Visualization and Software Simulations for Actualized Energy Savings

ASHRAE Local Chapter
Jan. 21, 2015

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40 Years: Energy and Quality of Life
A brief history of energy and life quality
Sustainability is the defining challenge

- Buildings in U.S.
  - 41% of primary energy/carbon 73% of electricity, 34% of gas

- Buildings in China
  - 60% of urban building floor space in 2030 has yet to be built

- Buildings in India
  - 67% of all building floor space in 2030 has yet to be built
Energy Consumption and Production

- **U.S. Primary Energy Consumption**
  - Residential Buildings: 28%
  - Commercial Buildings: 22%
  - Industrial: 41%
  - Transportation: 19%
  - Other: 31%

- **Commercial Site Energy Consumption by End Use**
  - Space Heating: 45%
  - Water Heating: 18%
  - Lighting: 6%
  - Space Cooling: 9%
  - Cooking: 4%
  - Refrigeration: 4%
  - Electronics & Computers: 12%
  - HVAC: 32%
  - Other: 13%

- **The Role of Renewable Energy in the Nation’s Energy Supply, 2009**
  - Total = 94.578 Quadrillion Btu
  - Natural Gas: 25%
  - Coal: 21%
  - Nuclear Electric Power: 9%
  - Hydropower: 35%
  - Renewable Energy: 8%
  - Petroleum: 37%

- **World Energy Production**

TN 2012 Electric Bill - $1,533
Presentation summary

• Scientific Paradigms
• Roof Savings Calculator
• Visual Analytics
• Knowledge Work
• Autotune
• Publications
Presentation summary

• Scientific Paradigms (context)
• Roof Savings Calculator
• Visual Analytics
• Knowledge Work
• Autotune
• Publications
4th Paradigm –
The Science behind the Science

• Empirical – guided by experiment/observation
  – In use thousands of years ago, natural phenomena

• Theoretical – based on coherent group of principles and theorems
  – In use hundreds of years ago, generalizations

• Computational – simulating complex phenomena
  – In use for decades

• Data exploration (eScience) – unifies all 3
  – Data capture, curation, storage, analysis, and visualization
  – Jim Gray, free PDF from MS Research
Presentation summary

• Scientific Paradigms
• Roof Savings Calculator
• Visual Analytics
• Knowledge Work
• Autotune
Urban Heat Island Effect and Albedo Engineering

Image from Lawrence Berkeley National Laboratory
Computer tools for simulating cool roofs

Roof Savings Calculator (RSC)

Chris Scruton
CEC

R. Levinson, H. Gilbert, H. Akbari

INDUSTRY

COLLABORATIVE R&D

Marc LaFrance
DOE BT

WBT
Joe Huang, Ender Erdem

A. Desjarlais, W. Miller, J. New

LBNL

ORNL
Roof Savings Calculator

• Replaces:
  – EPA Roof Comparison Calc
  – DOE Cool Roof Calculator

• Minimal questions (<20)
  – Only location is required
  – Building America defaults
  – Help links for unknown information
RSC = AtticSim + DOE-2.1E

AtticSim - ASTM C 1340 Standard For Estimating Heat Gain or Loss Through Ceilings Under Attics
Commercial building types

Office

“Big Box” Retail

Warehouse

RoofCalc.com impact

Dashboard

100,000+ visitors, 200+ user feedback,

Average: ~81 visitors/day
# Nationwide results

Cost savings for offices - 14 cities, local utility prices, 22 roof types

<table>
<thead>
<tr>
<th>Description</th>
<th>Reflectance</th>
<th>Emisivity</th>
<th>SRI</th>
<th>Houston $ saved</th>
</tr>
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<tbody>
<tr>
<td>BUR No Coating</td>
<td>10</td>
<td>90</td>
<td>6</td>
<td>42</td>
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<tr>
<td>Mineral Mod Bit</td>
<td>25</td>
<td>88</td>
<td>25</td>
<td>103</td>
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<tr>
<td>Single Ply</td>
<td>32</td>
<td>90</td>
<td>35</td>
<td>230</td>
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<tr>
<td>Mineral Mod Bit</td>
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<td>279</td>
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<tr>
<td>Mineral Mod Bit</td>
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<td>291</td>
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<tr>
<td>Coating over BUR</td>
<td>49</td>
<td>83</td>
<td>55</td>
<td>433</td>
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<tr>
<td>Metal</td>
<td>49</td>
<td>83</td>
<td>55</td>
<td>208</td>
</tr>
</tbody>
</table>

---

Summer operation of HVAC duct in ASHRAE climate zone 3
Enhanced RSC Site

Input Parameter GUI

Result Output

Database

User

Hyperion

RSC Engine

Savings

Simulation

Exists?

Inputs

Savings

Total Savings: $178

Heating

Cooling

These numbers represent our estimate of your energy costs. You can specify new values and re-calculate.

Electricity price (cents per kWh):

11.68

Natural gas price (dollars per 1000 ft²):

11.65

Re-calculate savings
“We speak piously of … making small studies that will add another brick to the temple of science. Most such bricks just lie around the brickyard.”

RSC Service Example (Python)

```python
client = suds.client.Client('URL/TO/WEB/SERVICE/rsc.wsdl')
print(client)

sm = client.factory.create('schema:soapmodel')
load_soap_model_from_xml('../examplemodel.xml', sm)
sr = client.service.simulate(sm)
print(sr)

sm = client.factory.create('schema:soapmodel')
load_soap_model_from_xml('..examplemodel.xml', sm)
print(sm)
contents = client.service.test(sm)
with open('pytest.zip', 'wb') as outfile:
    outfile.write(base64.b64decode(contents))

...download example building and batch script from rsc.ornl.gov/web-service.shtml
```
Update 1 line of code to change servers

```python
import base64
import suds
import xml.dom.minidom
import logging

#def load_soap_model_from_xml(xmlfilename, soapmodel):

#def load_soap_results_from_xml(xmlfilename, soapresults):

logging.basicConfig()

test_type = ['simulate', 'test', 'upload', 'download']

print("hello there, initializing client")
client = suds.client.Client('http://evenstar.ornl.gov/RSC/service/rsc.wsdl')
print("printing client")
print(client)
raw_input('Press Enter to continue...'+"\n")
```
Millions of simulations visualized for DOE’s Roof Savings Calculator and deployment of roof and attic technologies through leading industry partners

<table>
<thead>
<tr>
<th>DOE: Office of Science</th>
<th>CEC &amp; DOE EERE: BTO</th>
<th>Industry &amp; Building Owners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine (AtticSim/DOE-2) debugged using HPC Science assets enabling visual analytics on $3 \times 10^6$ simulations</td>
<td>Roof Savings Calculator (RSC) web site/service developed and validated [estimates energy and cost savings from roof and attic technologies]</td>
<td>CentiMark, the largest nation-wide roofing contractor (installs 2500 roofs/mo), is integrating RSC into their proposal generating system (20+ companies now interested)</td>
</tr>
</tbody>
</table>

Leveraging HPC resources to facilitate deployment of building energy efficiency technologies
Personal story behind one of DOE’s RSC images

Duct Leakage

Leaky ducts in unconditioned spaces are effectively costing you money to condition the planet, not your house. Commercial buildings have typical leakage rate of 10–20%; likewise, residential buildings typically have duct leakage rates near 14%. The CEC’s Title 24 target leakage rate for inspected ducts is 4% and requires no greater than 6%. This calculator supports duct leakage rates of 4% and 14%.

Leaky Connection  Damaged Duct  Sealed Ducts
Presentation summary

• Scientific Paradigms
• Roof Savings Calculator
• Visual Analytics
• Knowledge Work
• Autotune
PCP - car data set
PCP bin rendering (data)

- Transfer function coloring:
  - Occupancy or leading axis
The power of “and” – linked views (info)

Multivariate Visualization of Large-Scale Parameter Sweeps

Parallel Coordinates Plots

Time-variant Function Plots

Category Charts

Climate Zone Map
Large Data Visualization Knowledge

Large Data Visualization
Outliers (wisdom)

- Selection of heating outliers
- Find all have box building type and in Miami
Presentation summary

• Scientific Paradigms
• Roof Savings Calculator
• Visual Analytics
• Knowledge Work (context)
• Autotune
McKinsey Global Institute Analysis

Exhibit E3
Estimated potential economic impact of technologies from sized applications in 2025, including consumer surplus

$ trillion, annual

<table>
<thead>
<tr>
<th>Technology</th>
<th>Low</th>
<th>High</th>
<th>Impact from other potential applications (not sized)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile Internet</td>
<td></td>
<td>3.7–10.8</td>
<td></td>
</tr>
<tr>
<td>Automation of knowledge work</td>
<td>5.2–6.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>The Internet of Things</td>
<td>2.7–6.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cloud technology</td>
<td>1.7–6.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Advanced robotics</td>
<td>1.7–4.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: McKinsey Global Institute analysis
$1000 machine helping meat machines
Humans and computers

- 3 lbs (2%), 20 watts (20%)
- 120-150 billion neurons
- 100 trillion synapses
  - Firing time ~milliseconds
- 11 million bits/second input
  - Consciousness - 40 bits/second
- Working memory – 4-9 words
- Long-term memory – 1-1k TB
- Complex, self-organizing

- PC – 40 lbs, 500 watts
- 4 cores
- 3 billion Hz
  - Firing time ~nanoseconds
- 100 million bits/second
  - Not yet
- 62,500,000 words
- Disk – 3TB, perfect recall
Learning associations

Full Results

Detailed Results
Presentation summary

• Scientific Paradigms
• Roof Savings Calculator
• Visual Analytics
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• Autotune
Existing tools for retrofit optimization

Simulation Engine
DOE—$65M (1995–?)

API
OpenStudio

EnergyPlus
Business limitations for M&V

3,000+ building survey, 23-97% monthly error

<table>
<thead>
<tr>
<th>Using Monthly utility data</th>
<th>CV(RMSE)</th>
<th>NMBE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASHRAE G14 Requires</td>
<td>15%</td>
<td>5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Using Hourly utility data</th>
<th>CV(RMSE)</th>
<th>NMBE</th>
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</thead>
<tbody>
<tr>
<td>ASHRAE G14 Requires</td>
<td>30%</td>
<td>10%</td>
</tr>
</tbody>
</table>
The Autotune Idea
Automatic calibration of software to data
The search problem

Problem/Opportunity:
~3000 parameters per E+ input file

2 minutes per simulation = 83 hours
ORNL High Performance Computing Resources

**Nautilus:**
1024 cores
4TB shared-memory

**Titan:**
299,008 CPU cores
18,688 GPU cores
710TB memory, distributed

**Jaguar:**
224,256 cores
360TB memory

**Kraken:**
112,896 cores

**Gordon:**
12,608 cores
SSD
HPC scalability for desktop software

- EnergyPlus desktop app
- Writes files during a run
- Uses RAMdisk
- Balances simulation memory vs. result storage
- Works from directory of input files & verifies result
- Bulk writes results to disk

Acknowledgment: Jibo Sanyal, ORNL R&D Staff
Computational complexity

Problems/Opportunities:
Domain experts chose to vary 156
Brute-force = $5 \times 10^{52}$ simulations

E+ parameters

LoKU
13.75 billion years

Need $4.1 \times 10^{28}$ LoKU
What is artificial intelligence?

• Give it (lots of) data
• It maps one set of data to another
• Paradigms
  – Unsupervised (clustering)
  – Reinforcement (don’t run into wall)
  – Supervised (this is the real answer)
• Methods for doing that… biologically motivated or not
MLSuite: HPC-enabled suite of machine learning algorithms

- Linear Regression
- Feedforward Neural Network
- Support Vector Machine Regression
- Non-Linear Regression
- K-Means with Local Models
- Gaussian Mixture Model with Local Models
- Self-Organizing Map with Local Models
- Regression Tree (using Information Gain)
- Time Modeling with Local Models
- Recurrent Neural Networks
- Genetic Algorithms
- Ensemble Learning

Acknowledgment: UTK computer science graduate Richard Edwards, Ph.D. (advisor Dr. Lynne Parker); now Amazon
MLSuite example

- EnergyPlus – 2-10 mins for an annual simulation

  ![EnergyPlus]

  - All objects in class version 7.0;
  - Simulation control: no, do zone sizing calc; no, do system sizing calc;
  - ~E+ - 4 seconds AI agent as surrogate model, 90x speedup, small error, brittle

- ~E+ - 4 seconds AI agent as surrogate model, 90x speedup, small error, brittle
“the world is the best model of itself.”
– Rodney Brooks, 1990, Elephants and nouvelle AI

Nouvelle AI. A robot should sense and then move according to simple rules such as “Avoid collisions” or “Wander.”
Source of Input Data

- 3 Campbell Creek homes (TVA, ORNL, EPRI)

- ~144 sensors/home, 15-minute data:
  - Temperature (inside/outside)
  - Plugs
  - Lights
  - Range
  - Washer
  - Radiated heat
  - Dryer
  - Refrigerator
  - Dishwasher
  - Heat pump air flow
  - Shower water flow
  - Etc.
MLSuite Architecture

Data Preparation

30x LS-SVMs
validation folds 1-10
input orders 1-3
Applications of machine learning

• Linear Regression predicting whole building energy use

House 1 (House 2 is similar)

House 3

House 3 Next hour

• Accuracy Metrics for best subset of sensors

\[
RMSE = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N} (y_i - p_i)^2}
\]

\[
MAPE = \frac{1}{N} \sum_{i=1}^{N} \frac{|y_i - p_i|}{y_i}
\]

\[
CV = \frac{RMSE}{y_{mean}} \times 100
\]

\[
MBE = \frac{1}{N-1} \sum_{i=1}^{N} (y_i - p_i) \times 100
\]

<table>
<thead>
<tr>
<th></th>
<th>HME FFNN</th>
<th>HME LS-SVM</th>
<th>SVR</th>
<th>FCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE(Watt-Hours)</td>
<td>569.96±50.13</td>
<td>582.61±33.97</td>
<td>603.85±40.55</td>
<td>581.87±41.67</td>
</tr>
<tr>
<td>MAPE(%)</td>
<td>17.07±1.19</td>
<td>15.94±0.92</td>
<td>15.48±0.87</td>
<td>17.37±1.02</td>
</tr>
<tr>
<td>CV(%)</td>
<td>20.14±1.65</td>
<td>20.59±1.12</td>
<td>21.32±1.32</td>
<td>20.56±1.37</td>
</tr>
<tr>
<td>MBE(%)</td>
<td>0.42±1.17</td>
<td>-0.07±0.89</td>
<td>-1.50±0.80</td>
<td>0.01±0.99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Best Four Sensors</th>
<th>Best Model</th>
<th>Top 10 Sensors</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMSE</td>
<td>1127.88±33.00</td>
<td>942.25±26.14</td>
<td>1129.04±32.38</td>
</tr>
<tr>
<td>MAPE</td>
<td>41.17±1.12</td>
<td>30.53±1.03</td>
<td>40.4483±1.29</td>
</tr>
<tr>
<td>CV</td>
<td>39.76±1.02</td>
<td>33.21±0.73</td>
<td>39.80±0.96</td>
</tr>
<tr>
<td>MBE</td>
<td>-0.04±0.90</td>
<td>-0.06±0.92</td>
<td>-0.05±1.05</td>
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<tr>
<td>ICOMP(IFIM)</td>
<td>2166.3±1.54</td>
<td>1845.88±21.25</td>
<td>2125.50±2.72</td>
</tr>
</tbody>
</table>
MLSuite: HPC-enabled Suite of Machine Learning algorithms

• Linear regression
• Feedforward neural network
• Support vector machine regression
• Non-linear regression
• K-means with local models
• Gaussian mixture model with local models

• Self-organizing map with local models
• Regression tree (using information gain)
• Time modeling with local models
• Recurrent neural networks
  • Genetic algorithms
  • Ensemble learning
## Evolutionary computation

How are offspring produced?

<table>
<thead>
<tr>
<th></th>
<th>Thickness</th>
<th>Conductivity</th>
<th>Density</th>
<th>Specific Heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bldg1</td>
<td>0.022</td>
<td>0.031</td>
<td>29.2</td>
<td>1647.3</td>
</tr>
<tr>
<td>Bldg2</td>
<td>0.027</td>
<td>0.025</td>
<td>34.3</td>
<td>1402.5</td>
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<tr>
<td>(1+2)₁</td>
<td>0.0229</td>
<td>0.029</td>
<td>34.13</td>
<td>1494.7</td>
</tr>
<tr>
<td>(1+2)₂</td>
<td>0.0262</td>
<td>0.024</td>
<td>26.72</td>
<td>1502.9</td>
</tr>
</tbody>
</table>

- Average each component
- Add Gaussian noise
- … “AI inside of AI”
Getting more for less

- EnergyPlus is slow
  - Full-year schedule
  - 2 minutes per simulation

- Use abbreviated 4-day schedule instead
  - Jan 1, Apr 1, Aug 1, Nov 1
  - 10 – 20 seconds per simulation

\[ r = 0.94 \quad \text{Monthly Electrical Usage} \]
\[ r = 0.96 \quad \text{Hourly Electrical Usage} \]
Evolutionary combination

4 of 19 experiments
1. Surrogate Modeling
2. Sensor-based Energy Modeling (sBEM)
3. Abbreviated Schedule
4. Island-model evolution
Automated M&V process Autotune calibration of simulation to measurements

XSEDE and DOE Office of Science

DOE-EERE BTO

Industry and building owners

Leveraging HPC resources to calibrate models for optimized building efficiency decisions

Features:
Works with “any” software
Tunes 100s of variables
Customizable distributions
Matches 1+ million points

Commercial Buildings

ASHRAE G14 Requires

<table>
<thead>
<tr>
<th></th>
<th>Monthly utility data</th>
<th>Hourly utility data</th>
</tr>
</thead>
<tbody>
<tr>
<td>CVR</td>
<td>15%</td>
<td>30%</td>
</tr>
<tr>
<td>NMBE</td>
<td>5%</td>
<td>10%</td>
</tr>
</tbody>
</table>

Residential home

Tuned input avg. error

Within $30/\text{day}$
(actual use $4.97/\text{day}$)

Hourly – 8%
Monthly – 15%

10+ companies interested
HPC-informed algorithmic reduction... to commodity hardware

LoKU
13.75 billion years

Need $4.1 \times 10^{28}$ LoKU

1 hour
That’s great, but how can I use it?

**Autotune**

**Home**  | **About**  | **Contact Us**
--- | --- | ---

**Introduction to Autotune**

Autotune can save time, effort, and money in modeling a building. Autotune uses a rough estimate of the building and real data to create models that more closely represent the building. All you have to do is get started with one of the setups and you can soon have models of your building.

**About This Website**

Autotune is designed to make the modeling process easier. You can start designing your model through the basic or advanced setup. If you have already completed the setup, you can enter your tracking number into the tracking box to review the progress of your order or download models if any are available.

*Enjoy the simplistic power of Autotune!*

**Create a model for your building**

**Basic Setup**

The basic setup is designed with simplicity in mind. If you have only the basic knowledge of the building, this is the choice of setup for you.

---

**Advanced or Experienced Setup**

The advanced setup is for those who are very knowledgeable with the specifications of the building. This setup will provide the most customized model and will result in quicker, more accurate results.

---

**IDF Generation**

| Timestep | 1 |
| Run Number | 1 |
| Floor Height | 3.9624 |
| Plenums | True |
| Orientation | 0.0 |
| Geometry Configuration | Rectangle |
| Zone Layout | Five Zone |
| Roof Style | Flat |
| Wall Type | Steel Frame Non Res |
| Roof Type | IEAD Non Res |
| South WWR | 0.477 |
| East WWR | 0.477 |
| North WWR | 0.477 |
| West WWR | 0.477 |
| South Window Type | Reference |
| East Window Type | Reference |
| North Window Type | Reference |
| West Window Type | Reference |
| HVAC Type | VAV |
| Heating Coil | Gas |
| Has Reheat | True |
| Reheat Coil | Electric |

60+ fields (optional)
Determine inputs to calibrate

<table>
<thead>
<tr>
<th></th>
<th>Restaurant</th>
<th>Hospital</th>
<th>Large Hotel</th>
<th>Large Office</th>
<th>Medium Office</th>
<th>Midrise Apartment</th>
<th>Primary School</th>
<th>Quick Service</th>
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<tbody>
<tr>
<td><strong>#Inputs</strong></td>
<td>49</td>
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<td><strong>#Groups</strong></td>
<td>49</td>
<td>146</td>
<td>71</td>
<td>45</td>
<td>38</td>
<td>82</td>
<td>113</td>
<td>54</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Secondary School</th>
<th>Small Hotel</th>
<th>Small Office</th>
<th>Stand-alone Retail</th>
<th>Strip Mall</th>
<th>Super Market</th>
<th>Warehouse</th>
<th>TOTAL</th>
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<tr>
<td><strong>#Inputs</strong></td>
<td>231</td>
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<td><strong>#Groups</strong></td>
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<table>
<thead>
<tr>
<th>Class</th>
<th>Object</th>
<th>Field</th>
<th>Default</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Distribution</th>
<th>Type</th>
<th>Group</th>
<th>Constraint</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Lights</td>
<td>Bakery_Lights</td>
<td>Watts per Zone</td>
<td>18.29</td>
<td>12.803</td>
<td>23.777</td>
<td>uniform</td>
<td>float</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Lights</td>
<td>Deli_Lights</td>
<td>Watts per Zone</td>
<td>18.29</td>
<td>12.803</td>
<td>23.777</td>
<td>uniform</td>
<td>float</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>ElectricEquipment</td>
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</table>
Provide actual data

Select location

Current Selection: Chicago, IL

Input Data

Electricity

Have a file containing energy usage:
Choose File No file chosen
Sample File: Monthly Sample, Hourly Sample

OR

Energy usage from previous months:

<table>
<thead>
<tr>
<th>January</th>
<th>February</th>
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<tbody>
<tr>
<td>Energy Usage kWh</td>
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<tr>
<td>March</td>
<td>April</td>
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<td>Energy Usage kWh</td>
<td>Energy Usage kWh</td>
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<tr>
<td>May</td>
<td>June</td>
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<tr>
<td>Energy Usage kWh</td>
<td>Energy Usage kWh</td>
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<td>July</td>
<td>August</td>
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<tr>
<td>Energy Usage kWh</td>
<td>Energy Usage kWh</td>
</tr>
<tr>
<td>September</td>
<td>October</td>
</tr>
<tr>
<td>Energy Usage kWh</td>
<td>Energy Usage kWh</td>
</tr>
</tbody>
</table>

Gas

Temperature

Tune

You have completed all the steps of the wizard!
Click Tune below to Submit your Information

Email Address (optional):
Autotune returns calibrated model

### Metric

<table>
<thead>
<tr>
<th>Metric</th>
<th>Value</th>
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<tr>
<td>Input error average</td>
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<tr>
<td>Input error maximum</td>
<td>66.12</td>
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<td>Input error minimum</td>
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<tr>
<td>Input error variance</td>
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### CV(RMSE)

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<td>CO2:Facility <a href="Monthly">kg</a></td>
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<td>Carbon Equivalent:Facility <a href="Monthly">kg</a></td>
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<td>Cooling:Electricity <a href="Hourly">J</a></td>
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### NMBE

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143+ outputs
## Performance and availability

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<th>Monthly utility data</th>
<th>ASHRAE G14 Requires</th>
<th>Autotune Results</th>
<th>Monthly utility data</th>
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<td>NMBE</td>
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<td>0.35%</td>
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</table>

Results from 24 Autotune calibrations  
(3 building types - 8, 34, 79 tuned inputs each)  
Results from 20,000+ Autotune calibrations  
(15 types – 47-282 tuned inputs each)  

FY15 project to begin integration of Autotune web service as an OpenStudio application  
Free to use. Pay for cloud computing.
Discussion

Oak Ridge National Laboratory
EESD – Martin Keller
ETSD – Johney Green
BTRIC – Patrick Hughes & Ed Vineyard
WBCI – Melissa Lapsa

Joshua New, Ph.D.
newjr@ornl.gov