

BTO Program Peer Review



Energy Efficiency &
Renewable Energy



OpenStudio

TDM – Amir Roth (OpenStudio/BCL Core)

TDM – Joan Glickman (Asset Score Tool)

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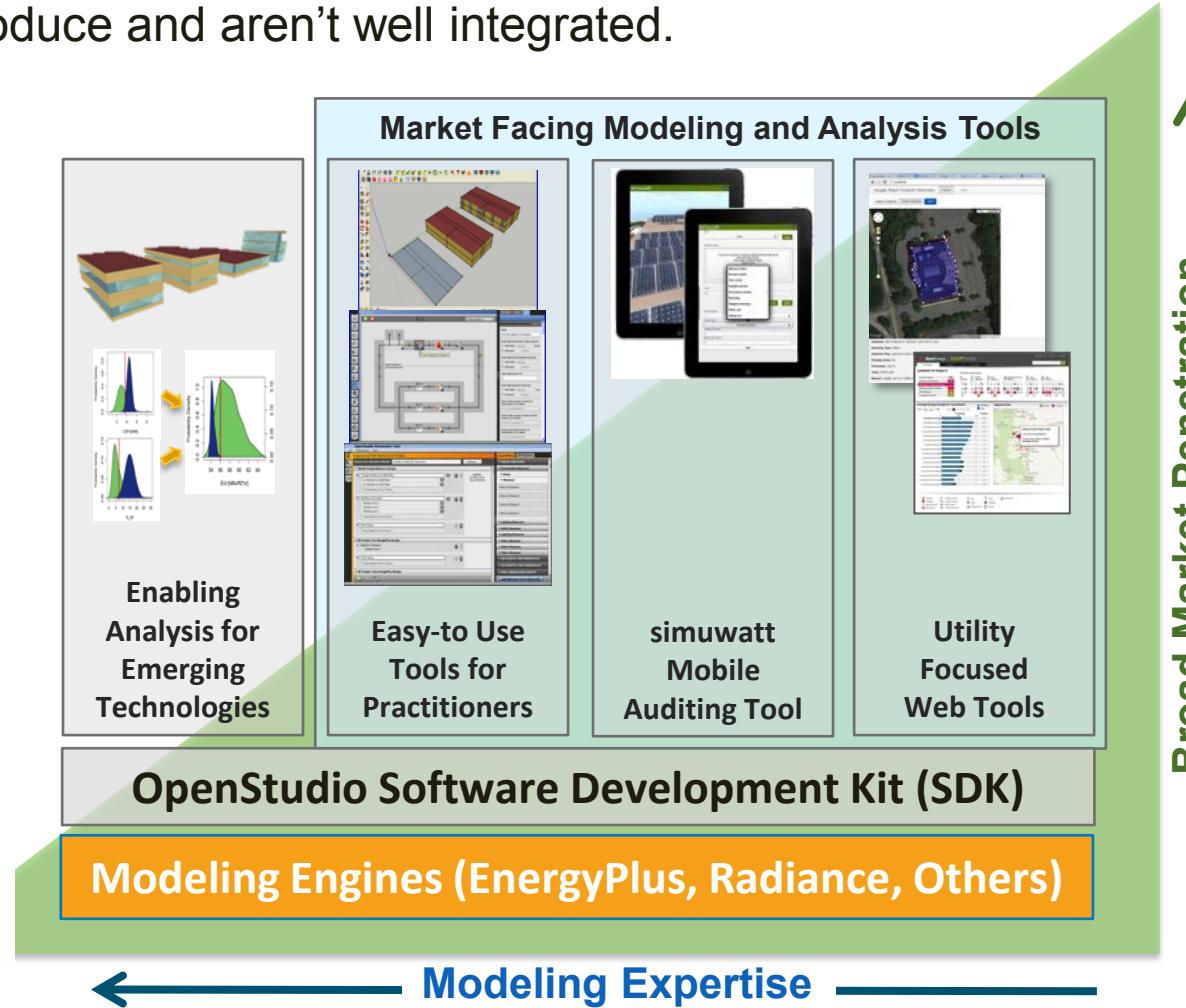
April 2nd 2013

Purpose & Objectives

Problem: Building energy analysis has historically been costly and produces uncertain results depending upon practitioner skill and available input data. New tools are expensive to produce and aren't well integrated.

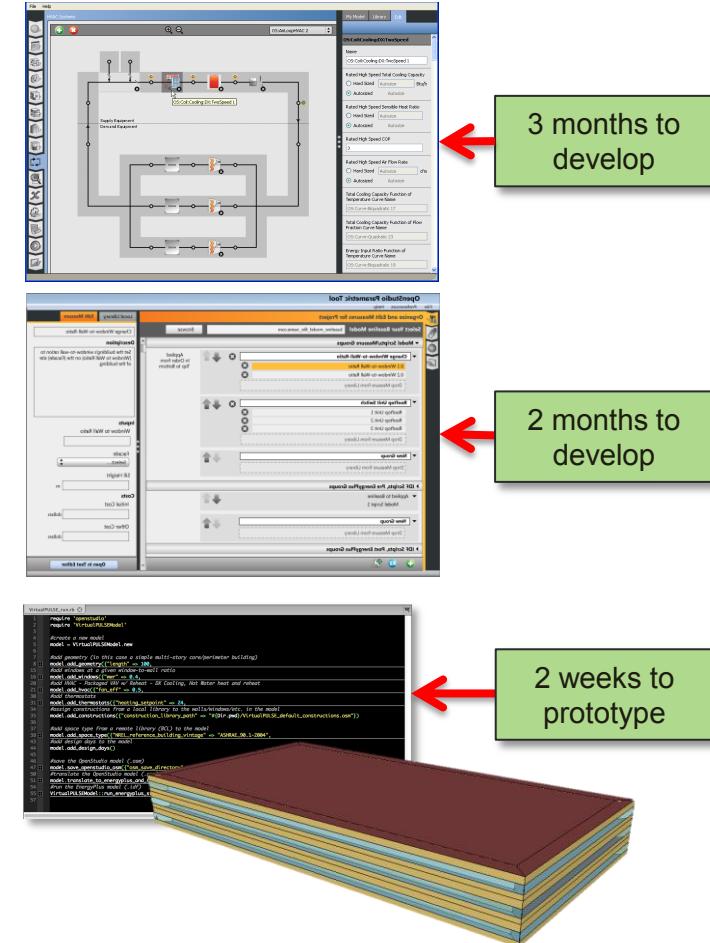
Impacts: OpenStudio is DOE's platform for rapid, collaborative development of energy analysis applications. It is being used by the labs, EEB, the private sector, and others to create market facing tools.

Project Focus: The project cross cuts ET and CBI to spur adoption of new and existing EE technologies by making tools available to a wide range of decision makers.



Approach:

- **Rapid application development:**
 - Cross platform, multi-language support
 - Easy to write web apps for energy modeling
 - Maximum code reuse for low cost
 - Highly efficient, automated model construction
- **Open Source:**
 - Why reinvent the wheel?
 - Remove barriers for adoption
 - OpenStudio is creating a community
- **Interoperability:**
 - Multiple simulation engines
 - BIM (gbXML, IFC)
 - Title 24 compliance engine (SDD)
 - Sandia's DAKOTA Library for analysis



Key Issues:

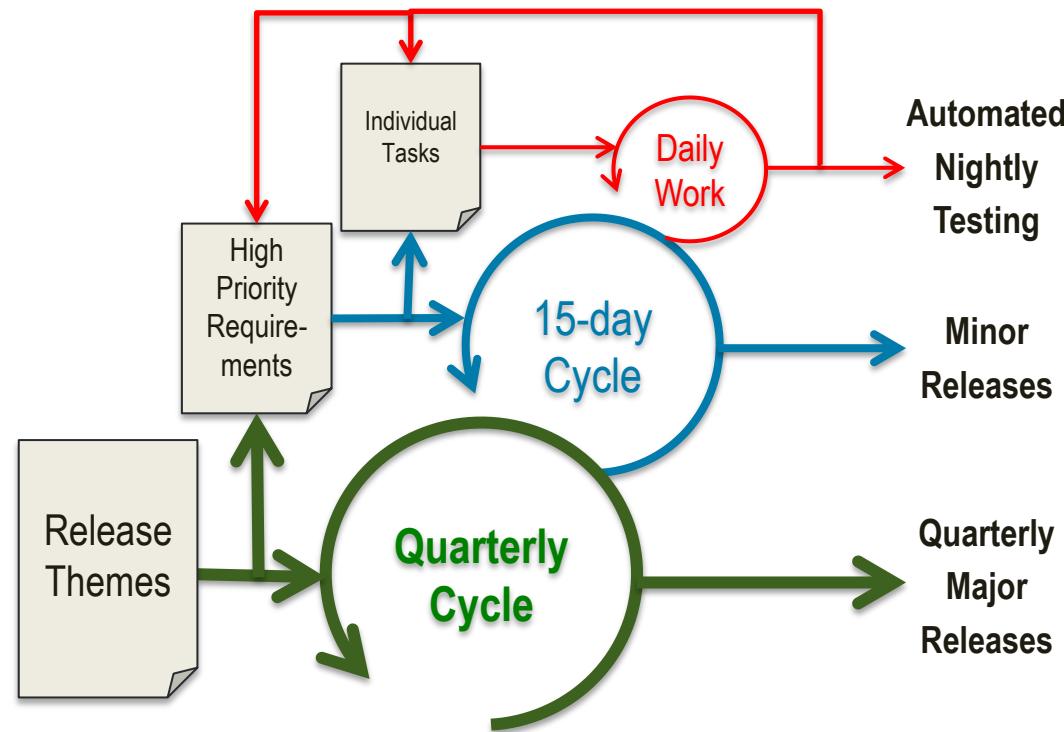
- Full coverage of all EnergyPlus objects still in progress – a moving target
- Need modularized build process for lighter apps that don't require everything in OpenStudio
- Heavy adoption is putting additional pressure on team for user and developer support

Approach:

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

Distinctive Characteristics:

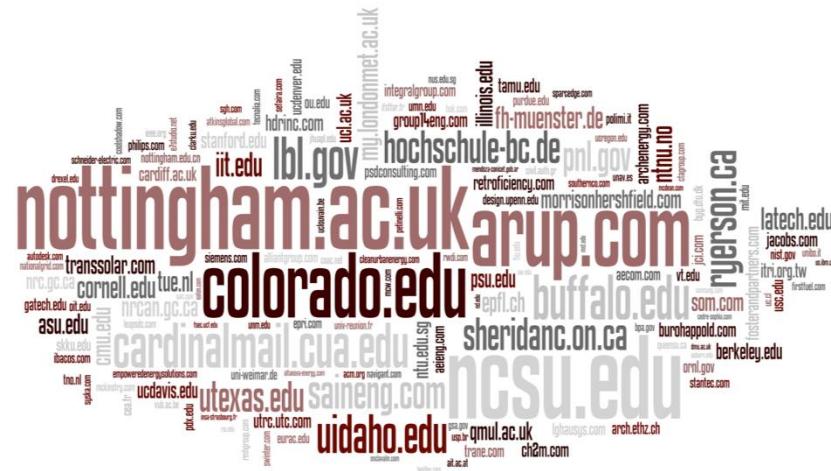
- Flexibility to **quickly** produce new desktop, mobile, and web tools that are easily **integrated** with one another
- **Agile process** allows focus to change as new requirements emerge
- Rigorous approach to creating software for the marketplace - **not a research project**
- Open, collaborative approach to software development that welcomes partners from other labs, institutions, and the private sector.



Accomplishments and Progress

Accomplishments:

- **Substantial adoption of OpenStudio**
 - Practitioners
 - Researchers
 - Software developers
 - Utilities
 - **Significant new capability for:**
 - Rapid desktop, mobile or web application development
 - Efficient automated model generation (Short script → 1000s of .idf lines)
 - Extensive tool, model, and data interoperability
 - Parametric analysis and extensible measures formalism



Progress on Goals:

- **Continued to meet aggressive quarterly release schedule**
 - **On-track to meet key deliverables related to**
 - OpenStudio-based parametric analysis
 - User generated (crowd-sourced) content for Building Component Library (BCL)
 - Private sector stakeholders

OpenStudio Partners (Partial List)



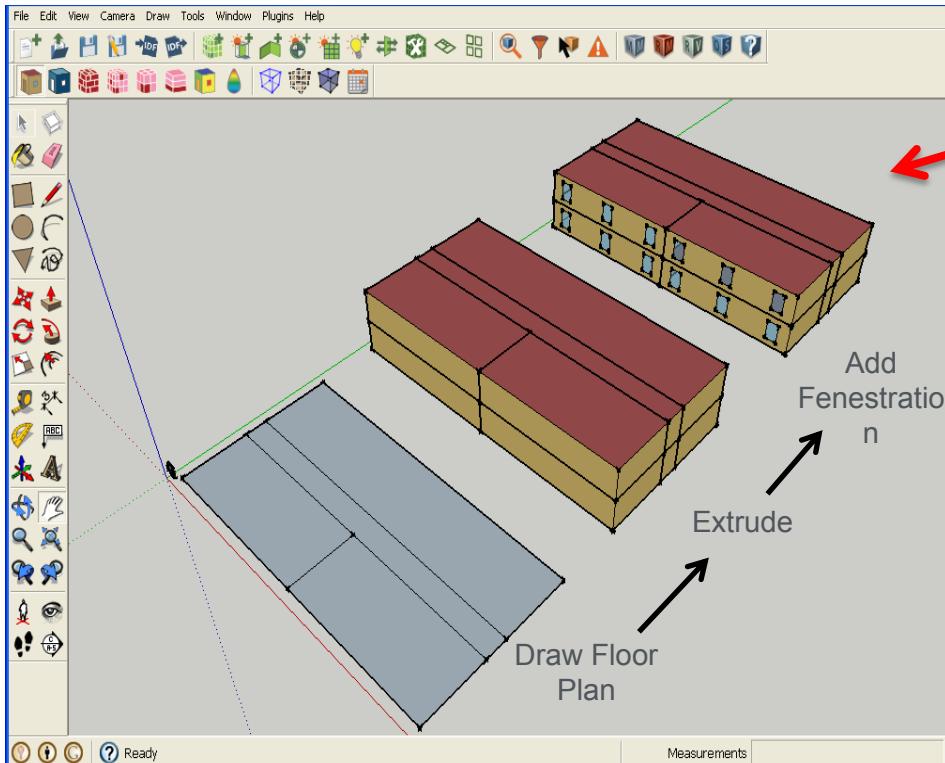
Natural Resources Canada Ressources naturelles Canada



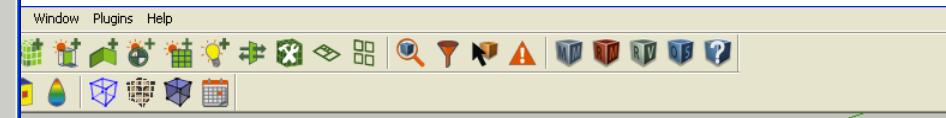
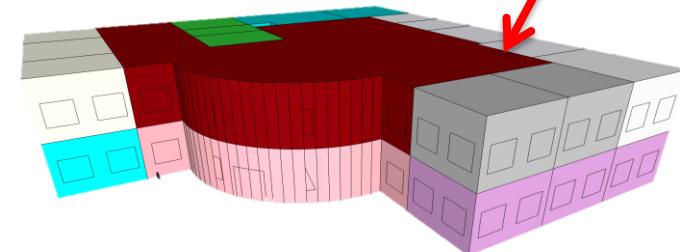
The OpenStudio Tool Suite – An OpenStudio SDK Sample Application

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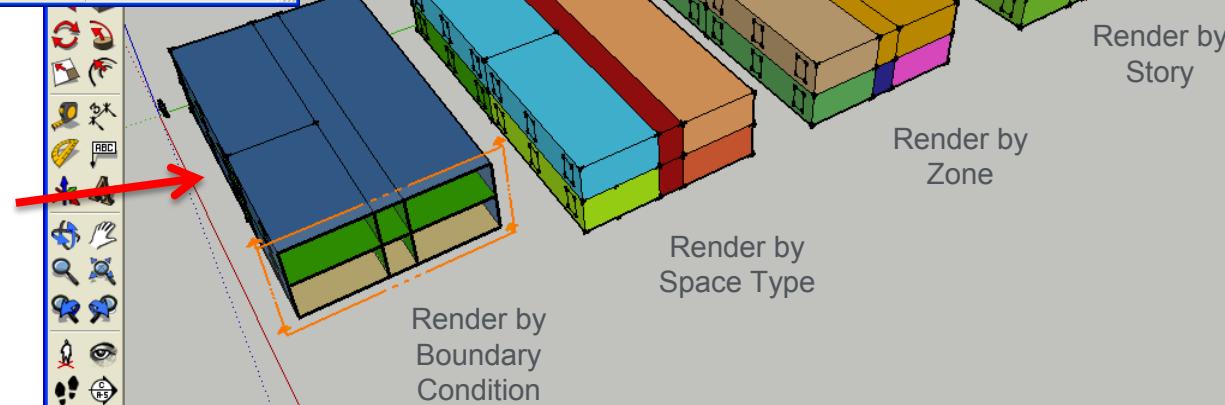
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Draw envelope in minutes using SketchUp, or import from BIM



Quickly assign constructions, loads, and schedules via templates and specify zones



Render by Boundary Condition

Render by Zone

Render by Story

Render by Story

Simple Workflows and Modern Software Paradigms with the OpenStudio Suite

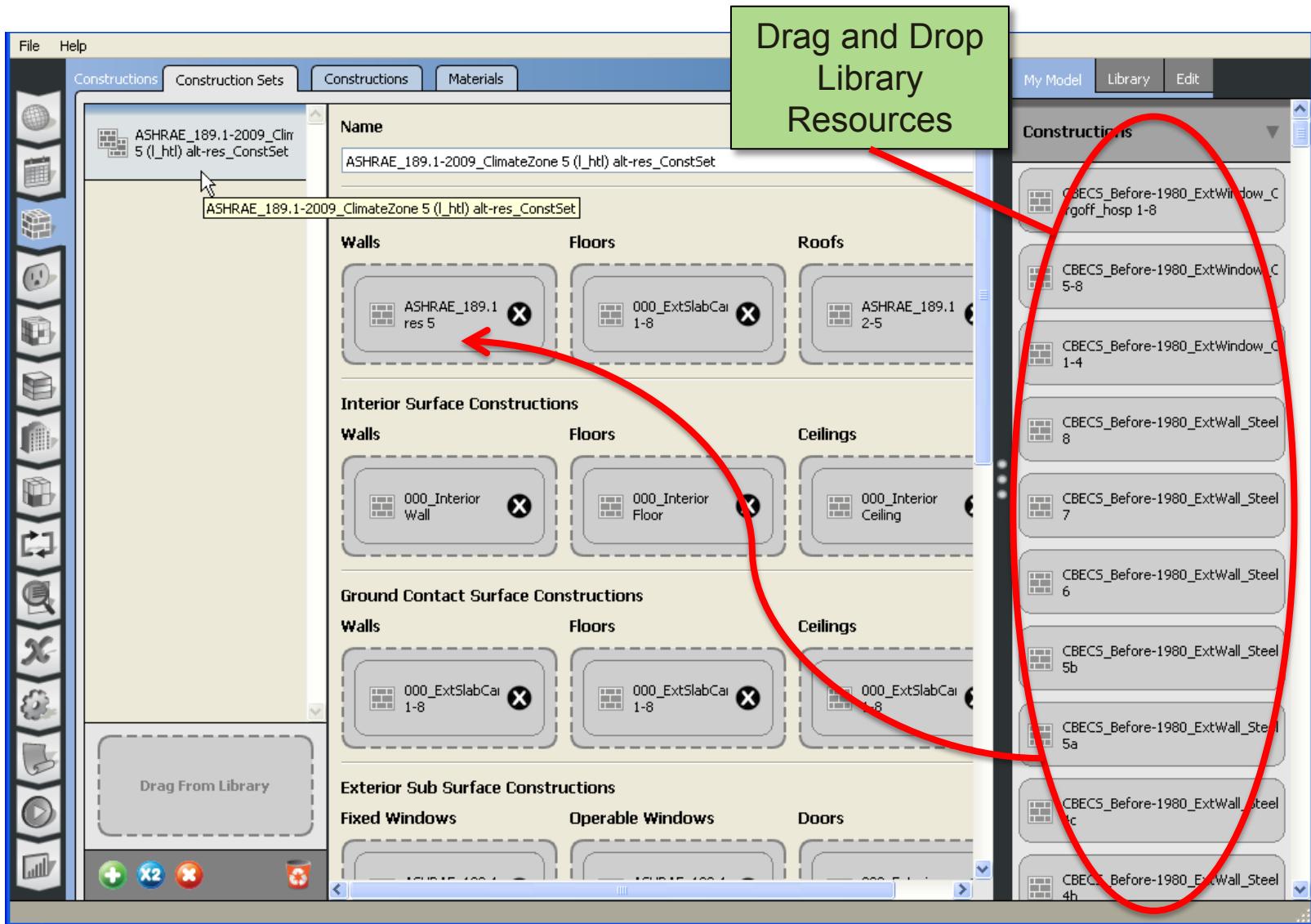
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Define
Resources

Workflow

Review
Results



Selecting Templated HVAC Systems with the OpenStudio Suite

File Help

HVAC Systems

1. Pick a System
2. Add Your Zones
3. Done

Supply Equipment
Demand Equipment

OpenStudio

HVAC Systems

Packaged DX Rooftop VAV with Reheat

Add to Model

Packaged Rooftop VAV with Parallel Fan Power Boxes and reheat

Add to Model

Packaged Rooftop VAV with Reheat

Add to Model

My Model Library Edit

OS:Node

Name OS:Node 13

OS:SetpointManager:SingleZone:Reheat

Name OS:SetpointManager:SingleZone:Reheat 1

Minimum Supply Air Temperature -99 F

Maximum Supply Air Temperature 99 F

Control Zone Name OS:ThermalZone 4

Drag and Drop HVAC Systems for Advanced Users

File Help

HVAC Systems

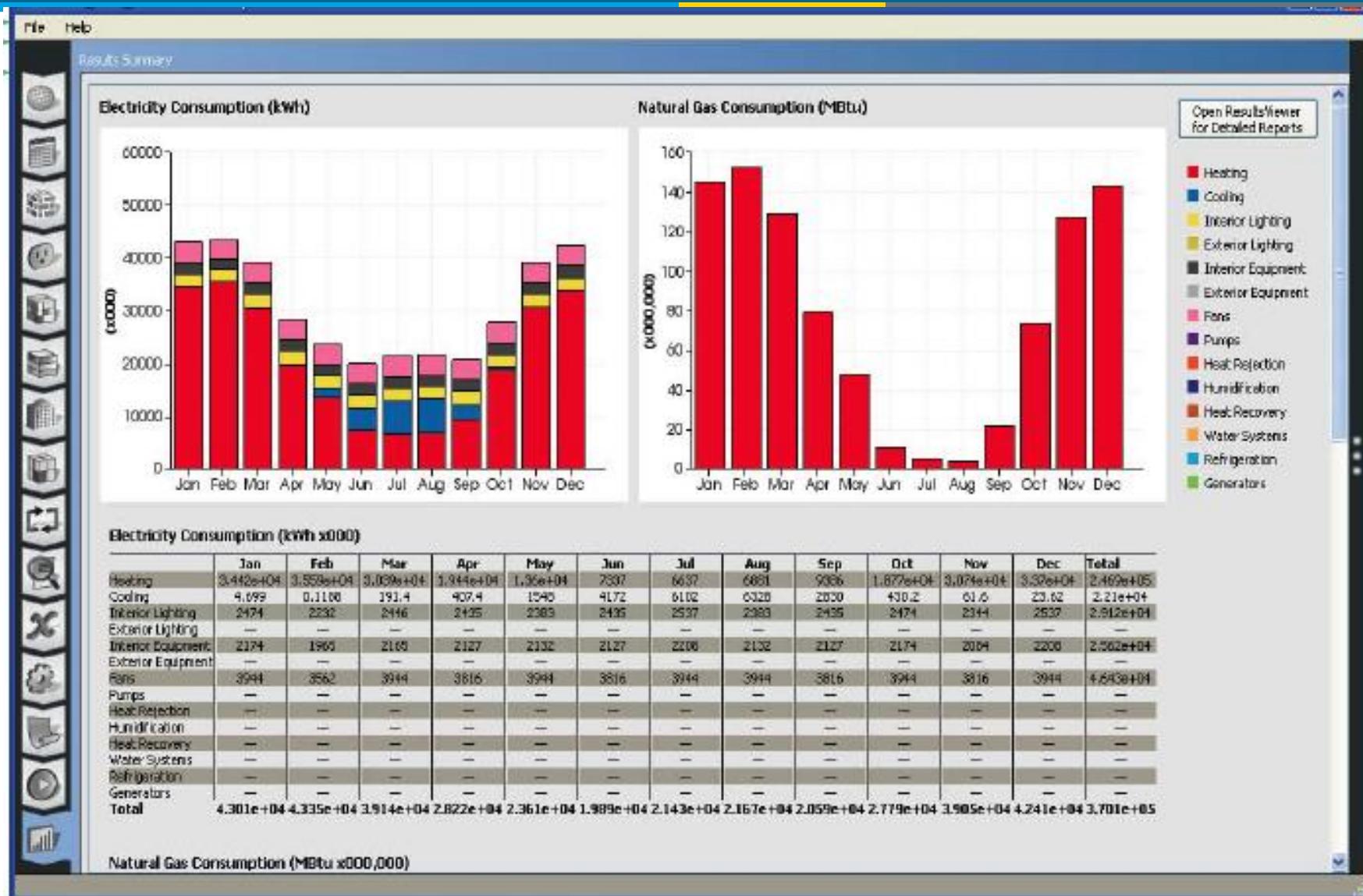
OS:AirLoopHVAC 2

...or customize your own

The screenshot shows a HVAC system design software interface. On the left is a vertical toolbar with icons for various tools. The main workspace displays a schematic of an air loop. At the top, there are buttons for adding (+) and removing (-) components, and search/magnifying glass icons. A dropdown menu shows "OS:AirLoopHVAC 2". In the center, a green box contains the text "...or customize your own". The schematic shows a supply air duct with two diffusers at the top, connected to a central coil component labeled "OS:Coil:Cooling:DX:TwoSpeed 1". This coil is connected to a return air duct with a filter and a damper. Below the main duct, there are three parallel branch ducts, each containing a coil and a damper, labeled "ZONE". The right side of the interface features a panel titled "OS:Coil:Cooling:DX:TwoSpeed" with several configuration fields:

- Name: OS:Coil:Cooling:DX:TwoSpeed 1
- Rated High Speed Total Cooling Capacity:
 - Hard Sized: Autosize Btu/h
 - Autosized: Autosize
- Rated High Speed Sensible Heat Ratio:
 - Hard Sized: Autosize
 - Autosized: Autosize
- Rated High Speed COP: 3
- Rated High Speed Air Flow Rate:
 - Hard Sized: Autosize cfm
 - Autosized: Autosize
- Total Cooling Capacity Function of Temperature Curve Name: OS:Curve:Biquadratic 17
- Total Cooling Capacity Function of Flow Fraction Curve Name: OS:Curve:Quadratic 23
- Energy Input Ratio Function of Temperature Curve Name: OS:Curve:Biquadratic 18

High Level Simulation Results Summaries with the OpenStudio Suite



Credit: David Goldwasser / NREL

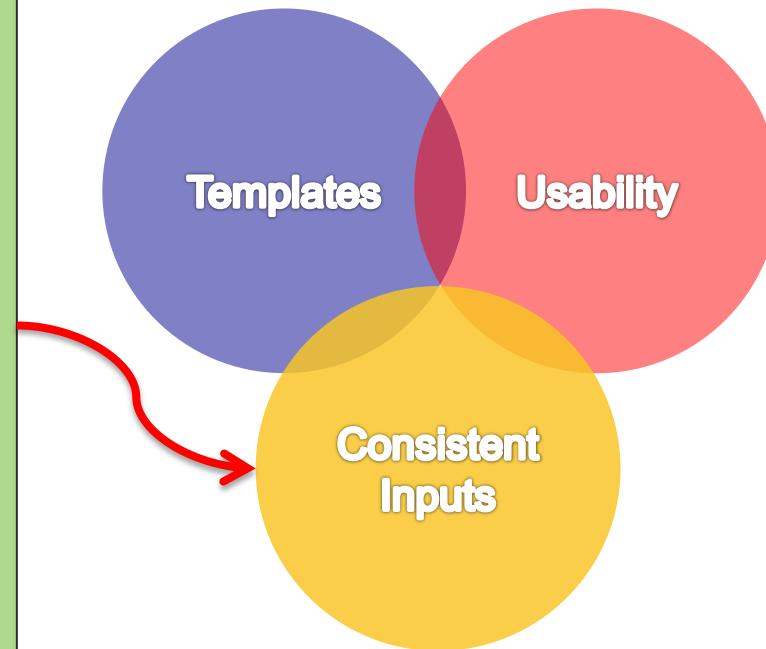
eere.energy.gov

How Do We Improve Input Data Quality for OpenStudio-Based Tools?

- Input data remains a serious issue for modelers
- Garbage In = Garbage Out → Quality In = Quality Out
- **Solution:** Standardize input data and seamlessly link to OpenStudio-based tools

An Internet-connected source of building energy modeling data:

- Enables drag-and-drop modeling for **quick** technology evaluation
- Provides **consistent**, detailed inputs to drive decision-making
- **Searchable** readily available within applications
- **Crowd sourced** content leverages sector knowledge



Fast, Low-Cost, Reliable Energy Modeling Outcomes

The Building Component Library (BCL)

• Components:

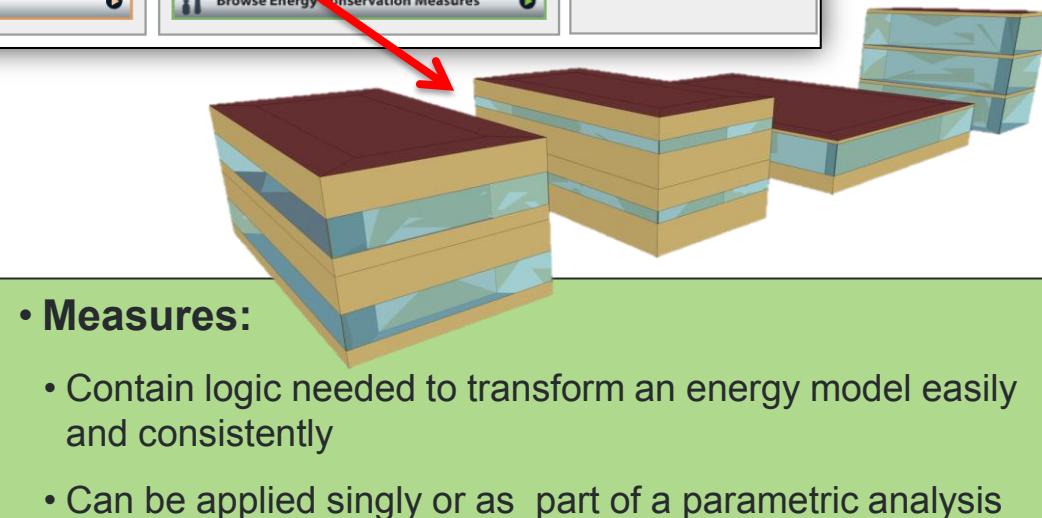
- Assembled to form complete energy models
- Include constructions, lights, schedules, weather data, PV modules, and more
- Supports faceted searching from web site or API

The screenshot shows the main interface of the Building Component Library. At the top, there's a navigation bar with 'Welcome, Guest!', 'Login', 'Register', and a search bar. Below the header, there's a large graphic illustrating the workflow: 1. Search for a component or energy conservation measure, 2. Filter results and download the specific file or files you need, 3. Add component data to your building energy model, and 4. Run simulation and review results. To the right of this graphic is a section titled 'Building Component Library' which describes it as a repository for building data used to create building energy models. Below this are two main search categories: 'Components' (Total Components: 28,652) and 'Energy Conservation Measures' (Total Measures: 1). Each category has a 'Search' button and a 'Browse' link.

This screenshot shows a detailed view of a specific component: 'ASHRAE 90.1 Constructions Exterior Wall Steel-Framed NR'. It includes a thumbnail image of the wall construction, a 'Attributes' table, a 'Source' section, and a 'Files' section. The 'Attributes' table contains the following data:

	SI Units
Standard	ASHRAE 90.1 Constructions
Construction	Exterior Wall
Construction type	Steel-Framed
Effective r-value	0.4421 ft ² F/h/Btu
Insulation minimum r-value	R ft ² F/h/Btu
Film coefficients	false
OpenStudio Type	OS:Construction

The 'Source' section lists 'EnergyPlus 7.0.0.036' and 'OpenStudio 0.7.0'. The 'Files' section lists three files: 'ASHRAE 90.1 Constructions_Exterior Wall_Steel-Framed_NR_v7.0.0.036.idf', 'ASHRAE 90.1 Constructions_Exterior Wall_Steel-Framed_NR_v0.7.0.osm', and 'ASHRAE 90.1 Constructions_Exterior Wall_Steel-Framed_NR_v0.7.0.osc'. A red arrow points from this detail page to a 3D model of a building wall section shown below.



The New OpenStudio Parametric Analysis Tool

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The screenshot shows the OpenStudio Parametric Tool interface with three main panels:

- Organize and Edit Measures for Project:** This panel allows users to select a baseline model and manage measure groups. A red arrow points from the 'Change Window-to-Wall-Ratio' group to a callout box.
- Create and View Reports:** This panel includes a 'Select Report Type' dropdown and a 'OpenStudio High-level Comparison' section. A red arrow points from the comparison table to another callout box.
- OpenStudio High-level Comparison:** This panel displays energy performance metrics for various alternative models. A red arrow points from the table to a third callout box.

Callout Boxes (Annotations):

- Select measures from BCL and apply them to your baseline model** (Associated with the 'Organize and Edit Measures for Project' panel)
- Inspect measures applied to specific alternative models** (Associated with the 'OpenStudio High-level Comparison' panel)
- Compare energy performance, cost reduction, and paybacks** (Associated with the 'OpenStudio High-level Comparison' panel)
- As we will discuss, results are exported for other purposes** (Associated with the 'Create and View Reports' panel)

OpenStudio High-level Comparison Data (Table):

Name	Measures Applied	Annual Energy Cost Reduction (\$)	Annual Electricity Use Reduction (kWh)	Annual Electricity Peak Demand Reduction (kW)	Annual Natural Gas Usage Reduction (Therms)	Site EUI Reduction (kBtu/ft ² *yr)
alternative1_file ...	M1.2-0.2 WWR on North Facade	\$5,000	5%	\$15,000	3%	9
alternative2_file ...	M1.3-0.3 WWR on North Facade	\$4,000	4%	\$10,000	2%	6
alternative3_file ...	M1.4-0.4 WWR on North Facade					
	M1.4-0.4 WWR on North Facade					
alternative3_file ...	M2.4-0.4 Other Measure Name					
	M3.2-0.4 Other Measure Name					
alternative3_file ...	M1.4-0.4 WWR on North Facade					
	M3.2-0.4 Other Measure Name					

EEB and the DOE Asset Score Tool Use OpenStudio Scripted Models for Web Apps

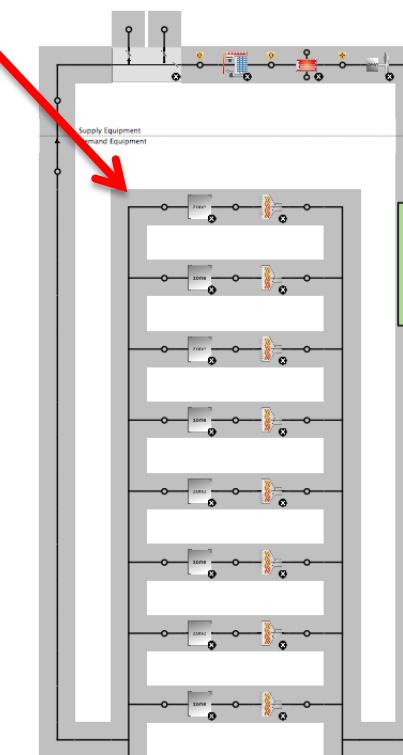
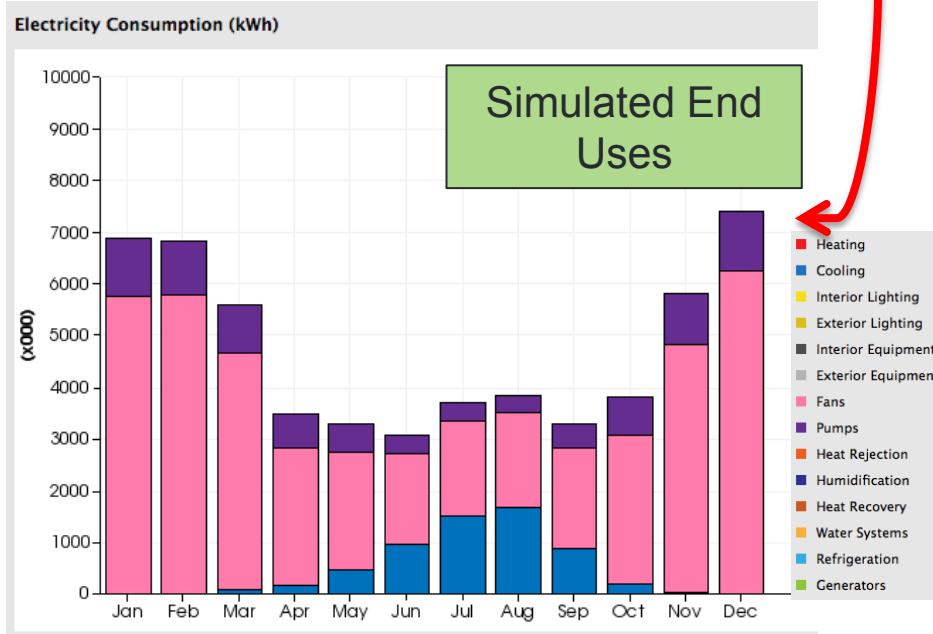
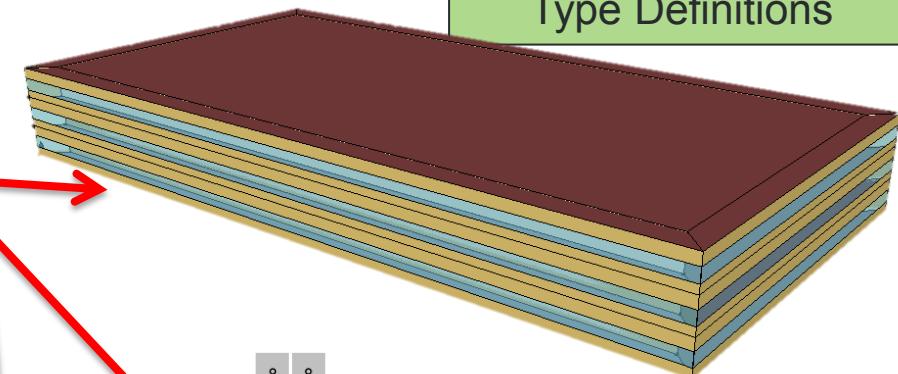


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```
VirtualPULSE_run.rb
1 require 'openstudio'
2 require 'VirtualPULSEModel'
3
4 #create a new model
5 model = VirtualPULSEModel.new
6
7 #add geometry (in this case a simple multi-story core/perimeter building)
8 model.add_geometry({ "length" => 100,
9                      "width" => 50,
10                     "height" => 30 })
11 #add windows at a given window-to-wall ratio
12 model.add_windows({ "wwr" => 0.4,
13                      "area" => 1000 })
14 #add HVAC - Packaged VAV w/ Reheat - DX Cooling, Hot Water heat and cool
15 model.add_hvac({ "fan_eff" => 0.5,
16                      "heat_rejection_eff" => 0.75,
17                      "heat_recovery_eff" => 0.85 })
18 #add thermostats
19 model.add_thermostats({ "heating_setpoint" => 24,
20                      "cooling_setpoint" => 75 })
21 #assign constructions from a local library to the windows/doors in the model
22 model.add_constructions({ "construction_library_path" => "#Dir\VirtualPULSE_default_constructions.osm" })
23
24 #add space type from a remote library to the model
25 model.add_space_type({ "NREL_reference_building_virtua" => "ASHRAE_90.1-2004" })
26
27 #add design days to the model
28 model.add_design_days()
29
30 #save the OpenStudio model (.osm)
31 model.save_openstudio_osm({ "osm_save_directory" => Dir.pwd,
32                      "model" => model })
33 #translate the OpenStudio model (.osm) to an EnergyPlus model (.idf)
34 model.translate_to_energyplus_and_save_idf({ "idf_save_directory" => Dir.pwd,
35                      "model" => model })
36 #run the EnergyPlus model (.idf)
37 VirtualPULSEModel.run_energyplus_simulation({ "idf_directory" => Dir.pwd,
38                      "model" => model })
```

13 Lines of Ruby Code + Comments

Geometry and Space Type Definitions



Detailed HVAC and Zoning



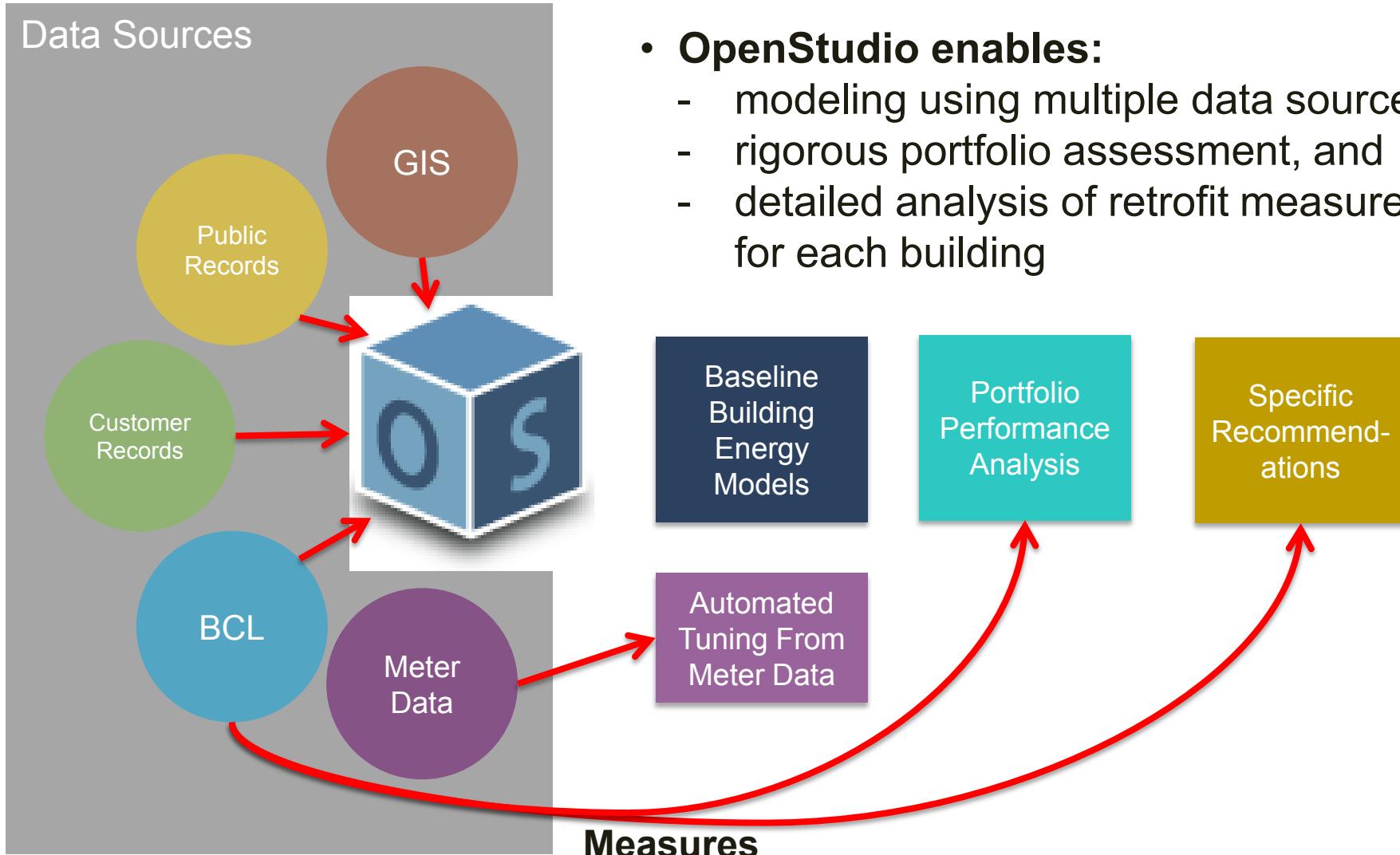
Pacific Northwest
NATIONAL
LABORATORY

eebHUB
Energy Efficient Buildings Hub

National Grid is Using OpenStudio to Automate Modeling from Mined Data



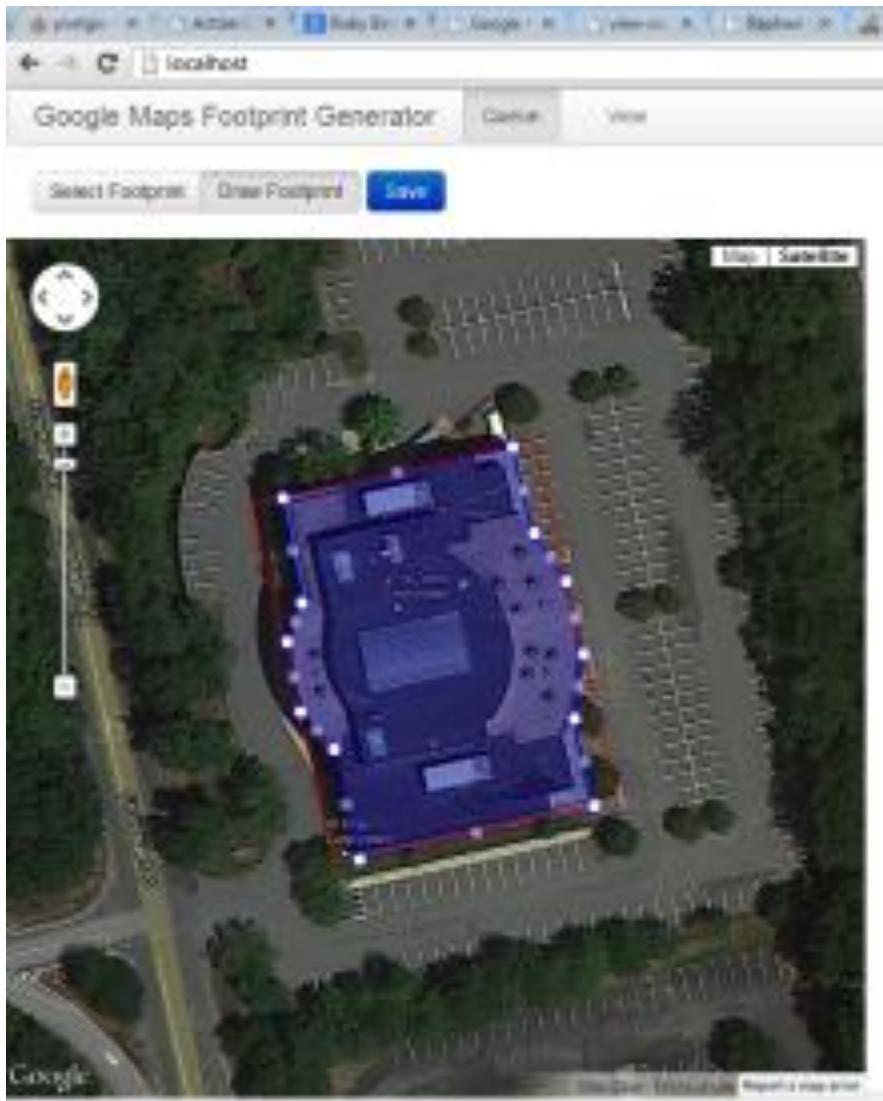
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What High Level Data Are Used to Create NGrid's Baseline Models?

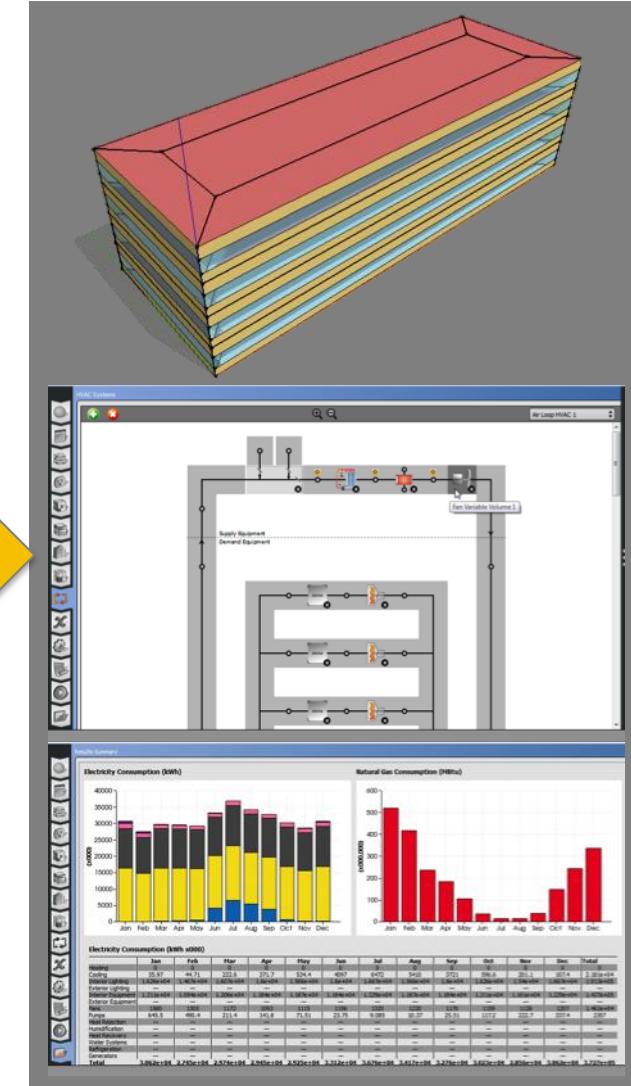
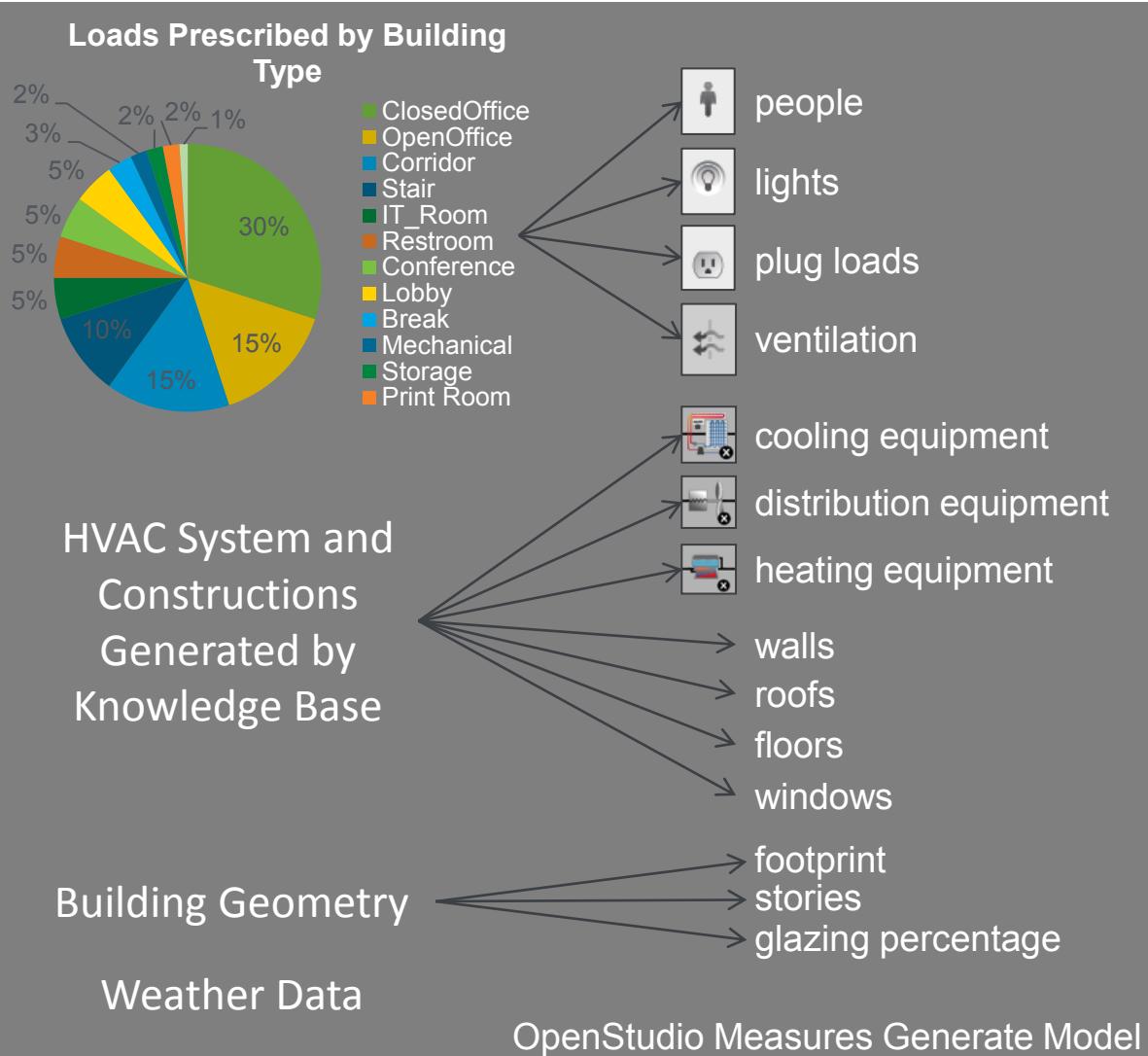


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- **Address:** PII
- **Size:** 10,000 ft²
- **Number of Floors:** 3
- **Vintage:** 1982
- **Building Type:** Office
- **Web app assists with geometry extraction**

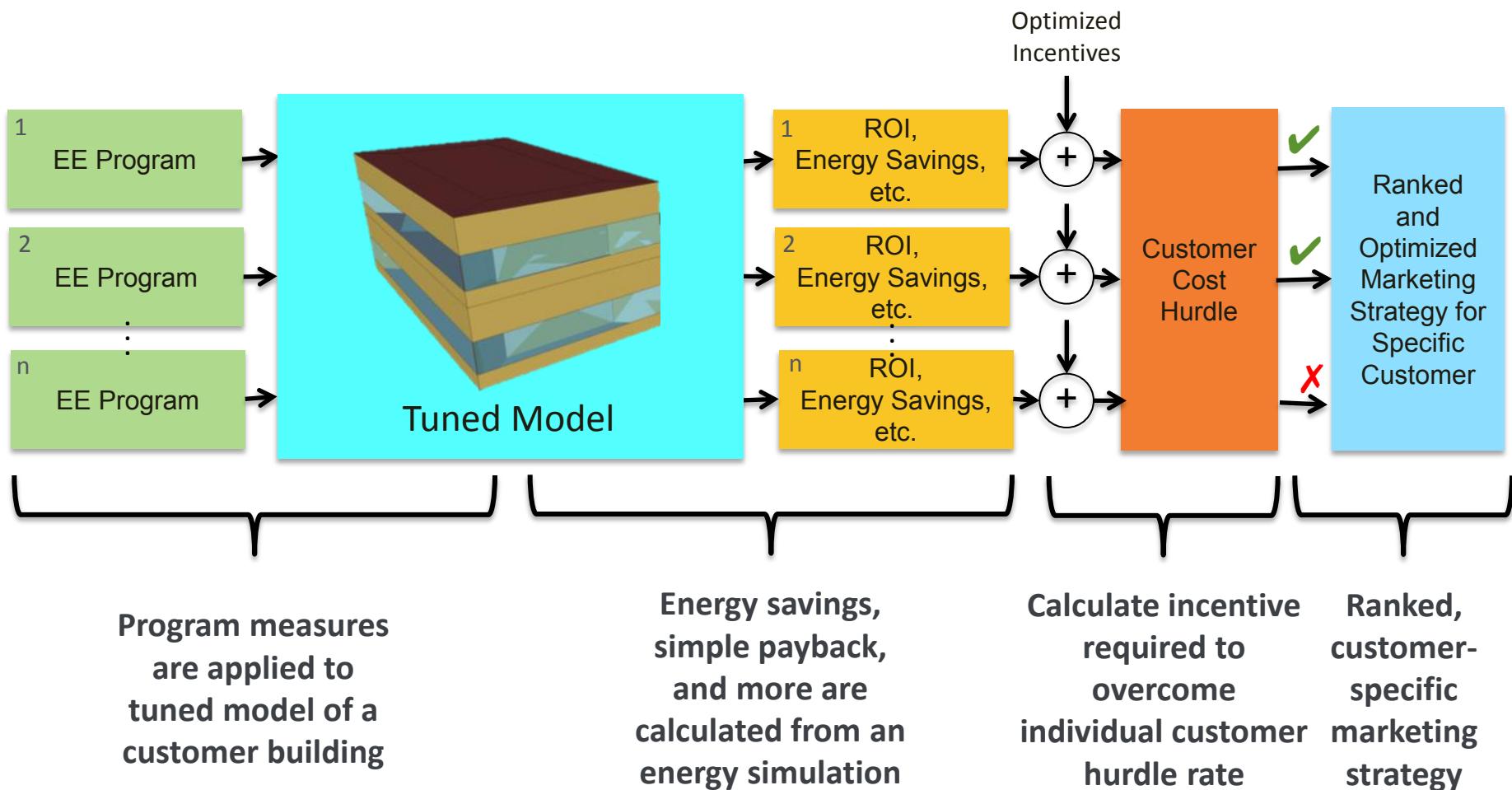
An OpenStudio-Enabled Expert System to Create Baseline Models for NGrid



NGrid's Approach to Incentive Program Design – The Long Term Goal



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Repeat Across Portfolio

nationalgrid

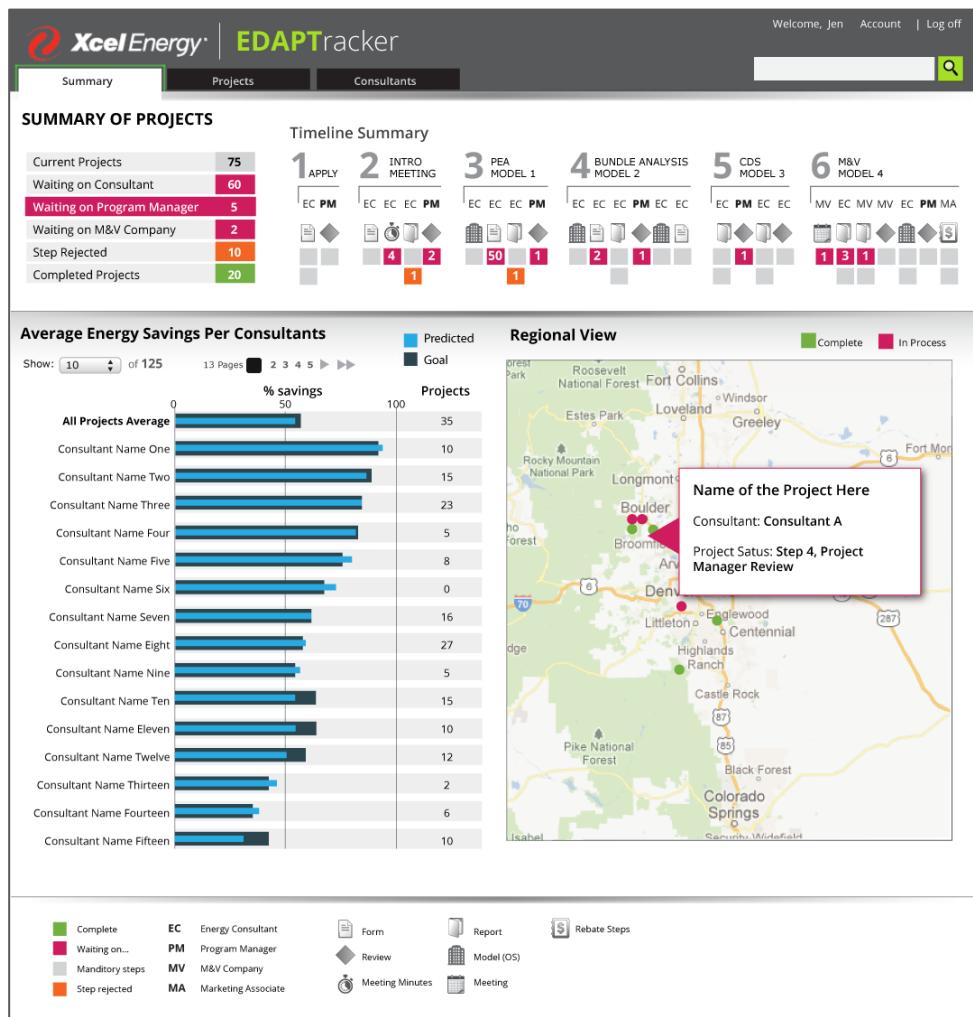
Xcel Energy's Energy Design Assistance Program Tracker (EDAPT)

- **Problem:** Reduce cost of Xcel's EDA program, while maintaining quality as additional energy consultants are engaged

- **Solution:**

- EDAPT web service tracks projects, manages data and communications, and reports program-wide outcomes
- OpenStudio and BCL are expanded to include automated quality and EDA protocol checking
- EDAPT connects high level project data with model outcomes to streamline reporting

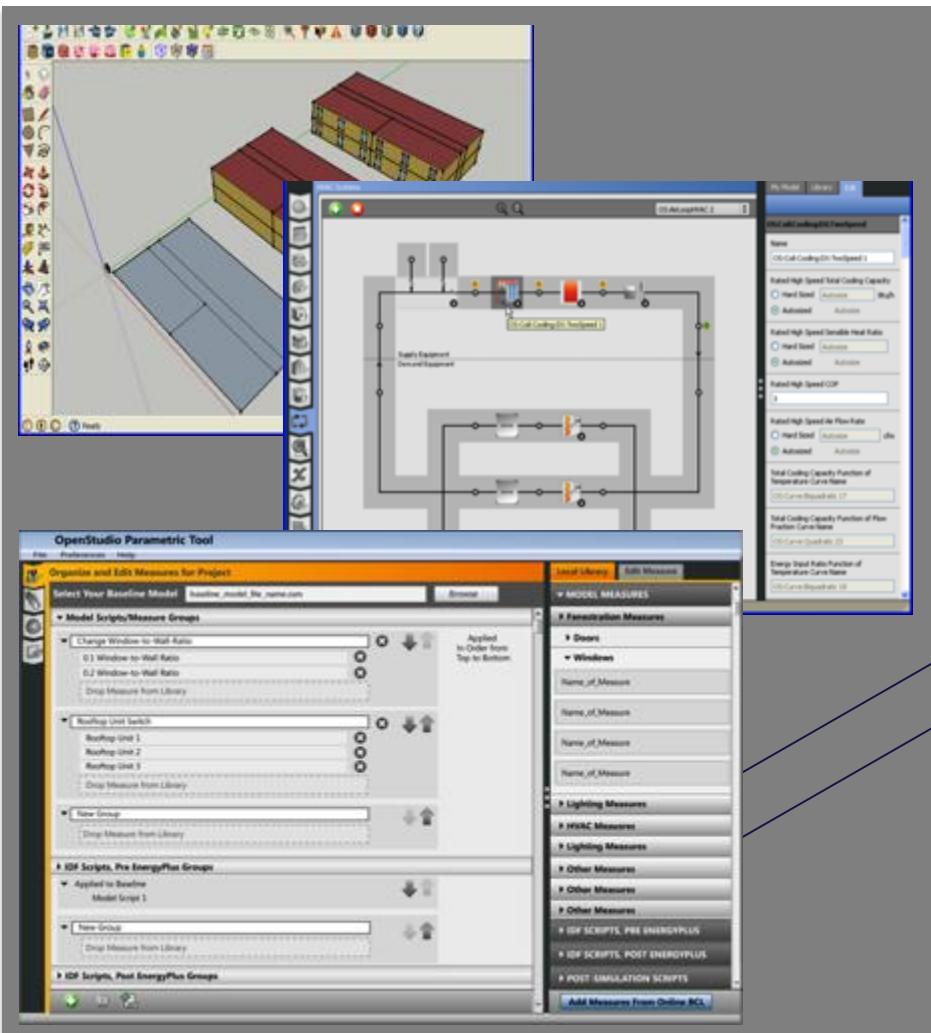
- **Launching in June 2013**



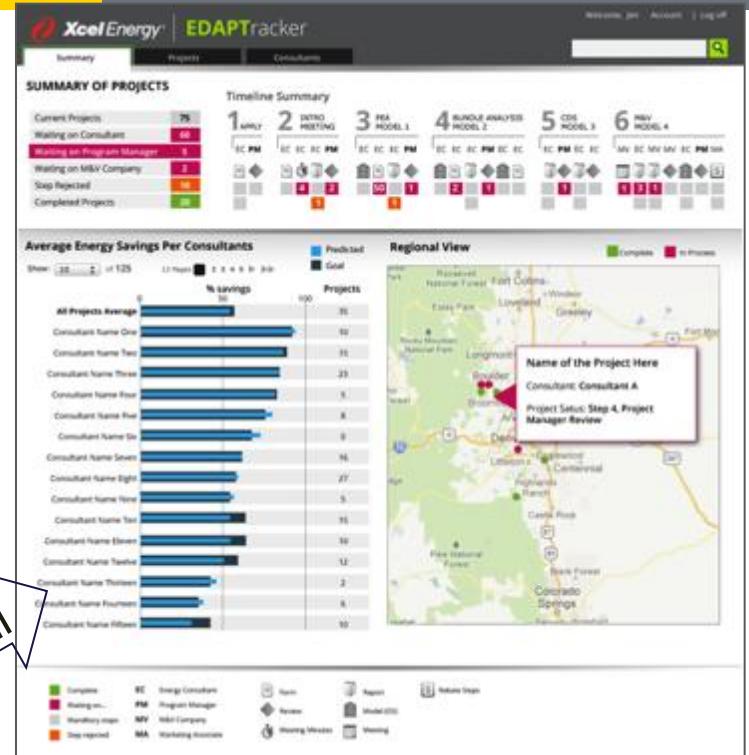
OpenStudio-EDAPT Integration

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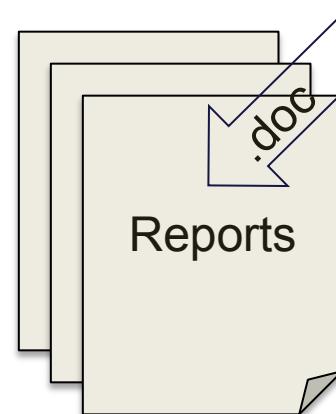
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OpenStudio baseline and design alternate models along with simulation results



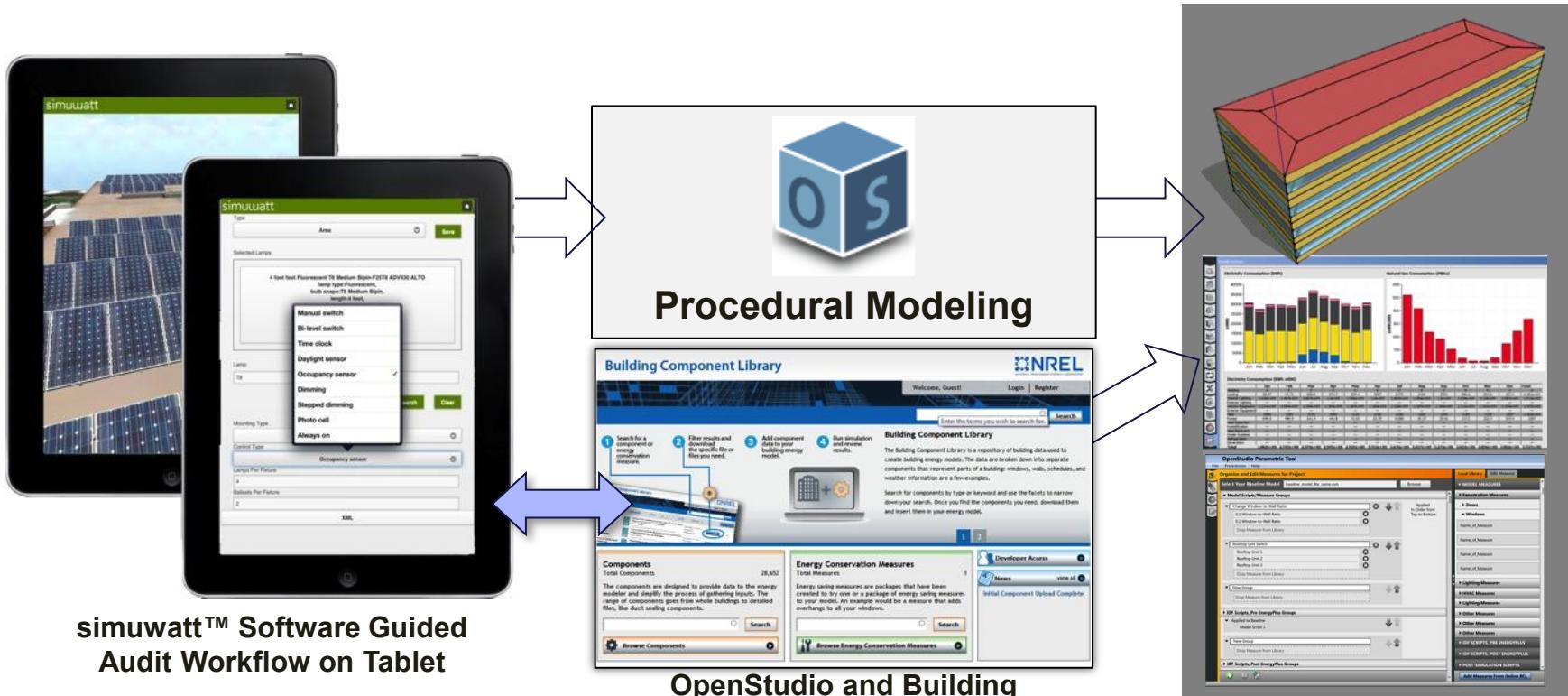
.xml



EDAPT web portal automatically generates report templates from project data and OpenStudio output

 **Xcel Energy**

An OpenStudio-Enabled Product for Auditing and PV System Design



simuwatt™ Software Guided Audit Workflow on Tablet

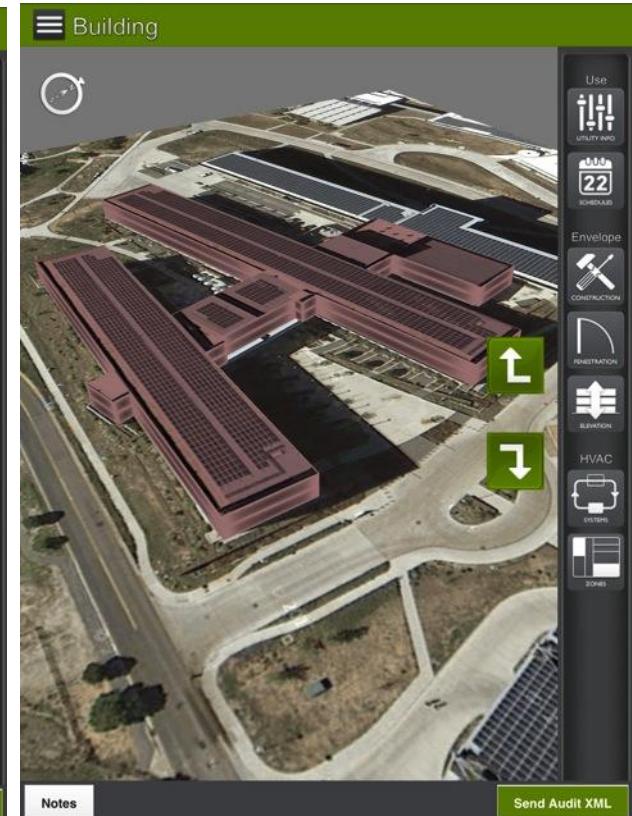
OpenStudio and Building Component Library (BCL)

Analysis of Baseline and Energy Conservation Measures

Key Goals

- **Reduce cost** of investment-grade, level 3 audits below current cost of level 1 or 2
- Produce **higher quality, more consistent** audits with **greater residual value**
 - Not simply a report that prescribes actions and quantifies savings
 - Data and models aggregate and can be reused for further cost reduction in EISA 2007 compliance, portfolio assessment, etc.

- Comprehensive workflow is modeled after NREL Deployment's proven methodology
- UI design guided with input from industry professionals



- Workflow includes space-by-space load assignment, scheduling, HVAC system specification, photo logging, note taking, and more
- Component definitions pulled from BCL



Load Allocation to Spaces

Title: Lights

Default Days
Set defaults for all weekdays and weekends

Profiles
Specify profile date ranges and days that will override defaults

Holidays
Select holidays that are observed

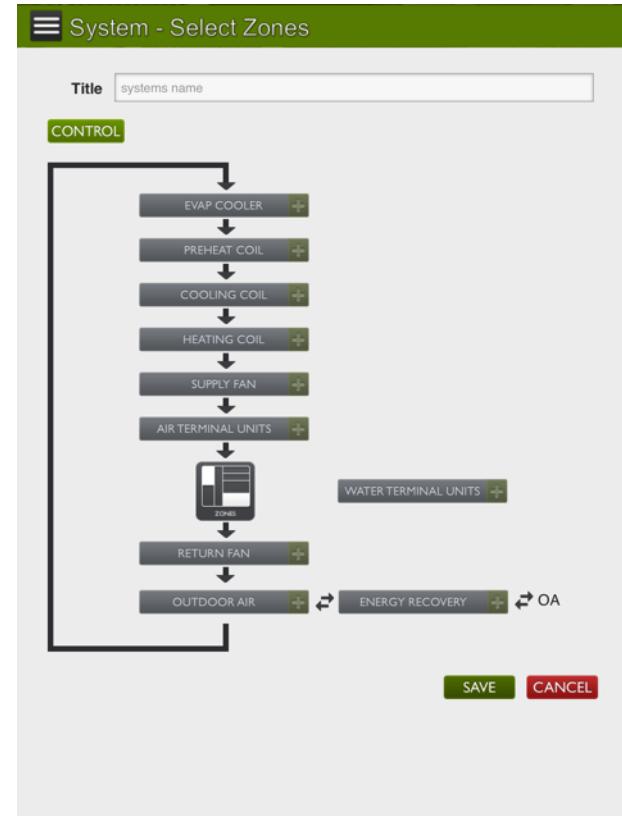
New Year's Day	Birthday of Martin Luther King Jr.
Washington's Birthday	Memorial Day
Independence Day	Labor Day
Columbus Day	Veterans Day
Thanksgiving Day	After Thanksgiving Day
Christmas Eve	Christmas Day

Special Periods
These will override any other profiles

+ PROFILE

SAVE CANCEL

Schedule Specification



HVAC System Specification

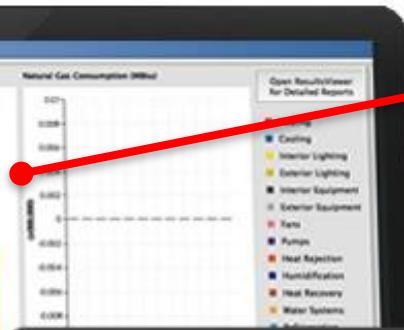
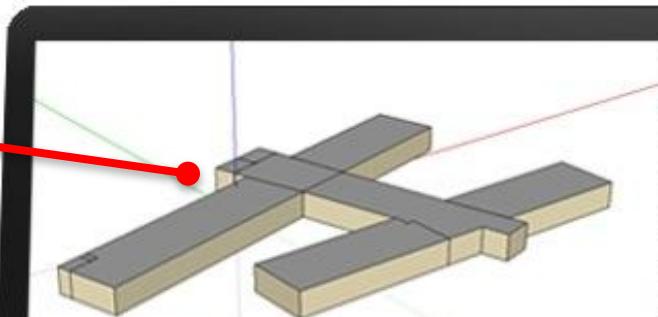
simuwatt

Data Seamlessly Converted to Baseline

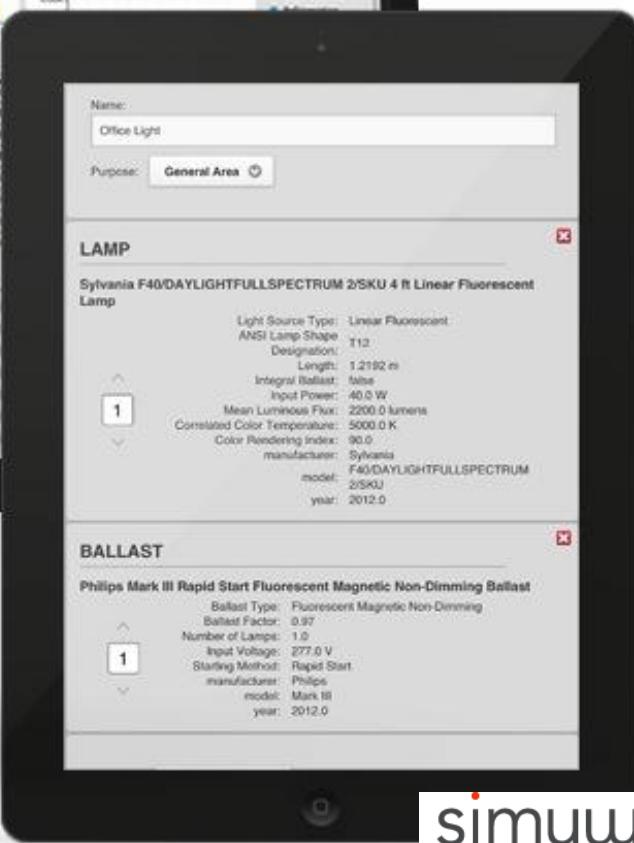
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Automatically
Generated
OpenStudio
Model
Geometry



Simulated
End Uses in
OpenStudio
Application



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Project Plan & Schedule

Project Initiation Date: Q1/FY10

Planned Completion Date: Ongoing with Frequent Off-Ramping of Components
(e.g. BCL transitioned to private sector by Q4/FY13)

Release Schedule: Bi-weekly (Agile) Minor Releases
Quarterly Major Releases with DOE-Prescribed Focus Areas

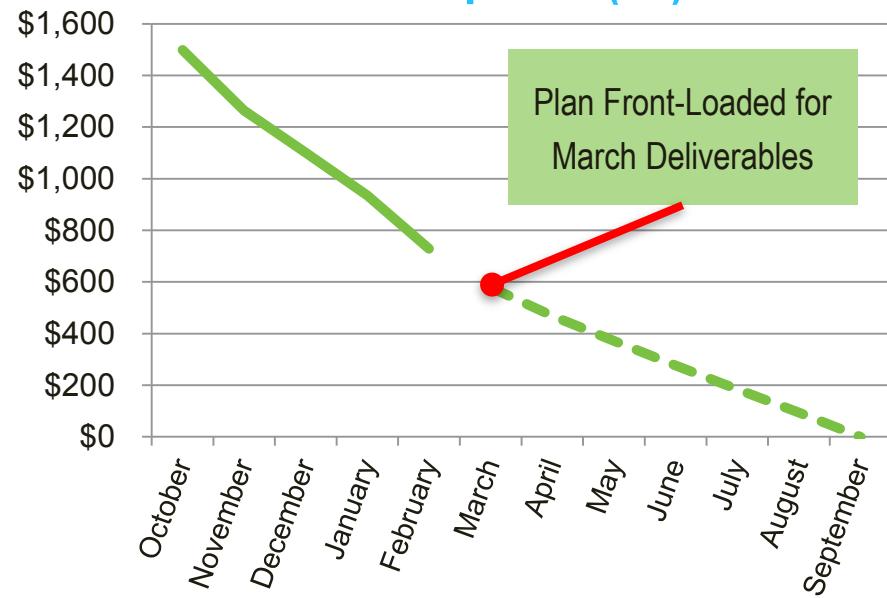
Summary				Legend							
Agreement Number	19987				Work completed						
Project Number	NREL-FY13-14 & NREL-				Active Task						
					Milestones & Deliverables (Origin)						
					Milestones & Deliverables (Actual)						
				FY2012		FY2013		FY2014			
Task / Event	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)	Q4 (Jul-Sep)	Q1 (Oct-Dec)	Q2 (Jan-Mar)	Q3 (Apr-Jun)
Project Name: OpenStudio and Building Component Library											
Q1 Milestone: OS 0.6 (Initial BCL Integration with OpenStudio)		◆									
Q2 Milestone: OS 0.7 (First Version of OpenStudio App with BCL Integration)		◆	◆								
Q3 Milestone: OS 0.8 (App Suite Workflow Improvements and DEnCity)			◆	◆							
Q4 Milestone: OS 0.9 (BIM Interop and Initial Support for BCL Measures)				◆	◆						
Q1 Milestone: OS 0.10 (Sim Settings Tab and Backend Work for PAT)					◆	◆					
Q2 Milestone: OS 0.11 (Initial Version of PAT and BCL UGC)						◆					
Q3 Milestone: OS 1.0 (PAT Economics and Measures)							◆	◆			
Q4 Milestone: OS 1.1 (Cloud Support and additional Measures)								◆	◆	◆	◆

Project Budget

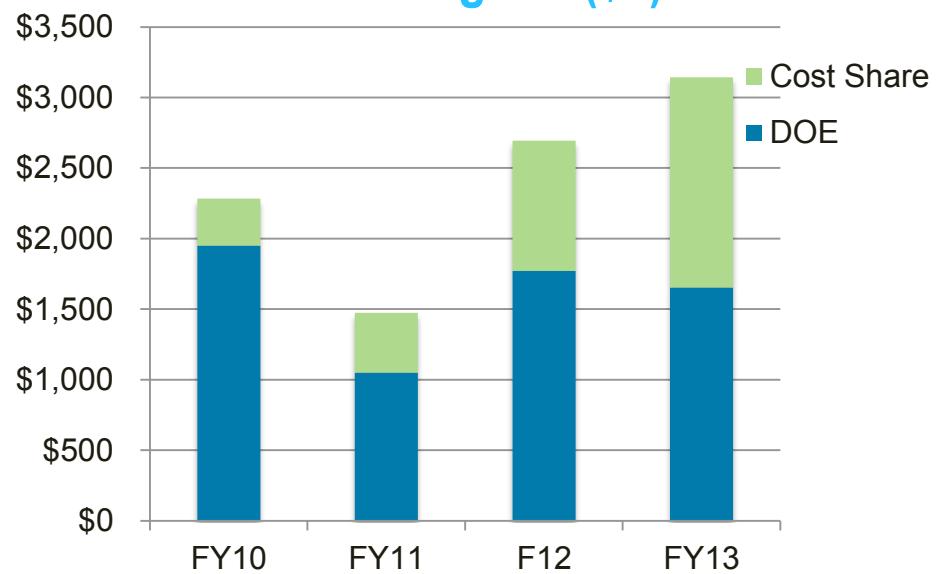
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FY13 Spend* (\$k)



FY10-13 Budgets* (\$k)



Additional Funding Sources:



* FY13 Spend and Budget Includes both OpenStudio/BCL and Asset Score CBI Budgets

Project Integration, Collaboration & Market Impact

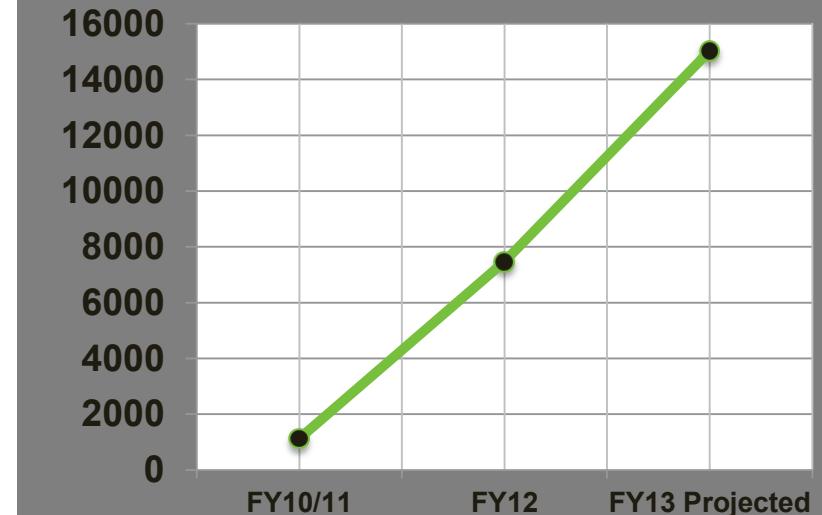
Partners, Subcontractors, and Collaborators:

- Many - spanning other national laboratories, EEB, universities, and the private sector
- RFP for training and user support partners released in February (Train the trainers)

Technology Transfer, Deployment, Market Impact:

- Adoption metrics encompass diverse user base from academia and private sector
- Some noteworthy private sector uptake examples were presented in earlier slides - many more in process
- CEC and utilities are using OpenStudio as a means of shifting the market to EnergyPlus

Registered Users



10,496 Total Registered Users
1,153,650 Total Web Page Views
240,317 Total YouTube Video Views

Communications:

- Multiple training workshops (NREL, AIA, IBPSA, BPA, International, and others)
- Online training at <http://openstudio.nrel.gov> and on YouTube (Over 100 videos)
- Online discussion and user support forums
- Publications through IBPSA, ACEEE, WREF, etc.
- Frequent webinars
- Multiple universities teaching with OpenStudio

- Continue making quarterly releases of SDK
- Near-term Capability
 - Add more components and measures to BCL
 - Provide OpenStudio Cloud Support for Practitioners
 - Additional HVAC Systems, Commercial Refrigeration
 - Add additional Quality Checking (QC) automation
 - Extensible Results Visualizations
 - Build System Improvements
- Utility App Replication
 - Xcel and National Grid Technology Exchange
 - ComEd
 - Others?
- Off-Ramping
 - BCL – In Process
 - Training and User Support – In Process
 - Tool Suite – Seeking Partner
- Greater interoperability
 - Additional engines – CONTAM integration at EEB
 - Data sources – e.g. TPEx, OpenEI, DSIRE, etc.
- Support SDK Adoption for New Products and Applications

Thank you!

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