2016 Winter Conference

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Seminar 59 - Simulation Calibration Methods: Which Should I Choose?

Autotune Calibration and Trinity Test Evaluation

Orlando, Florida

Learning Objectives

1. Provide an overview of different techniques of calibration
2. Describe Bayesian calibration methods
3. Describe a method of test for evaluating the efficacy of model calibration techniques
4. **Describe the working of online Trinity Test web service**

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Acknowledgments

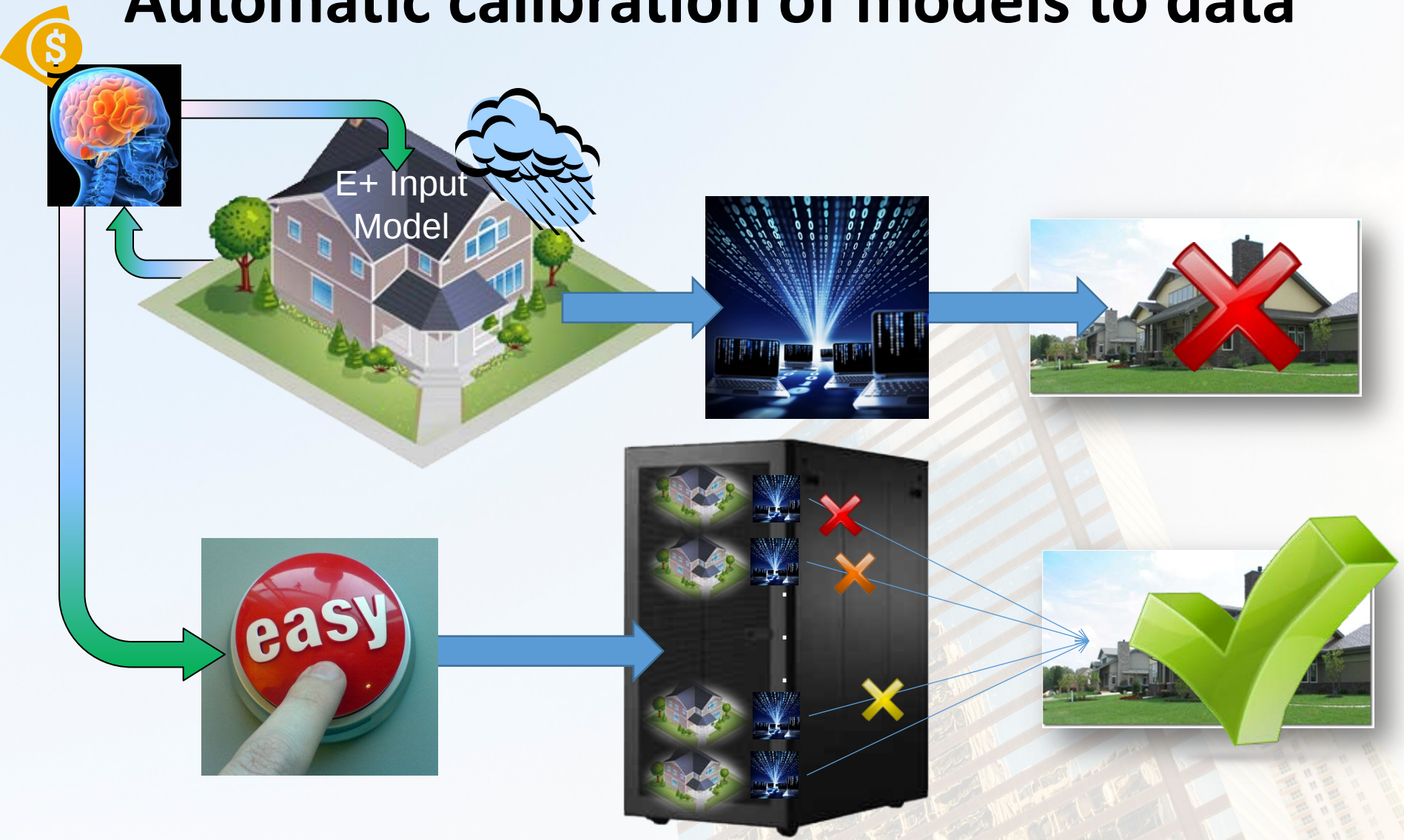
- Amir Roth – DOE BTO
- Laboratory Directed R&D – ORNL
- Innovative and Novel Computation Impact on Theory and Experiment (INCITE)
- Oak Ridge Leadership Computing Facility (OLCF)
- Extreme Science and Engineering Discovery Environment (XSEDE)
- Aaron Garrett – JSU
- Jibonananda Sayal, Som Shrestha, Mahabir Bhandari, Charles Castello – ORNL
- Richard Edwards, Lynne Parker – UT
- Buzz Karpay – Karpay Associates
- Zheng O'Neill – UA

Outline/Agenda

- Autotune
  - What is it?
  - How good is it?
  - How can I use it?
- Trinity Test
  - Quantified performance of any calibration
  - Large-scale calibration studies
- Which should you use?

Autotune

Automatic calibration of models to data



Supercomputers for Buildings

- Titan is the world's #1 fastest buildings energy model (BEM) simulator
- 500,000+ EnergyPlus building simulations in less than an hour
- 125.1 million U.S. buildings could be simulated in 2 weeks
- 8 million simulations for DOE ref. buildings
- 270TB of simulation data

CPU Cores	Wall-clock Time (mm:ss)	Data Size	EnergyPlus Simulations
16	18:14	5 GB	64
32	18:19	11 GB	128

65,536	44:52	23 TB	262,144
131,072	68:08	45 TB	524,288

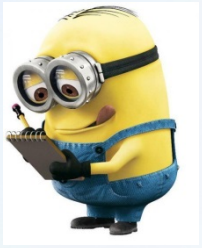
Suite of Machine Learning

- Linear Regression
- Non-Linear Regression
- Feedforward Neural Network
- Support Vector Machine 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 (combinations of multiple algorithms)

Integrated mixture of Commercial, Research, and Open Source software

MLSuite Architecture

Data Preparation

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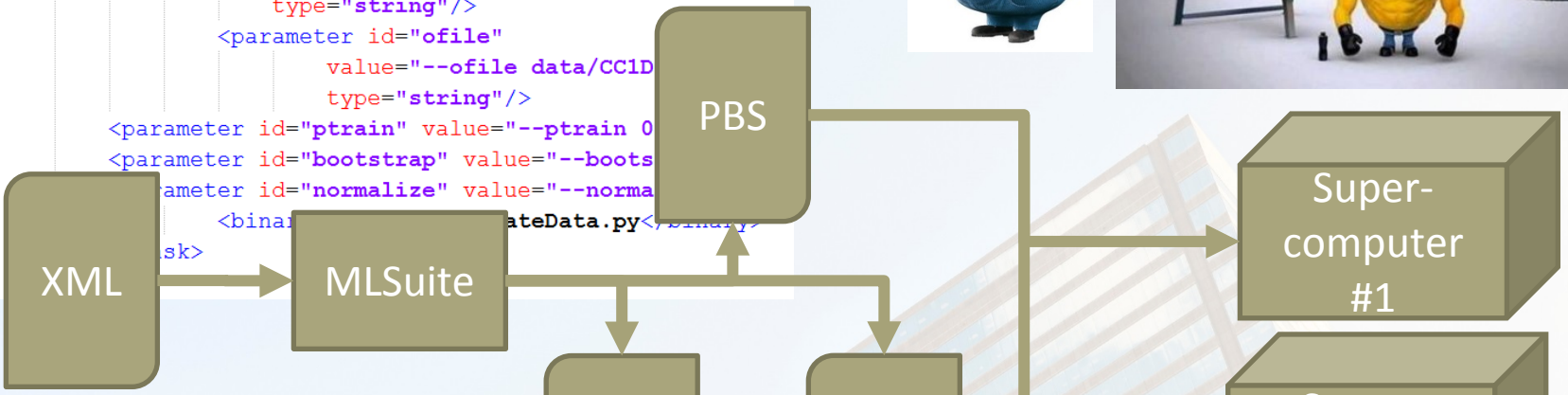
        <parameter id="ofile"
            value="--ofile data/CC1D
            type="string"/>
    <parameter id="ptrain" value="--ptrain 0
    <parameter id="bootstrap" value="--boots
        ameter id="normalize" value="--norma
        <binar                    ateData.py</
    sk>
```




```
    <Task>
    •••
    </Task>
</Job>
```

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        r id="data" value=                    mat"/>
        r id="output"
        alue="--ofile results/LSSVM/CC1/"/>
    <parameter id="fold" value="--fold" type="string"/>
    <parameter id="foldv" value="1" maxvalue="10" step="1"
        type="numeric"/>
    <parameter id="order" value="--order" type="string"/>
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        type="numeric"/>
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    <binary path="">Launch.py</binary>
```
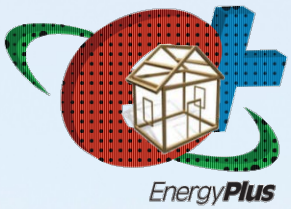
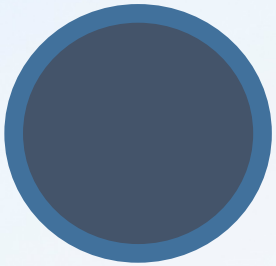

30x LS-SVMs

validation folds 1-10

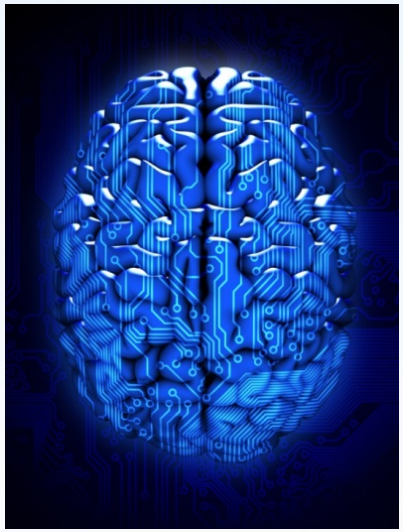
input orders 1-3

Evolutionary Process



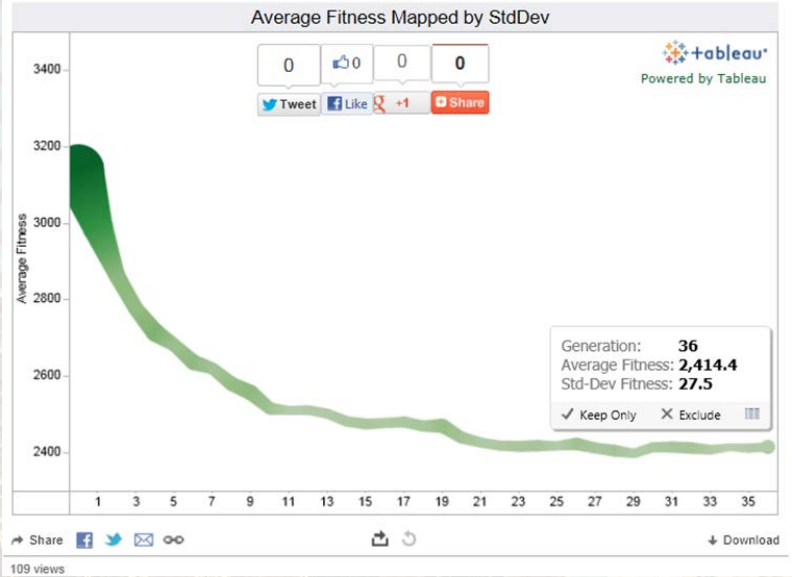


Island Hopping



Winner: NSGA-II
(settings, architecture, and other optimizations)

Allows timely, robust calibration with a low error rate to measured data

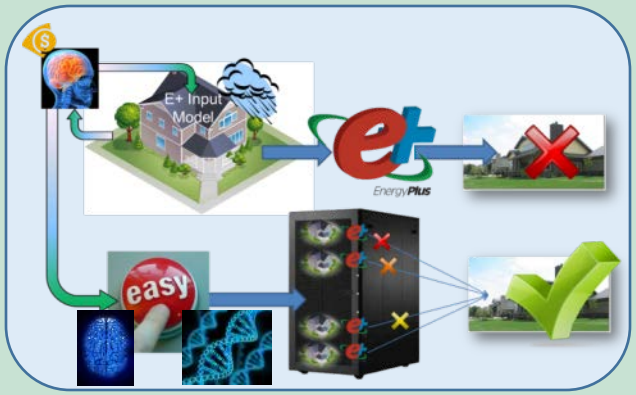


Autotune Performance

DOE Office of Science → **DOE-EERE: BTO** → **Industry and building owners**

High Performance Computing

- Different calibration algorithms
- Machine learning – big data mining
- Large-scale calibration tests



Features

- Calibrate any model to data
- Calibrates to the data you have (monthly utility bills to submetering)
- Runs on a laptop and in the cloud

- 30+ Publications: **`http://bit.ly/autotune_papers`**
- Open source (GitHub): **`http://bit.ly/autotune_code`**

Results

		ASHRAE G14 Requires
Monthly utility data	CVR	15%
	NMBE	5%
Hourly utility data	CVR	30%
	NMBE	10%

Results of 20,000+ Autotune calibrations
(15 types, 47-282 tuned inputs each)

Other error metrics

Residential home	Tuned input avg. error
Within 30¢/day (actual use $4.97/day)	Hourly – 8% Monthly – 15%
	3 bldgs, 8-79 inputs

Leveraging HPC resources to calibrate models for optimized building efficiency decisions

Performance and Availability

		ASHRAE G14 Requires	Autotune Results
Monthly utility data	CVR	15%	0.32%
	NMBE	5%	0.06%
Hourly utility data	CVR	30%	0.48%
	NMBE	10%	0.07%

Results from 24 Autotune calibrations
(3 building types - 8, 34, 79 tuned inputs each)

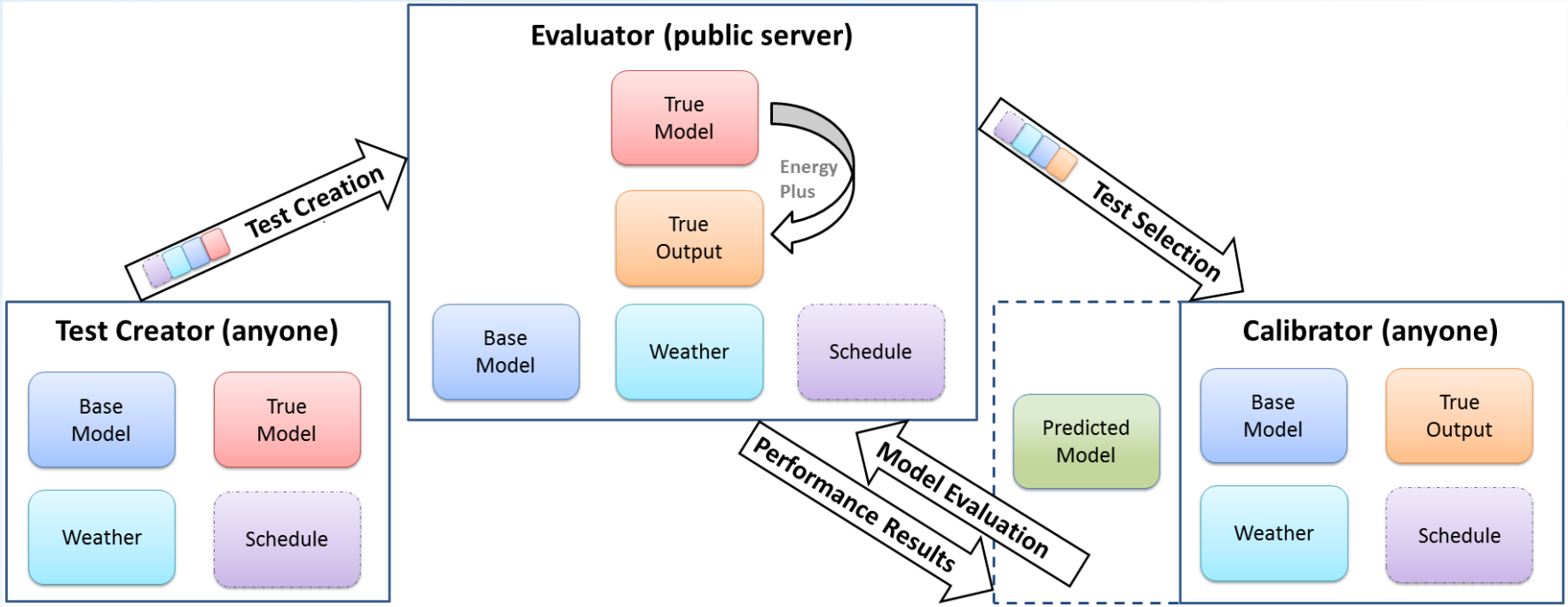
		ASHRAE G14 Requires	Autotune Results
Monthly utility data	CVR	15%	1.20%
	NMBE	5%	0.35%
Hourly utility data	CVR	30%	3.65%
	NMBE	10%	0.35%

Results from 20,000+ Autotune calibrations
(15 types – 47-282 tuned inputs each)

Open source on GitHub:
http://bit.ly/autotune_code
Standalone demo and Vagrant/VirtualBox image

FY15 project on indefinite hold for integrating Autotune web service as OpenStudio application
Free to use. Pay for cloud computing.

Trinity Test – what is it?



- "True" model – defined by the user for a specific test case; the answer key used to quantify accuracy of the calibrated model
- Calibration (edits) – simulation output as a surrogate for measured data

Advantages

- Reproducibility!
  - No specific, unique buildings of interest
  - No unshared data used for calibration
  - No different metrics
  - No focus on only simulation output
- Proliferation in calibration literature
  - Necessarily unique
  - Largely irreplicable
  - Essentially incomparable

Limitations

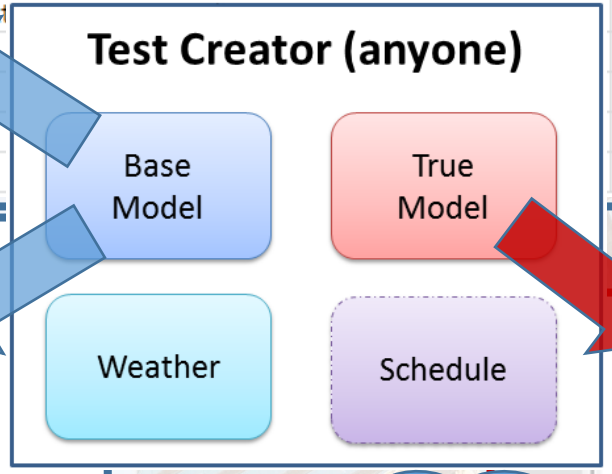
- Cleanroom approach which has removed all “noise” from the calibration process
  - No: sensor drift, missing data, utility data measured at different times, unaccounted for occupancy/behavior changes, model/form uncertainty (but can allow study)
- Allows use of any weather file (TMY)
  - For real-world application, you need AMY data
- No mapping of simulation output to measured data
  - Temperature gradients: what point is “Temp. of N wall?”
- No sensor placement/material issues
- Test results equally weight all inputs/outputs, even though some matter more than others

Results

	A	B	C	D	E	F	G	H	I	J
1	Class	Object	Field	Default	Minimum	Maximum	Distribution	Type	Group	Constraint
2	Lights	Bakery_Lights	Watts per Zone	18.29	12.803	23.777	uniform	float		
3	Lights	Deli_Lights	Watts per Zone	18.29	12.803	23.777	uniform	float		
4	ElectricEquipment	Bakery_MiscPlug_Ec	Design Level	11244	7870.8	14617.2	uniform	float		
5	ElectricEquipment	Deli_MiscPlug_Equi	Design Level	12105	8473.5	15736.5	uniform	float		
6	GasEquipment	Bakery_MiscGas_Eq	Design Level	5622	3935.4	7308.6	uniform	float		
7	GasEquipment	Deli_MiscGas_Equip	Design Level	6053	4237.1	7868.9	uniform	float		
8	Exterior:Lights	Exterior Facade Ligh	Design Level	13577	9503.9	17650.1	uniform	float		
9	ZoneInfiltration:Desig	Bakery_Infiltration	Flow per Exteri	0.000302	0.000211	0.000393	uniform	float	G0001	
10	ZoneInfiltration:Desig	Deli_Infiltration	Flow per Ex					float	G0001	
11	Schedule:Compact	CLGSETP_SCH	Field 4					float	CA1	
12	Schedule:Compact	CLGSETP_SCH	Field 7					float	CA2	HA2 - CA2 < - 1
13	Schedule:Compact	CLGSETP_SCH	Field 9					float	CA3	HA3 - CA3 < - 1
14	Schedule:Compact	CLGSETP_SCH	Field 11					float	CA4	HA4 - CA4 < - 1

IDF + CSV ⇔ XML

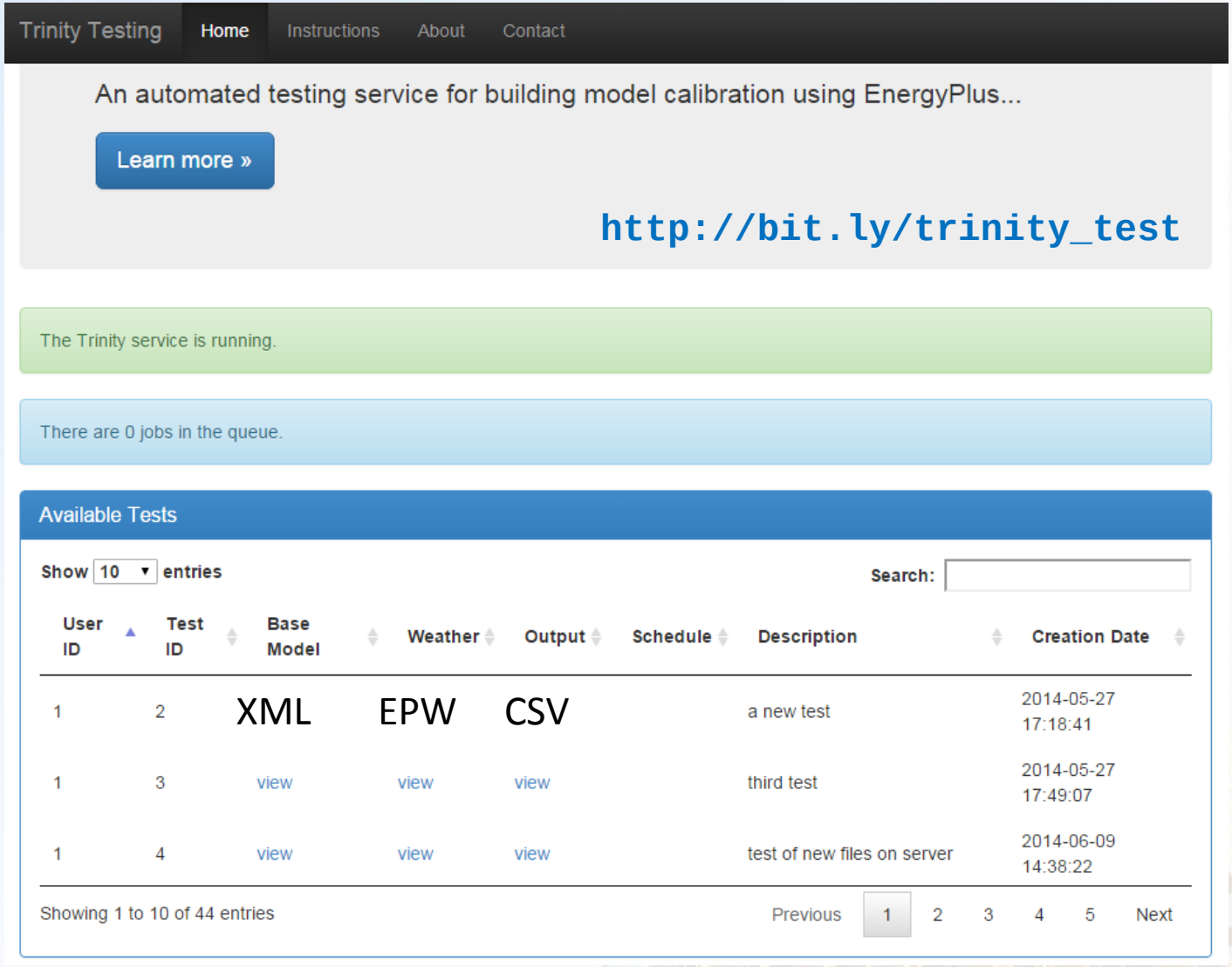
```
<Material>
    <Name>
        Metal Siding
    </Name>
    <Roughness>
        Smooth
    </Roughness>
    <Thickness tuneType="float"
               tuneMin="0" tuneMax="0.5"
               tuneDistribution="uniform"
               tuneGroup="A"
               tuneConstraint="A+B&lt;1">
        0.005
    </Thickness>
```



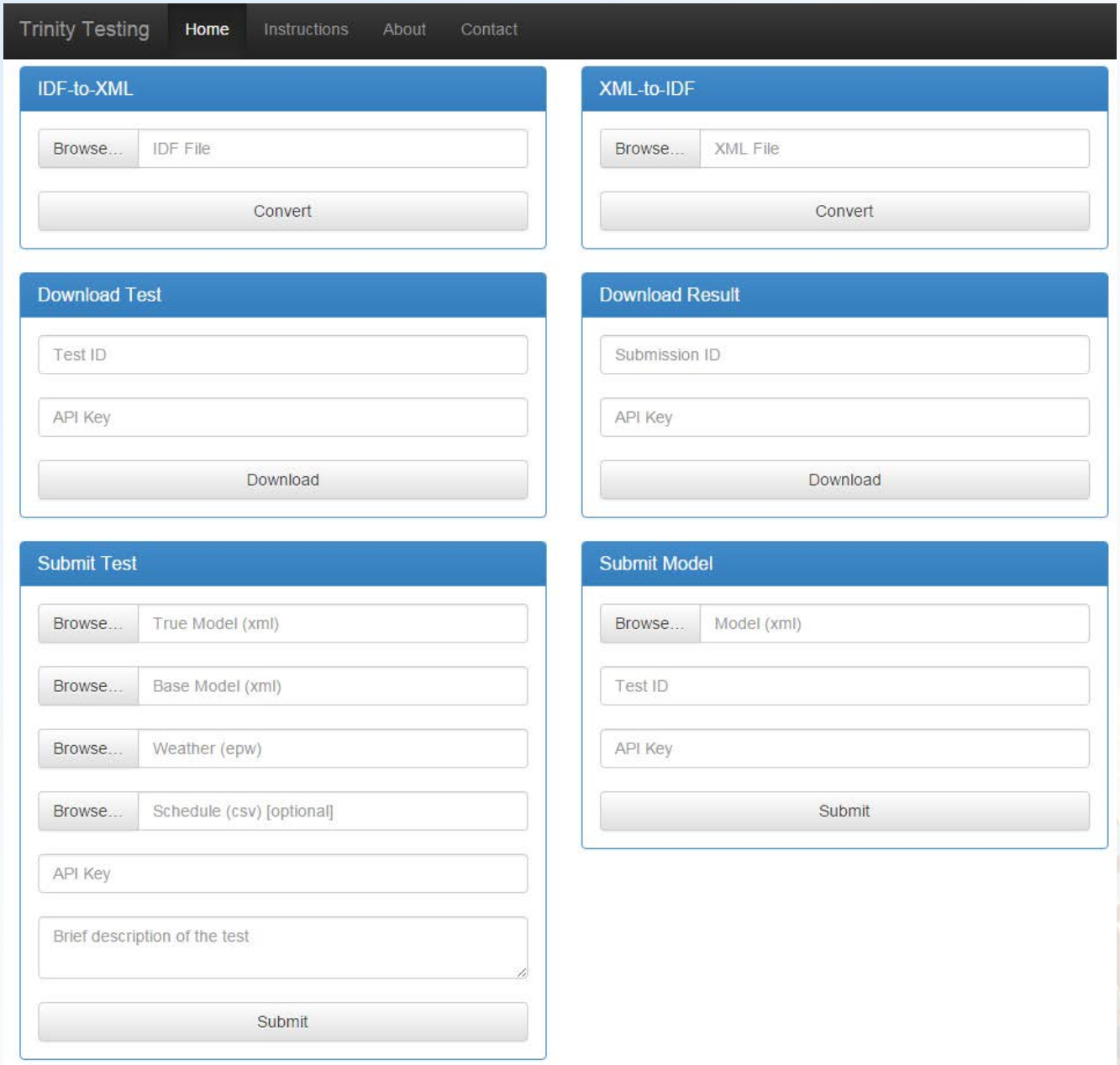
Thickness of metal siding?
Calibrator: Between 0 and 0.5 and less than 1-B
Oracle: 0.055

```
<Material>
    <Name>
        Metal Siding
    </Name>
    <Roughness>
        Smooth
    </Roughness>
    <Thickness>
        0.055
    </Thickness>
```

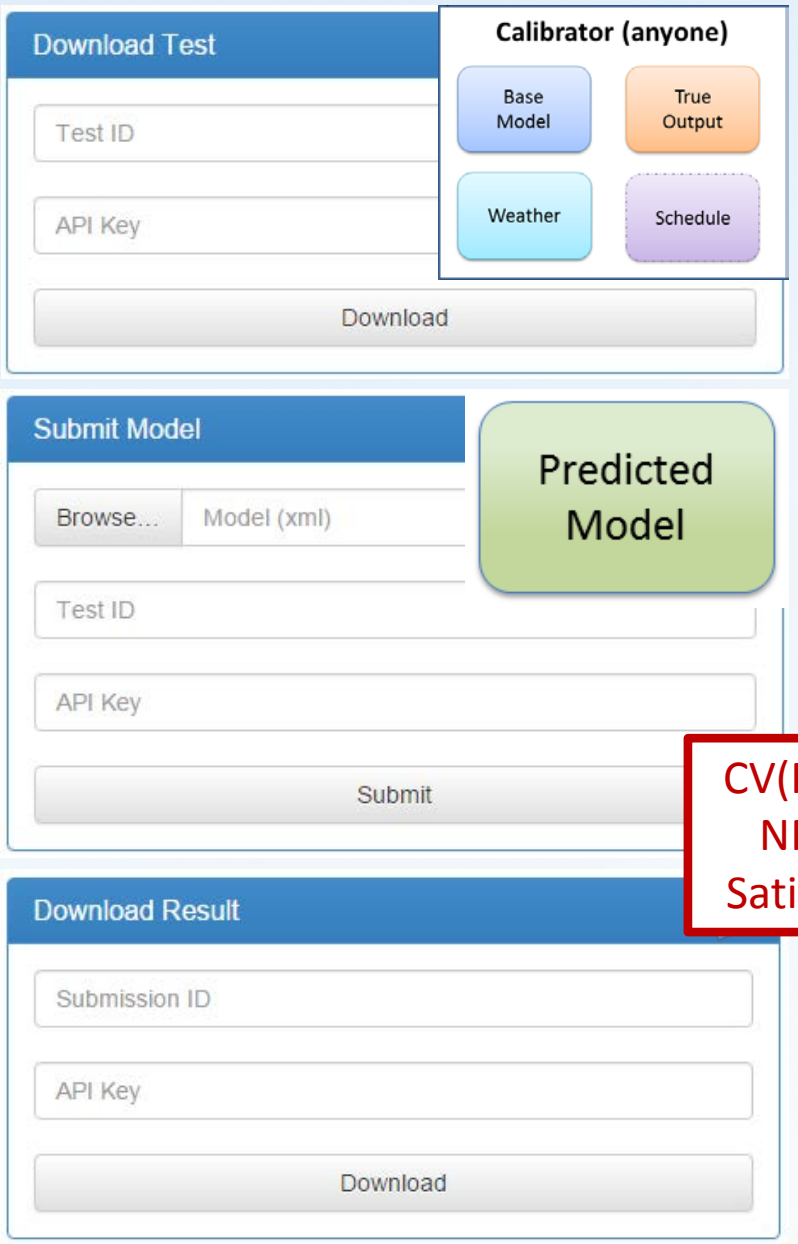
Website


Trinity Testing
Home
Instructions
About
Contact
An automated testing service for building model calibration using EnergyPlus...
Learn more »
http://bit.ly/trinity_test
The Trinity service is running.
There are 0 jobs in the queue.
Available Tests
Show 10 entries
Search:
User ID
Test ID
Base Model
Weather
Output
Schedule
Description
Creation Date
1 2 XML EPW CSV a new test 2014-05-27 17:18:41
1 3 view view view third test 2014-05-27 17:49:07
1 4 view view view test of new files on server 2014-06-09 14:38:22
Showing 1 to 10 of 44 entries
Previous 1 2 3 4 5 Next

Website/service



Results



Metric	Value
Input error average	24.38
Input error maximum	66.12
Input error minimum	0.09
Input error variance	228.53
CV(RMSE)	
CH4:Facility [kg](Monthly)	9.95
CO2:Facility [kg](Monthly)	15.42
CO:Facility [kg](Monthly)	20.40
Carbon Equivalent:Facility [kg](Monthly)	14.42
Cooling:Electricity [J](Hourly)	1577.96
Electricity:Facility [J](Hourly)	10.48
…	
acility [kg](Monthly)	-9.57
acility [kg](Monthly)	-14.78
cility [kg](Monthly)	-19.52
Carbon Equivalent:Facility [kg](Monthly)	-13.83
Cooling:Electricity [J](Hourly)	592.77
Electricity:Facility [J](Hourly)	-9.52
Electricity:Facility [J](Monthly)	-9.52
143+ outputs	

CV(RMSE)<30%
NMBE<10%
Satisfies G14!!!

20,000 Model Calibration Study

	Restaurant	Hospital	Large Hotel	Large Office	Medium Office	Midrise Apartment	Primary School	Quick Service
#Inputs	49	227	110	85	81	155	166	54
#Groups	49	139	67	43	36	78	109	54

	Secondary School	Small Hotel	Small Office	Stand-alone Retail	Strip Mall	Super Market	Warehouse	TOTAL
#Inputs	231	282	72	59	113	78	47	1809
#Groups	122	131	58	55	85	72	44	1142

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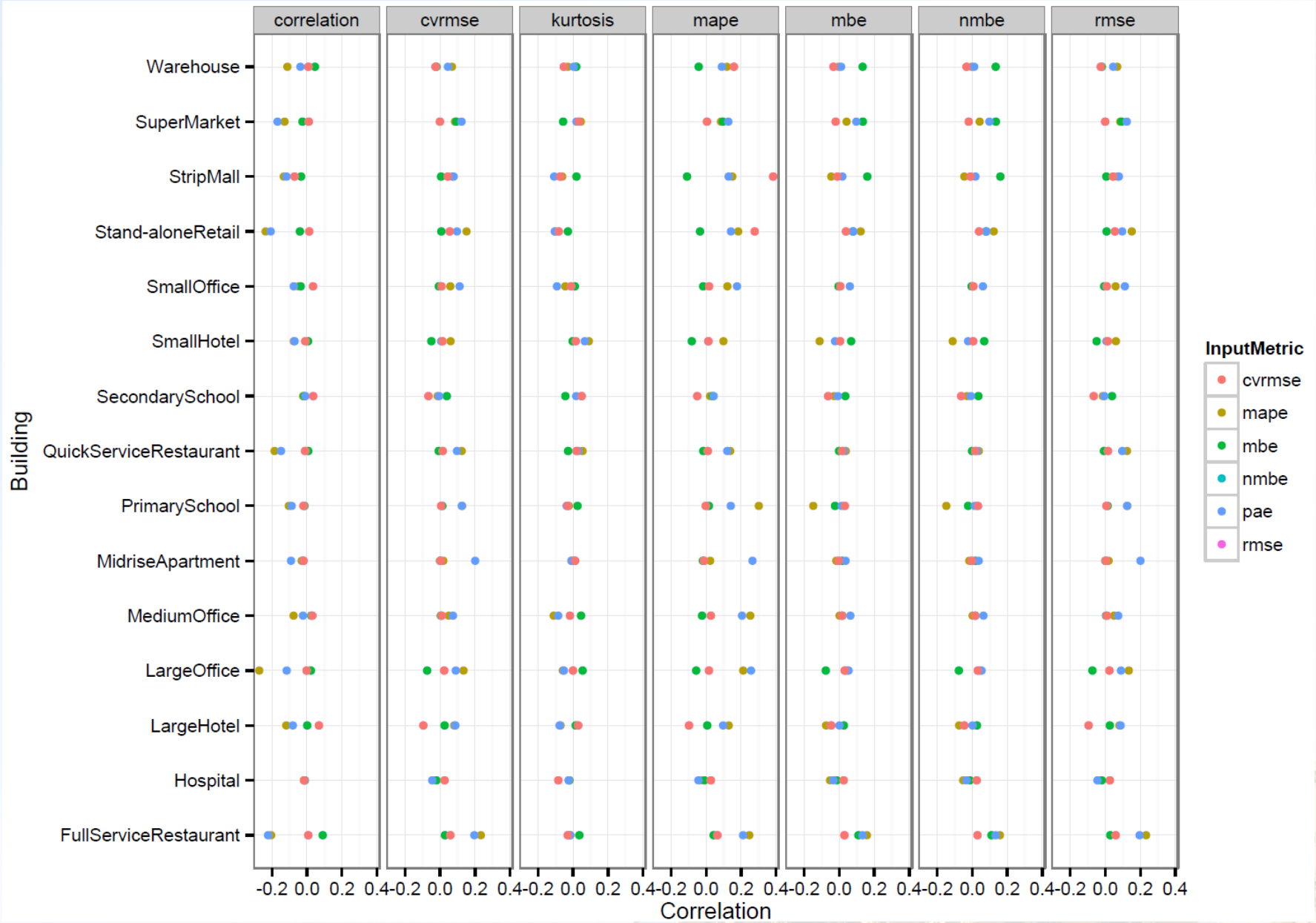
13	Schedule:Compact	CLGSETP_SCH	Field 9	24	16.8	31.2	uniform	float	CA3	HA3 - CA3 < - 1
14	Schedule:Compact	CLGSETP_SCH	Field 11	30	21	39	uniform	float	CA4	HA4 - CA4 < - 1
15	Schedule:Compact	HTGSETP_SCH	Field 4	15.6	10.92	20.28	uniform	float	HA1	
16	Schedule:Compact	HTGSETP_SCH	Field 7	15.6	10.92	20.28	uniform	float	HA2	
17	Schedule:Compact	HTGSETP_SCH	Field 9	21	14.7	27.3	uniform	float	HA3	
18	Schedule:Compact	HTGSETP_SCH	Field 11	15.6	10.92	20.28	uniform	float	HA4	

ASHRAE G14 Metrics Results



Questions?

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