia Fang (Group 14)

Dr. Ralph Muehleisen (ANL)

Brian Craig (ANL)

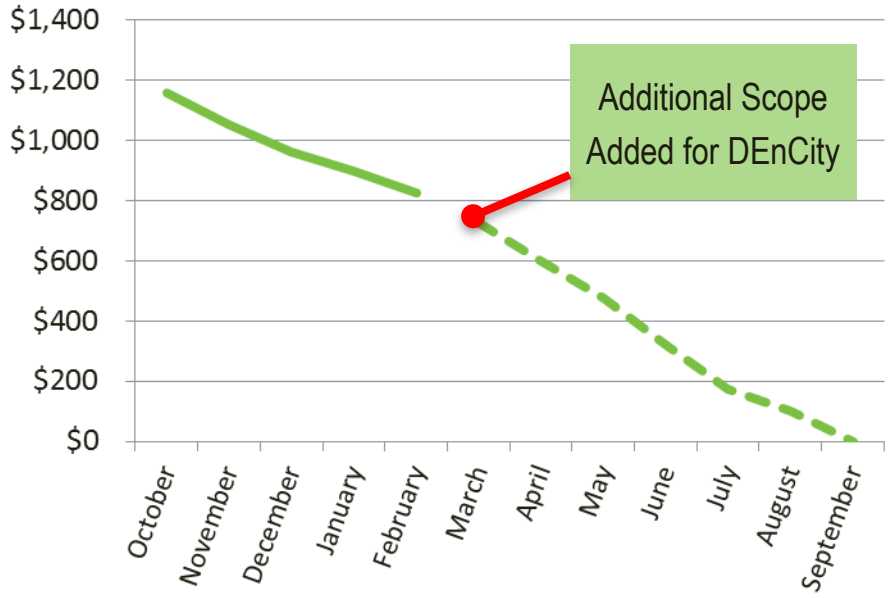
Dr. Jason DeGraw (PSU)

Phylroy Lopez (NRCan)

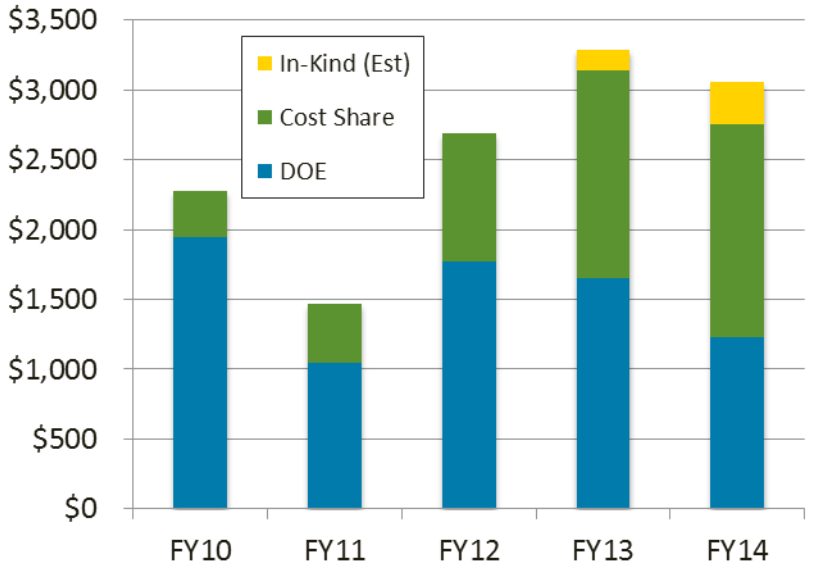
REFERENCE SLIDES

Project Budget

FY14 Spend* ($k)



FY10-14 Budgets* ($k)



Additional Funding Sources:

ESTCP

Xcel Energy

nationalgrid

ARCHITECTURAL ENERGY CORPORATION

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

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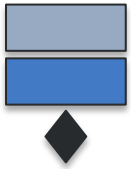
Project Plan and Schedule

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



	FY2012				FY2013				FY2014			
	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)
Project Name: OpenStudio Core												
Q1 Milestone: OpenStudio 0.6 Released (Initial BCL Integration with OpenStudio)	◆											
Q2 Milestone: OpenStudio 0.7 Released (First Version of OpenStudio App with BCL Integration)		◆										
Q3 Milestone: OpenStudio 0.8 Released (App Suite Workflow Improvements and DEnCity)			◆									
Q4 Milestone: OpenStudio 0.9 Released (BIM Interop and Initial Support for BCL Measures)				◆								
Q1 Milestone: OpenStudio 0.10 Released (Sim Settings Tab and Backend Work for PAT)					◆							
Q2 Milestone: OpenStudio 0.11 Released (Initial Version of PAT and BCL UGC)						◆						
Q3 Milestone: OpenStudio 1.0 Released (PAT Economics and Measures)							◆					
Q4 Milestone: OpenStudio 1.1 Released (Cloud Support and additional Measures)								◆				
Q1 Milestone: OpenStudio 1.2 Released (Commercial Refrigeration Systems)									◆			
Q2 Milestone: OpenStudio 1.3 Released (HVAC, Refrigeration, and OS Server Improvements)										◆		
Q3 Milestone: OpenStudio 1.4 Released (OS Server Workflow and HVAC Improvements)											◆	
Q4 Milestone: OpenStudio 1.5 Released (HVAC and Performance Improvements, DEnCity Development)												◆