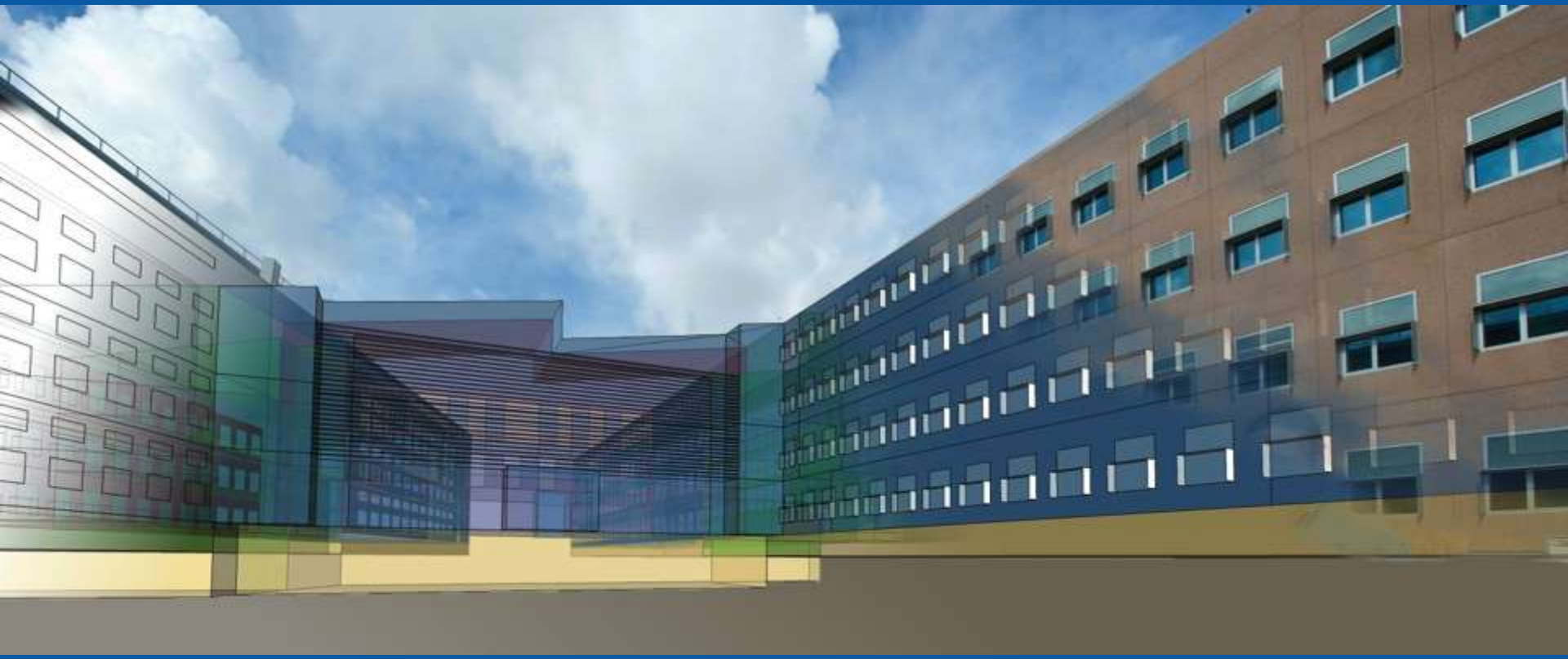
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

# Utility Application of DOE's Energy Analysis Platform



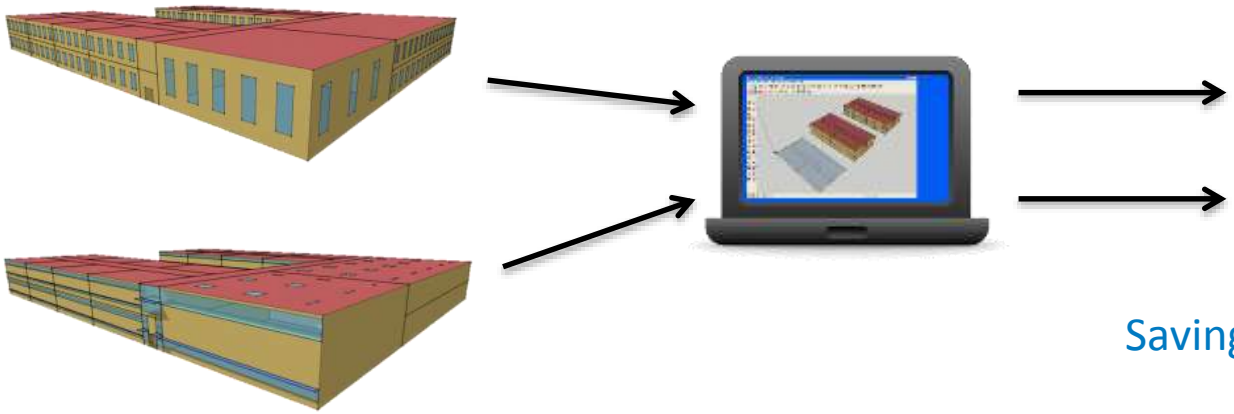
**Commercial Buildings Controls and Analysis Tools Team**
**Andrew Parker**
**May 15th, 2015**

# What is Energy Modeling?

**Tool to answer the question "what if I make XYZ changes to my building?"**

**Input:**
Building characteristics (shape, windows, insulation, lights, HVAC, etc.)

**Output:**
Energy usage, peak demand, utility cost, etc.



50,000 kWh 70kW

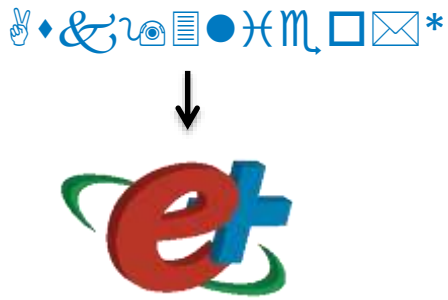
-35,000 kWh 50kW

Savings: 15,000 kWh 20kW

# DOE Energy Modeling Ecosystem

**EnergyPlus:**

- Successor to DOE-2
- State-of-the-art energy modeling software
- Funded, maintained, and updated by DOE
- Covers most cutting-edge technologies
- So everyone uses it, right?  Nope. Not very easy to use.



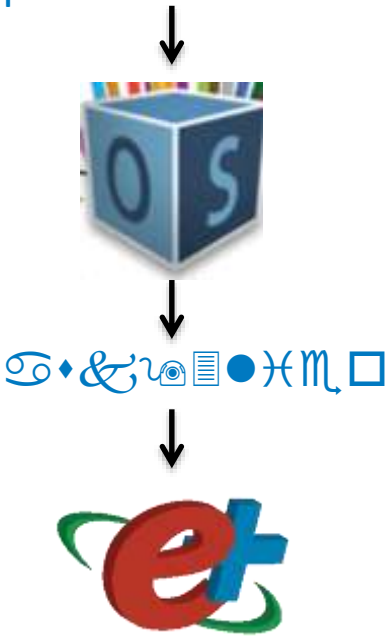
*wingdings

# DOE Energy Modeling Ecosystem

**OpenStudio:**

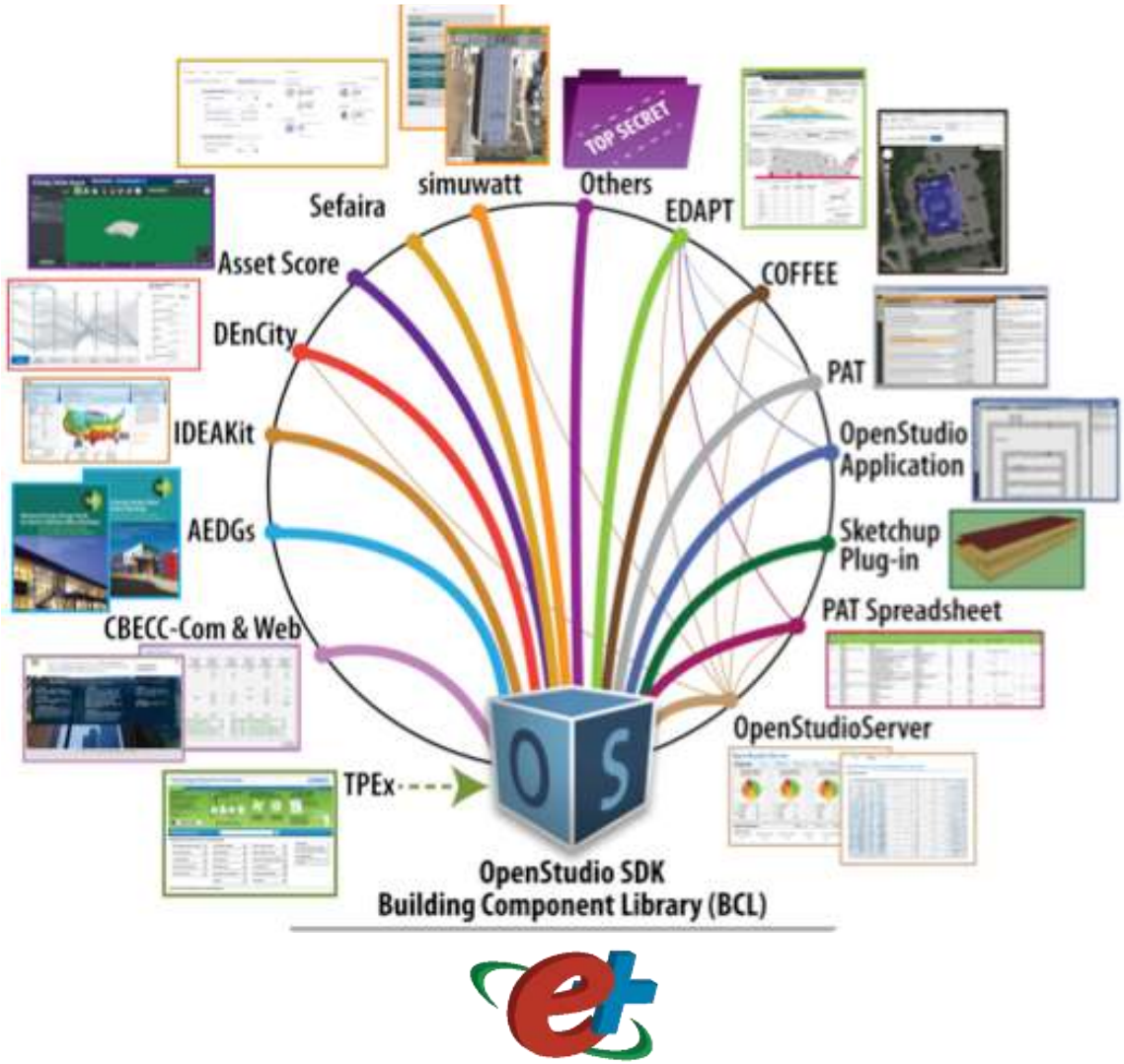
- Makes EnergyPlus easier to use (for people and other software)
- Free, open-source, cross-platform
- Funded by combo of DOE, utilities, private sector

150,000 sqft school with Chilled Water VAV



# DOE Energy Modeling Ecosystem

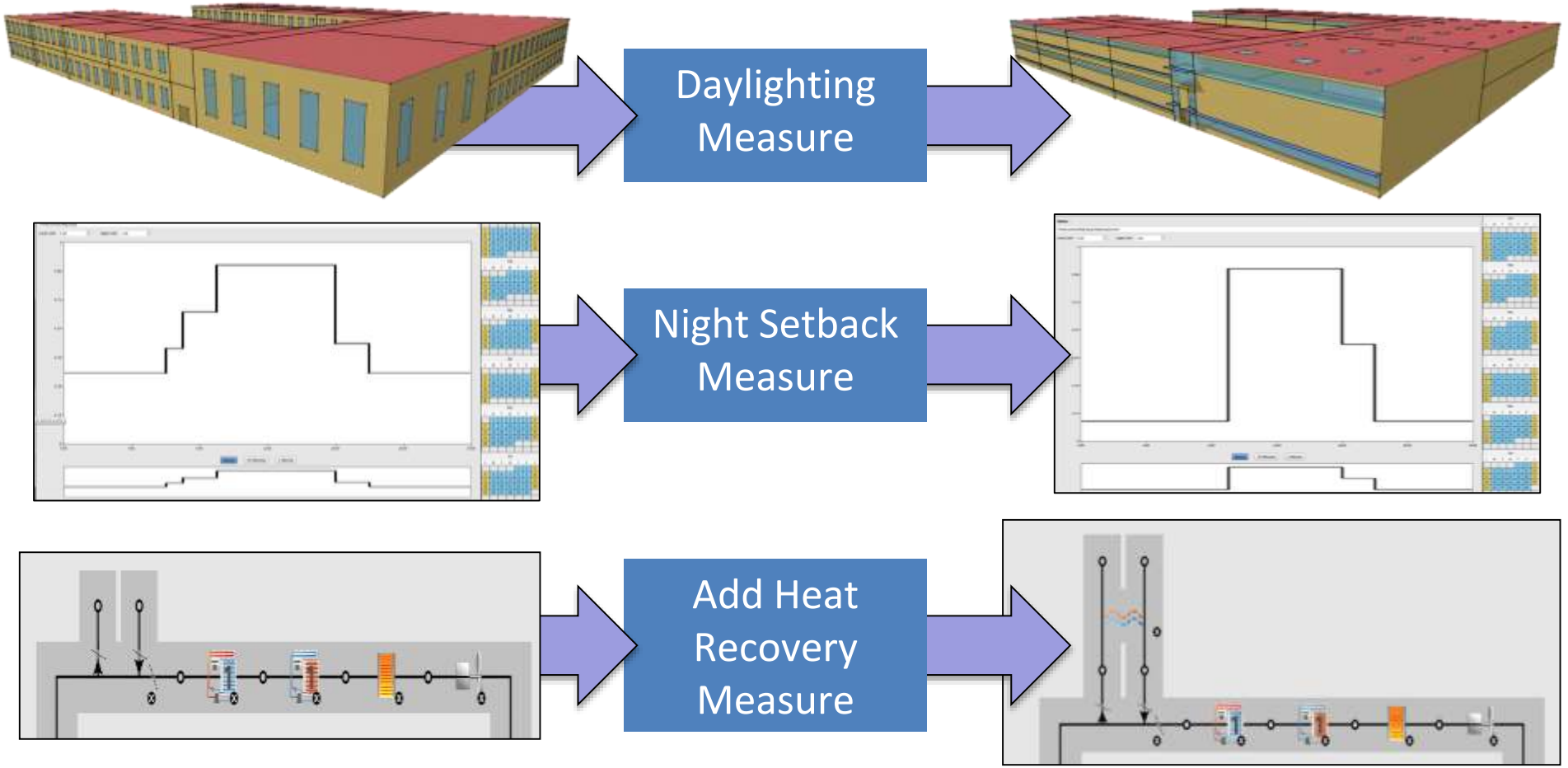
**Many applications use OpenStudio to access EnergyPlus**



# What's the difference?

- Sounds like (insert other energy modeling tool here)
- But I already know (insert other energy modeling tool here)
- But my implementers already know (ditto)

# Key Concept 1: OpenStudio Measures




**OpenStudio Measures:**

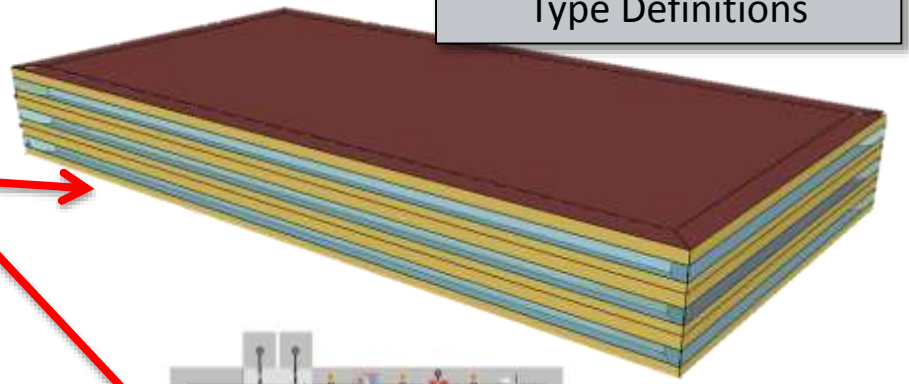
- Self contained scripts that transform an energy model easily and consistently
- Can be applied singly or as  part of a parametric analysis
- Key to “drag-and-drop” simplicity and platform extensibility

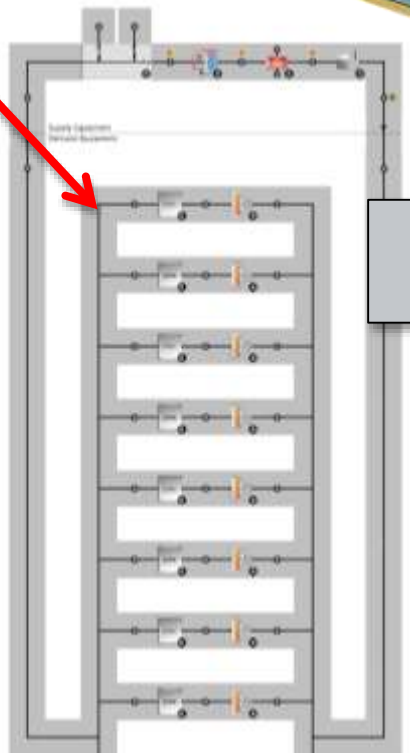
# Key Concept 2: Automated Modeling

```ruby
require 'openstudio'
require 'VirtualPULSEModel'

#create a new model
model = VirtualPULSEModel.new

#add geometry (in this case a simple multi-story core/perimeter building)
model.add_geometry({"length" => 100,
#add windows at a given window-to-wall ratio
model.add_windows({"wwr" => 0.4,
#add HVAC - Packaged VAV w/ Reheat - DX Cooling, Hot Water heat
model.add_hvac({"fan_eff" => 0.5,
#add thermostats
model.add_thermostats({"heating_setpoint" => 24,
#assign constructions from a local library to the
model.add_constructions({"construction_library
#add space type from a remote library
model.add_space_type({"NREL_reference_building_vintage" => "ASHRAE_90.1-2004",
#add design days to the model
model.add_design_days()

#save the OpenStudio model (.osm)
model.save_openstudio_osm({"osm_save_directory" => Dir.pwd,
#translate the OpenStudio model (.osm) to an EnergyPlus model (.idf)
model.translate_to_energyplus_and_save_idf({"idf_save_directory" => Dir.pwd,
#run the EnergyPlus model (.idf)
VirtualPULSEModel::run_energyplus_simulation({"idf_directory" => Dir.pwd,
```

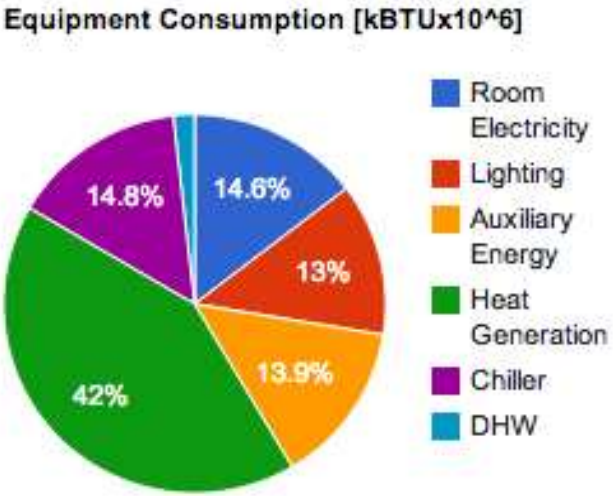
13 Lines of Ruby Code + Comments

Geometry and Space Type Definitions



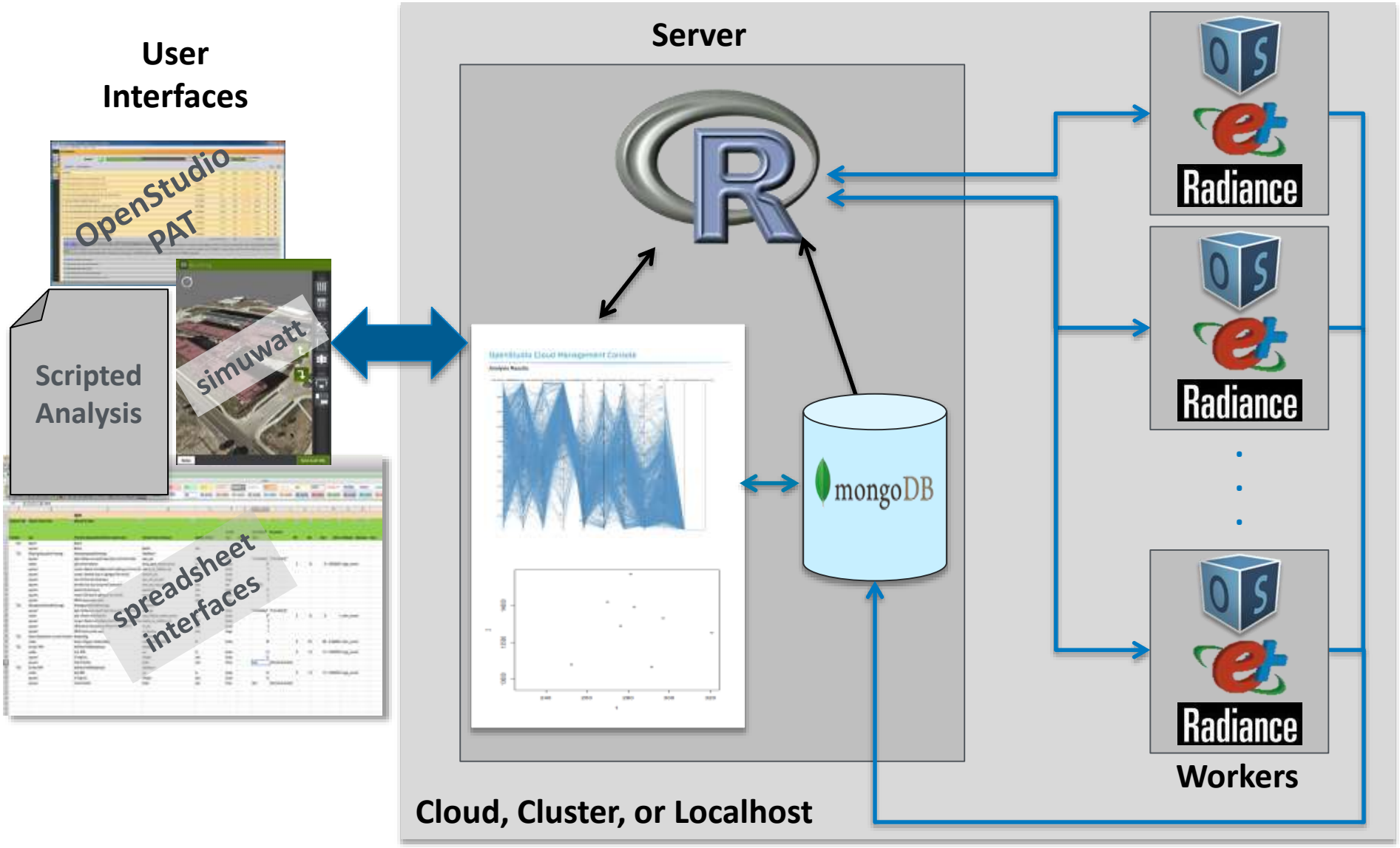


Detailed HVAC and Zoning

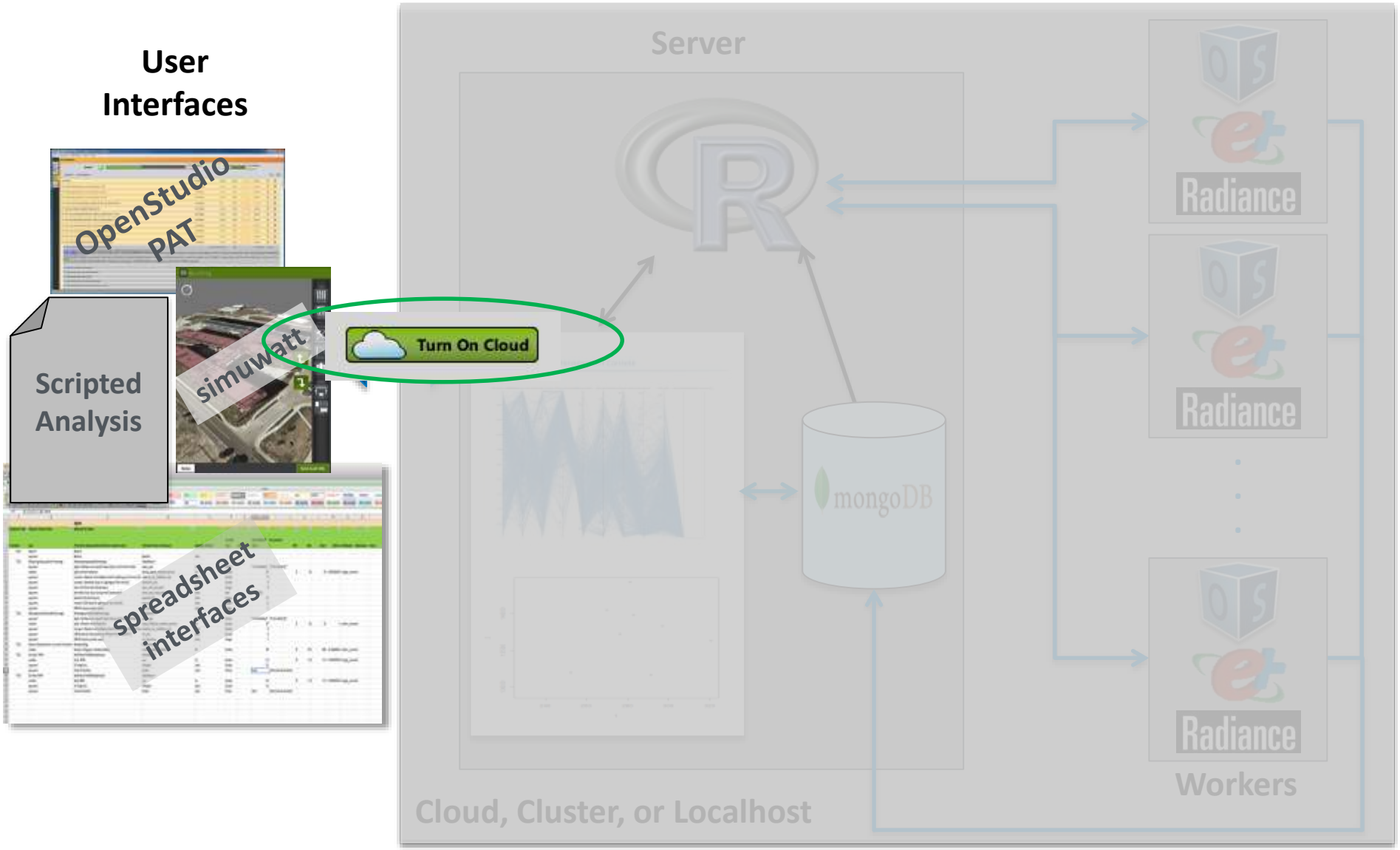



Simulated End Uses

# Key Concept 3: Cloud-Based Analysis



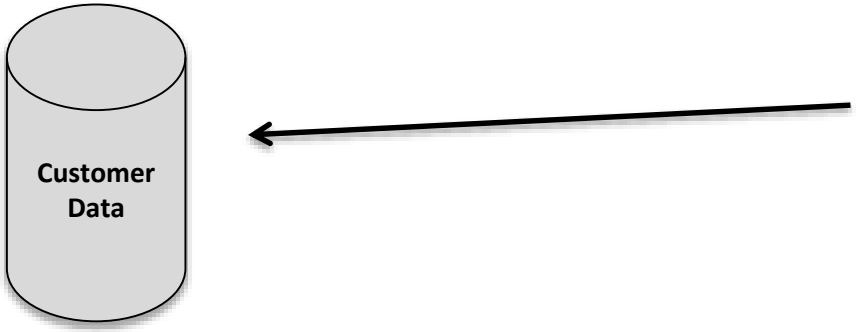
# Key Concept 3: Cloud-Based Analysis



# Utility Application #1 – COFFEE

nationalgrid

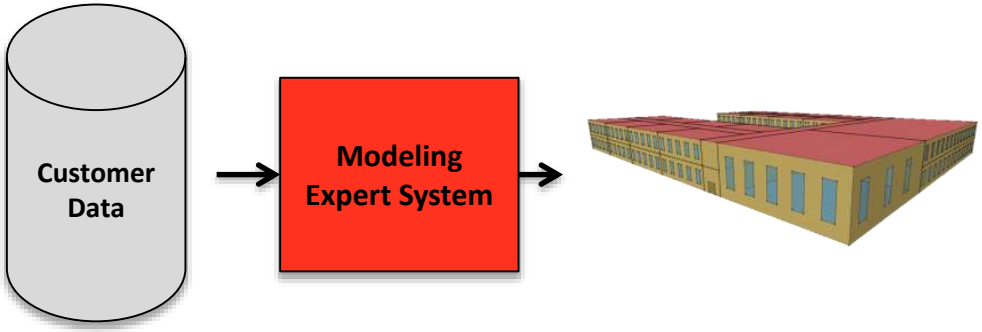
# Start with High Level Customer Data



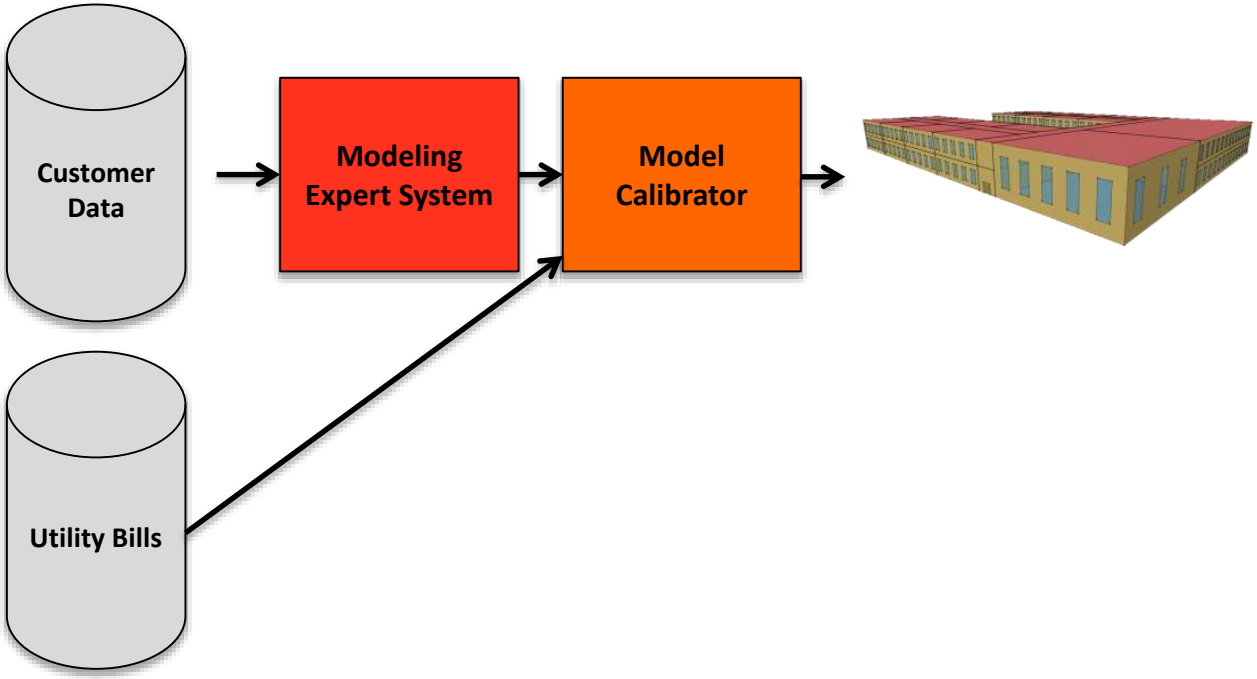

- **Address**
- **Size:** 10,000 $ft^2$
- **Number of Floors:** 3
- **Vintage:** 1982
- **Building Type:** Office
- **Retrofit rebate history**

nationalgrid

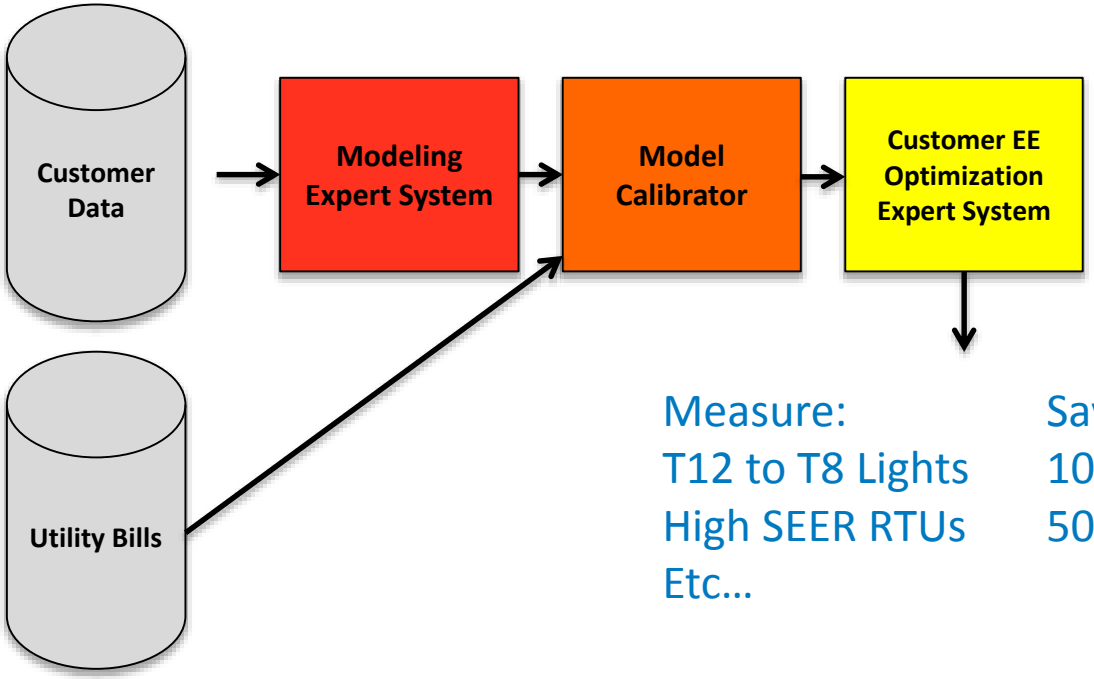
# Expert System to Create Initial Energy Model



# Add Utility Bills, Calibrate Model



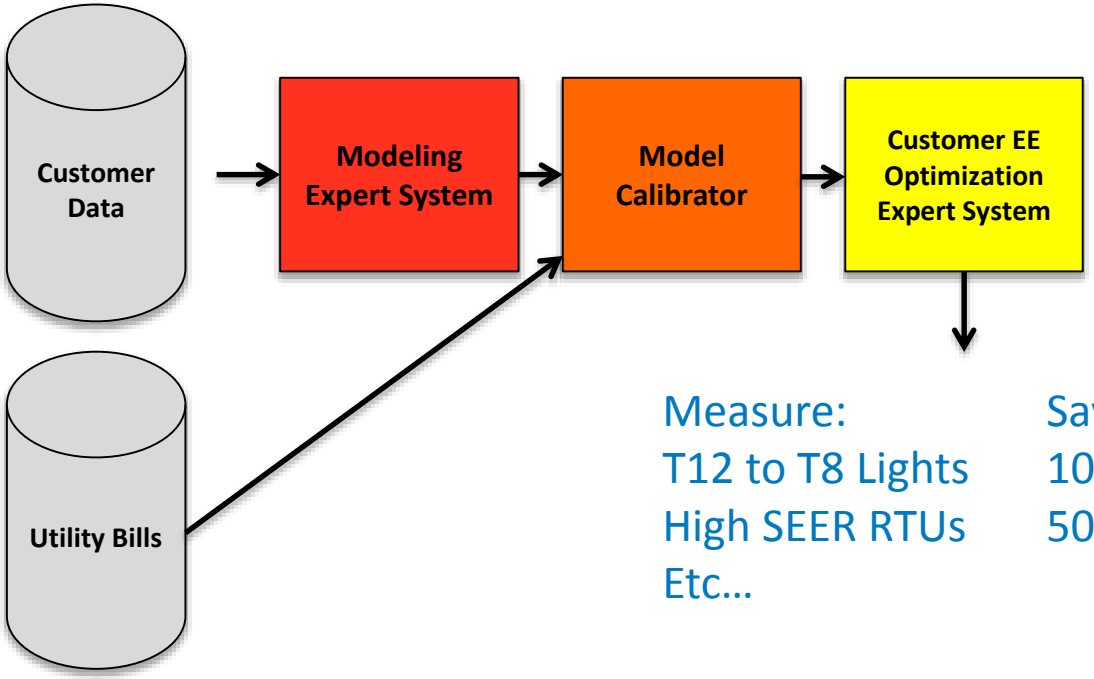
# Apply EE/DR Measures, Estimate Savings




| Measure: | Savings: |
|---|---|
| T12 to T8 Lights | 100kWh, 10kW |
| High SEER RTUs | 50kWh, 1kW |
| Etc… | |

nationalgrid

# …Repeat for Entire Portfolio




| Measure: | Savings: |
|---|---|
| T12 to T8 Lights | 100kWh, 10kW |
| High SEER RTUs | 50kWh, 1kW |
| Etc… | |

nationalgrid

# What do we have?

## Calibrated energy model for every customer

**Primary Uses:**

- Targeted incentive program advertising
- Informing EE sales reps; warm calls instead of cold calls
- Analysis to understand/inform achievability of regulatory requirements

**Other Uses:**

- Testing ideas for new programs on realistic portfolio at low cost
- Understanding impact of EE/DR on actual feeders and substations
  (AKA being able to speak the language of distribution/generation departments)

nationalgrid

# Yeah, but…

**Limitations:**

- Not always correct on case by case, but right overall
- Better than nothing
- Reasonable starting point for customer engagement
- EE sales reps can improve inferences via site visit; predictions improve
- Even if not perfect building-to-building, overall portfolio of models is pretty close

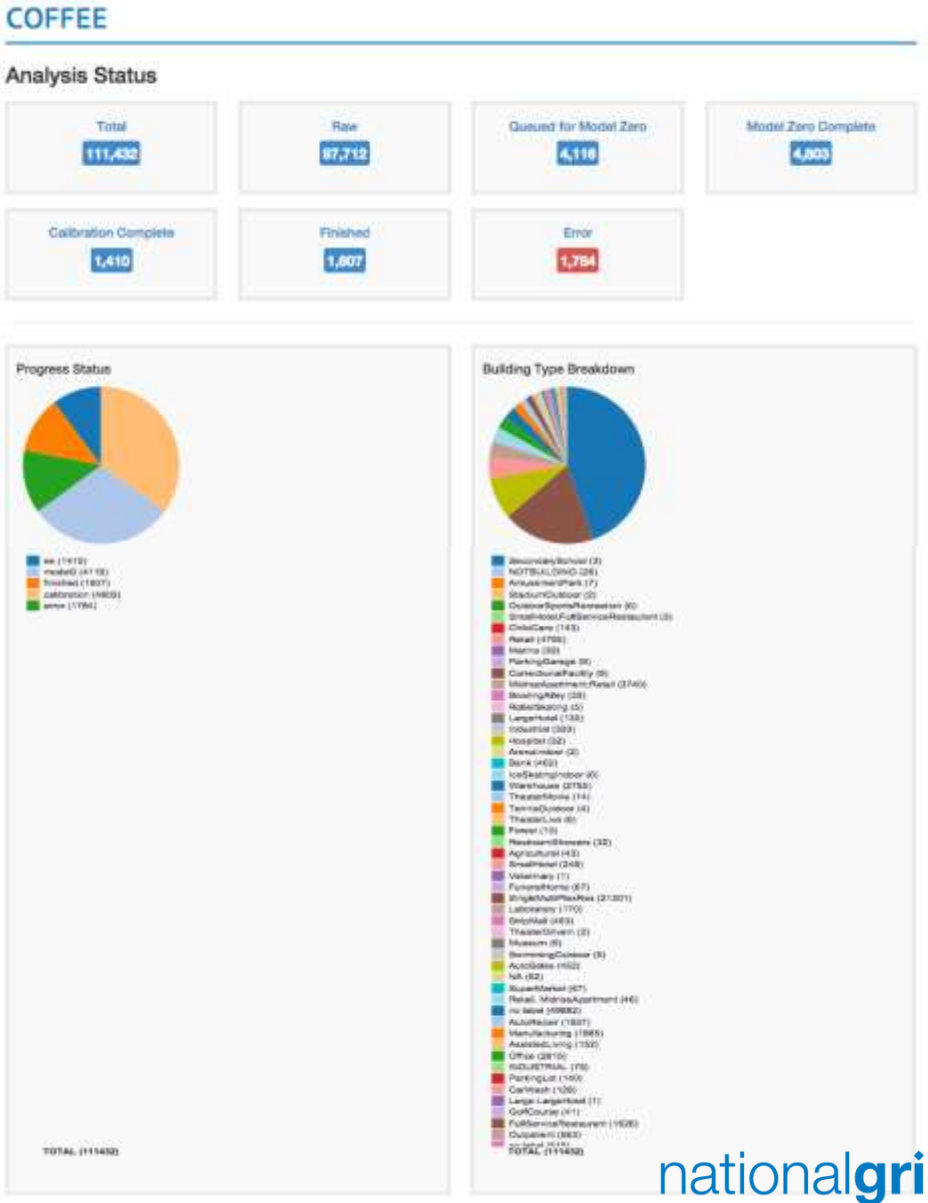
**Challenges:**

- Multi tenant/multi-meter buildings
- Building where other utilities provide gas
- Odd/niche building types

nationalgrid

# Initial COFFEE Results

- **Thousands of buildings in MA have been processed**
  - 3200 processing cores allocated
  - CPU time per building
    - Model 0: 2-3 minutes
    - Calibration: 25-40 minutes
    - EE Simulations:  70-115 minutes
- **$10-20 per building**



# Initial Model Creation Example

**Modeling Expert System**

## COFFEE

back to index / [redacted]

[redacted]

### Analysis Info

Details | Files

Current state: raw

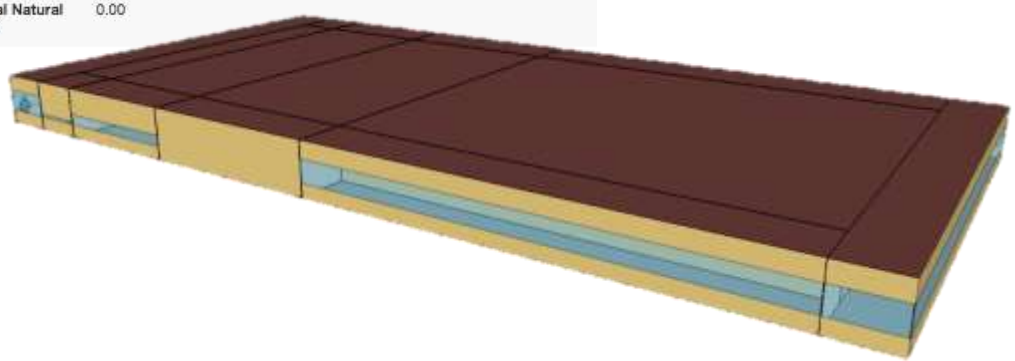
trigger queued_model0

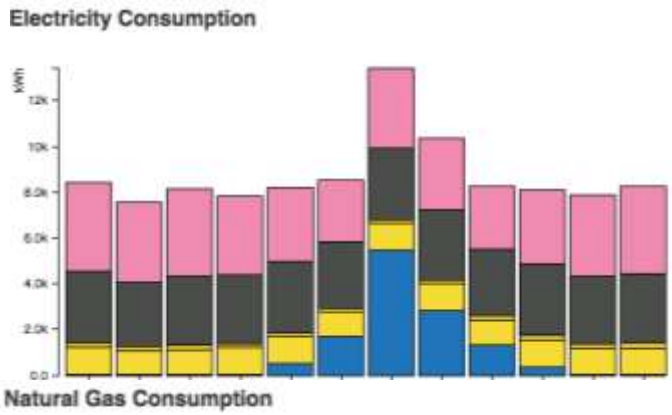
### Building Characteristics

| | |
|---|---|
| Building Type | Land |
| Square Footage | 15820 |
| Stories | 1 |
| Vintage | 1979 |

### Energy Results

| | Whole Building (2013) (kBtu/ft²) | Model Zero (kBtu/ft²) | Calibrated Model (kBtu/ft²) |
|---|---|---|---|
| Total Energy | 19.99 | | |
| Total Electricity | 19.99 | | |
| Total Natural Gas | 0.00 | | |






nationalgrid

# Model Calibration Example

**Model Calibrator**

## COFFEE

back to index / [redacted]

[redacted]

### Analysis Info

Details | Files

Current state: raw

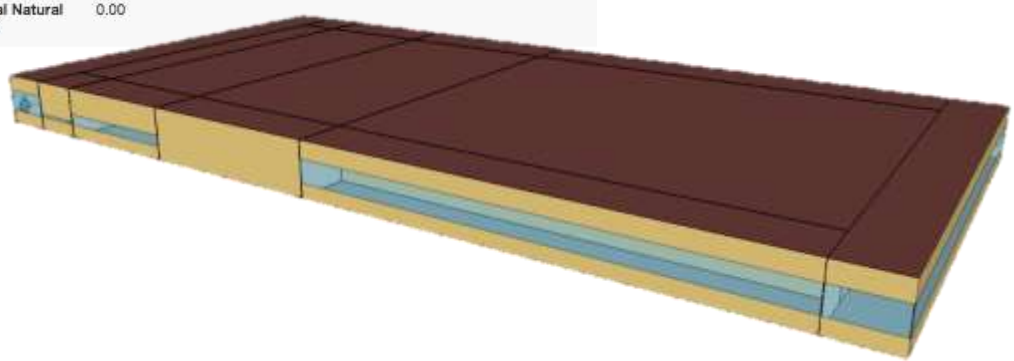
trigger queued_model0

### Building Characteristics

| | |
|---|---|
| Building Type | Land |
| Square Footage | 15820 |
| Stories | 1 |
| Vintage | 1979 |

### Energy Results

| | Whole Building (2013) (kBtu/ft²) | Model Zero (kBtu/ft²) | Calibrated Model (kBtu/ft²) |
|---|---|---|---|
| Total Energy | 19.99 | | |
| Total Electricity | 19.99 | | |
| Total Natural Gas | 0.00 | | |

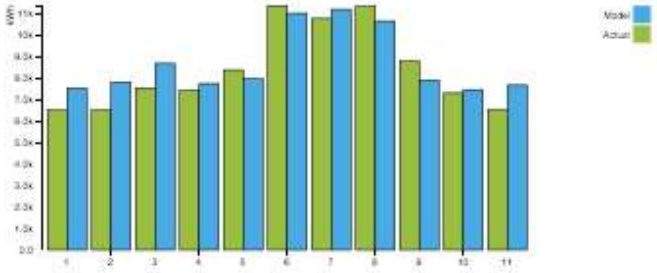


Calibration Method: ASHRAE 14-2002

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.

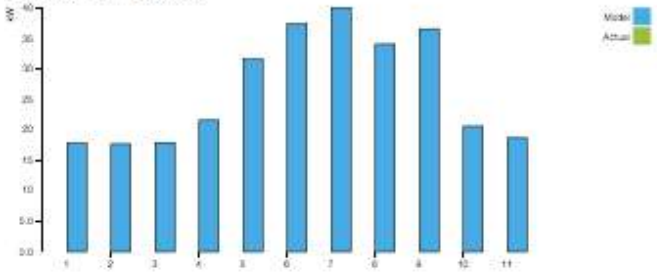
**Electricity Consumption (kWh)**

**CV(RMSE)** = 10.04
**NMBE** = -3.75




| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Start | 1/8 | 2/5 | 3/6 | 4/8 | 5/8 | 6/7 | 7/10 | 8/7 | 9/9 | 10/8 | 11/6 |
| End | 2/4 | 3/5 | 4/7 | 5/7 | 6/6 | 7/9 | 8/6 | 9/8 | 10/7 | 11/5 | 12/4 |
| Actual | 6,520 | 6,520 | 7,560 | 7,440 | 8,400 | 11,400 | 10,800 | 11,360 | 8,800 | 7,320 | 6,560 |
| Model | 7,542 | 7,819 | 8,696 | 7,764 | 7,975 | 11,050 | 11,231 | 10,682 | 7,920 | 7,477 | 7,690 |
| NMBE | 15.67% | 19.92% | 15.02% | 4.35% | -5.06% | -3.07% | 3.99% | -5.97% | -10% | 2.14% | 17.22% |

**Electricity Demand (kW)**




| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Start | 1/8 | 2/5 | 3/6 | 4/8 | 5/8 | 6/7 | 7/10 | 8/7 | 9/9 | 10/8 | 11/6 |
| End | 2/4 | 3/5 | 4/7 | 5/7 | 6/6 | 7/9 | 8/6 | 9/8 | 10/7 | 11/5 | 12/4 |
| Actual | — | — | — | — | — | — | — | — | — | — | — |
| Model | 17.8 | 17.7 | 17.9 | 21.6 | 31.6 | 37.4 | 40.1 | 34.1 | 36.6 | 20.6 | 18.7 |
| NMBE | — | — | — | — | — | — | — | — | — | — | — |

nationalgrid

# Raw EE Measure Analysis

Customer EE Optimization Expert System

- Annual energy simulations determine gas and electric energy saving potential for over 1100 retrofit options
- Each EE measure is considered independently and in combination

# EE Measure Financial Analysis

Customer Assessment

- **COFFEE creates and ranks EE measure bundles based on multiple investment criteria**
- **This set of recommendations is based on shortest simple payback and 15 year net value**

| Ranking | EE Measure Combination | Simple Payback (Years) | Net Value (15-yr) | Upfront Measure Cost | Cost Offset by Incentives | Energy Savings (kWh,%*) |
|---|---|---|---|---|---|---|
| 1 | • Programmable Thermostats (heating and cooling setbacks)<br>• Upgrade to LED Troffer | **1** | $41,034 | $1,263 | $632 | 201,191 (13%) |
| 2 | • Programmable Thermostats (heating and cooling setbacks)<br>• Lighting Controls (occupancy and daylight sensors) | **1** | $37,159 | $1052 | $526 | 182,166 (12%) |
| 3 | • Programmable Thermostats (heating and cooling setbacks)<br>• Lighting Controls (occupancy sensor only) | **1** | $34.555 | $1050 | $525 | 169,718 (11%) |

* Percent savings relative to the total energy consumption, 1,516,836kWh.

# EE Measure Financial Analysis

Customer Assessment

- **Alternate investment criteria produce different recommendations**
- **These EE measure bundles are created and ranked to produce best annual energy savings**

| Ranking | EE Measure Combination | Energy Savings (kWh,%*) | Upfront Measure Cost | Cost Offset by Incentives | Net Value (15-yr) | Simple Payback (Years) |
|---|---|---|---|---|---|---|
| 1 | • Programmable Thermostats (heating and cooling setbacks)<br>• Upgrade to LED Troffer<br>• Dual Enthalpy Economizer** | **203,332 (13%)** | $12,063 | $11.432 | $30,640 | 5 |
| 2 | • Programmable Thermostats (heating and cooling setbacks)<br>• Upgrade to LED Troffer | **201,191 (13%)** | $1,263 | $632 | $41,034 | 1 |
| 3 | • Programmable Thermostats (heating and cooling setbacks)<br>• Lighting Controls (occupancy and daylight sensors)<br>• Dual Enthalpy Economizer** | **184,392 (12%)** | $11,854 | $11,327 | $26,781 | 5 |

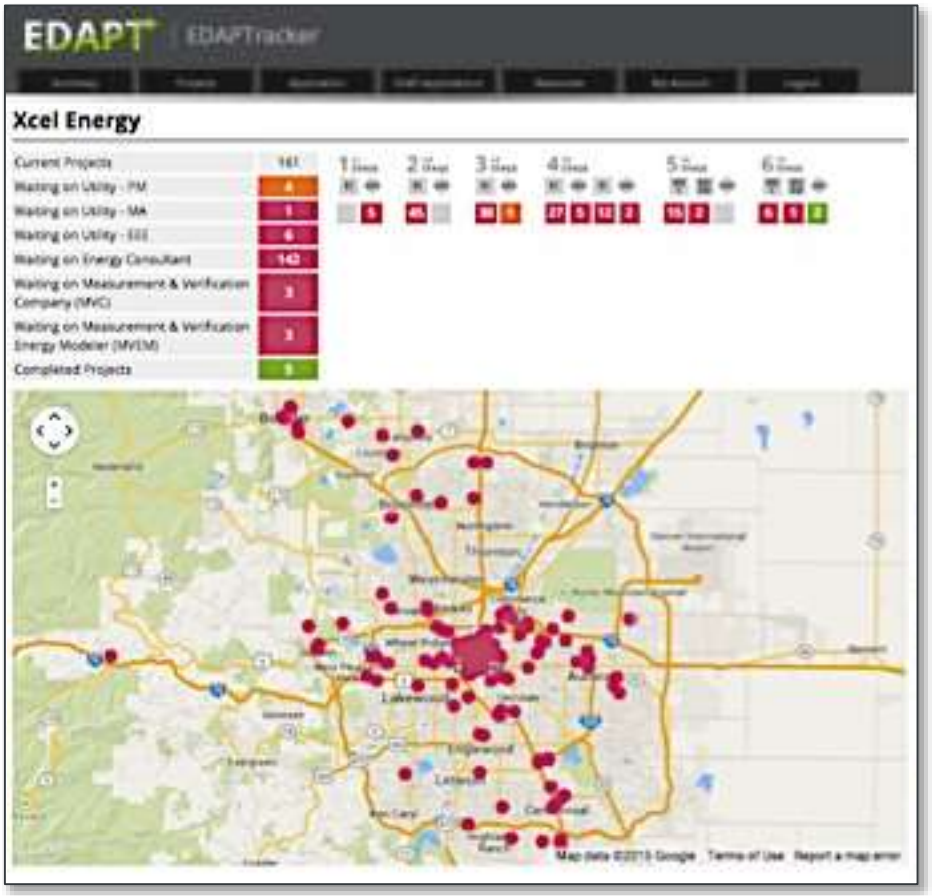
* Percent savings relative to the total energy consumption, 1,516,836kWh.

** Dual enthalpy economizer is not an incentivized measure for Ngrid's MA jurisdiction.

# Utility Application #2 - EDAPT

# Incenting New Construction Efficiency

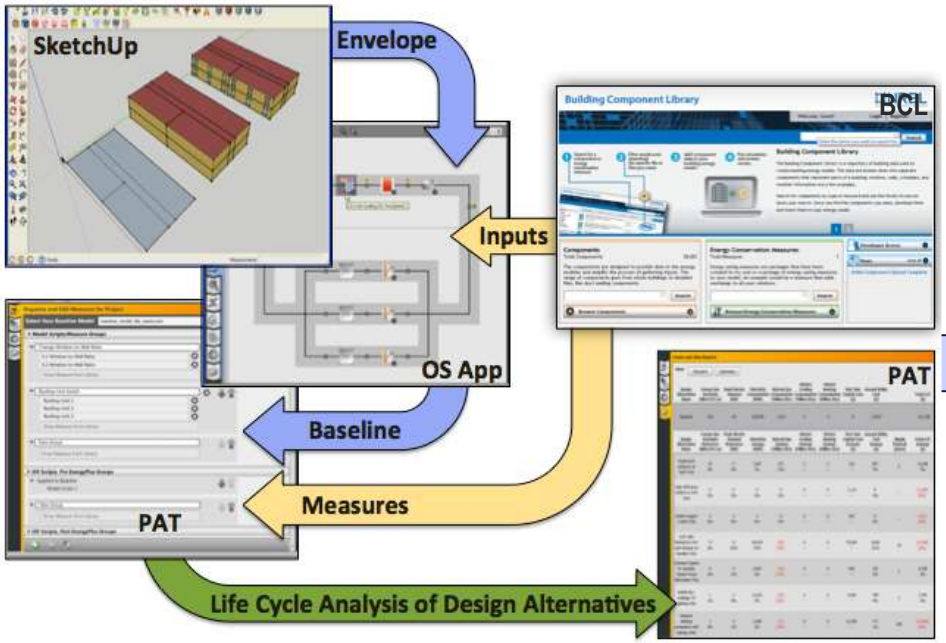
- **Energy Design Assistance (EDA)**
  - Programs are a primary tool to influence efficiency beyond code for new construction

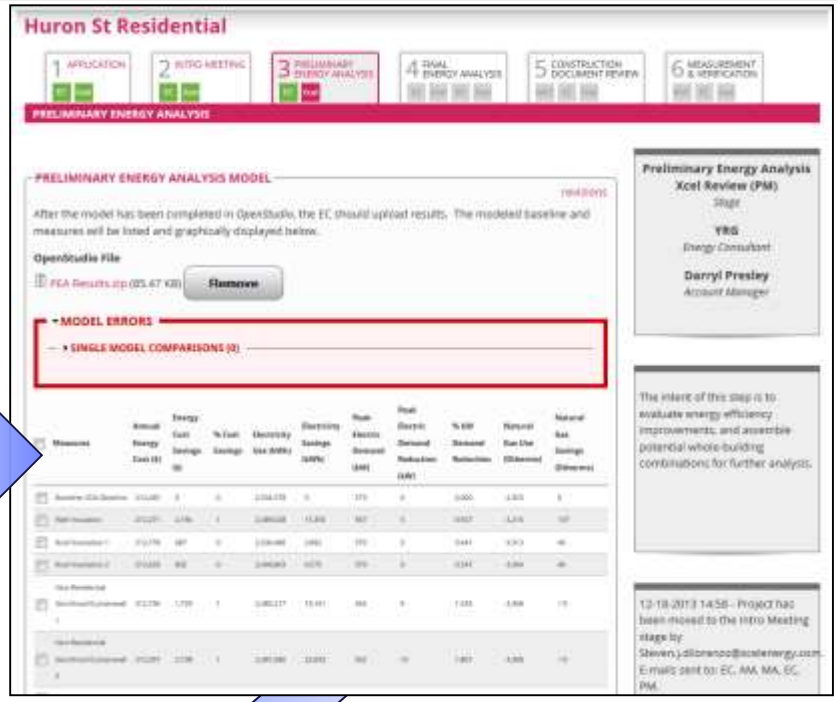



- **Problems:**
  - Viability jeopardized as codes become more stringent
  - Must pass cost effectiveness test
  - Must maintain quality

- **Solution:**
  - Web service tracks projects, manages data and communications, and reports program-wide outcomes
  - OpenStudio provides automated quality and EDA protocol checking
  - EDAPT connects project data with model outcomes to streamline reporting

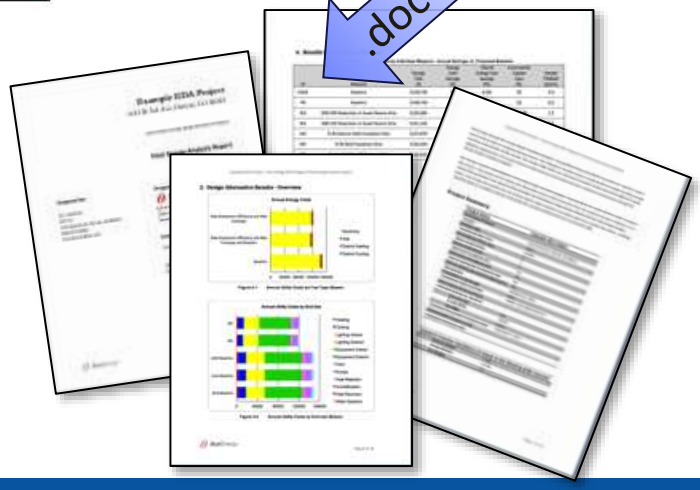
# OpenStudio-EDAPT Integration




.xml

.doc



**Analysis Results and QA/QC checks are uploaded to EDAPT**

**EDAPT automatically documents project data & OpenStudio output**

# Key Xcel Energy Outcomes

- Xcel estimates administrative savings of over $500k per year
- Program now uses 8 energy consultant firms (2 in 2013)
- Currently Over 160 projects in play (70 in 2013)