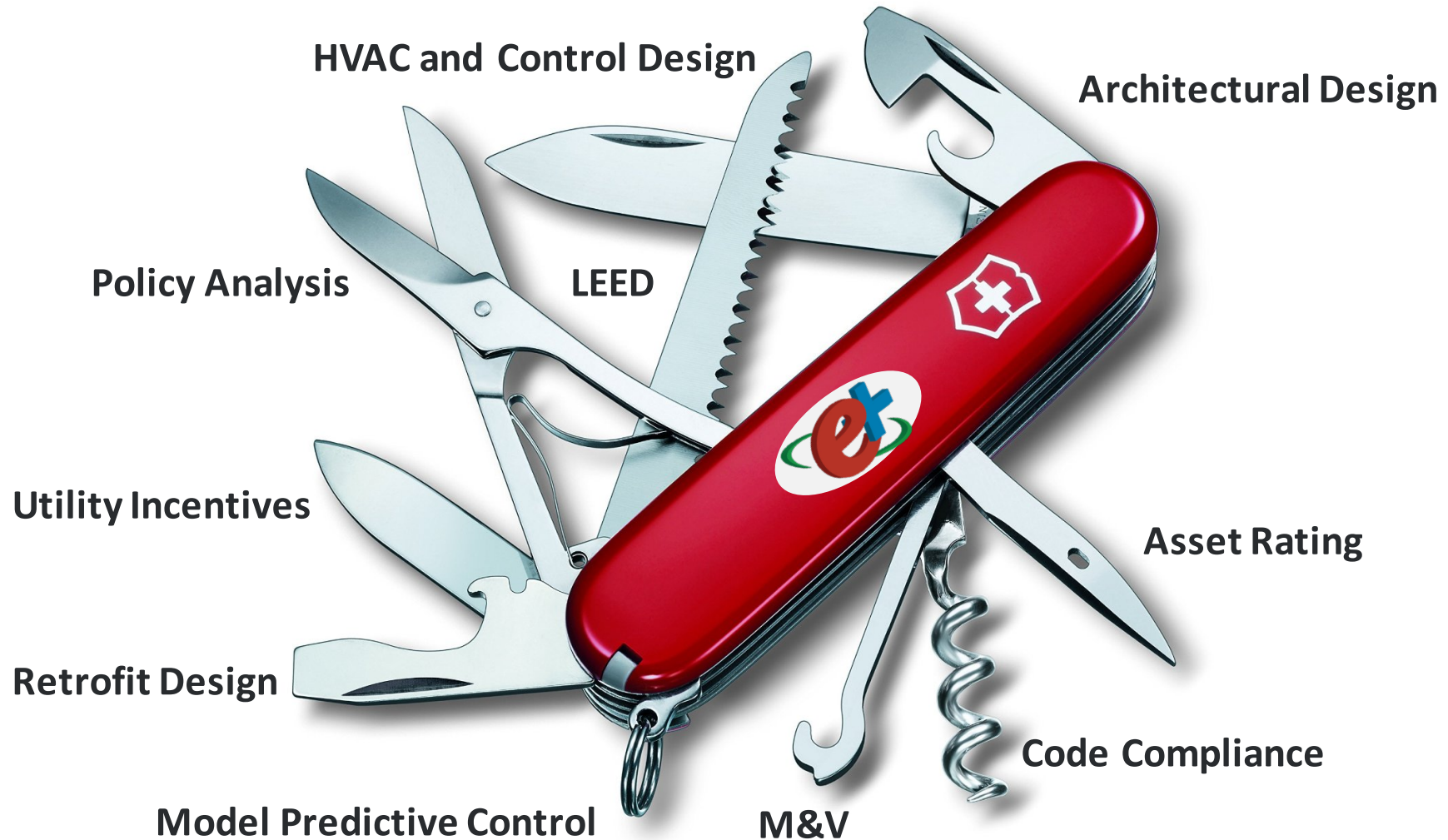


# BTO's Building Energy Modeling Program Overview

BTO Peer Review 2017



# BEM – The Ultimate (Meta) ECM

HVAC and control design

Architectural Design



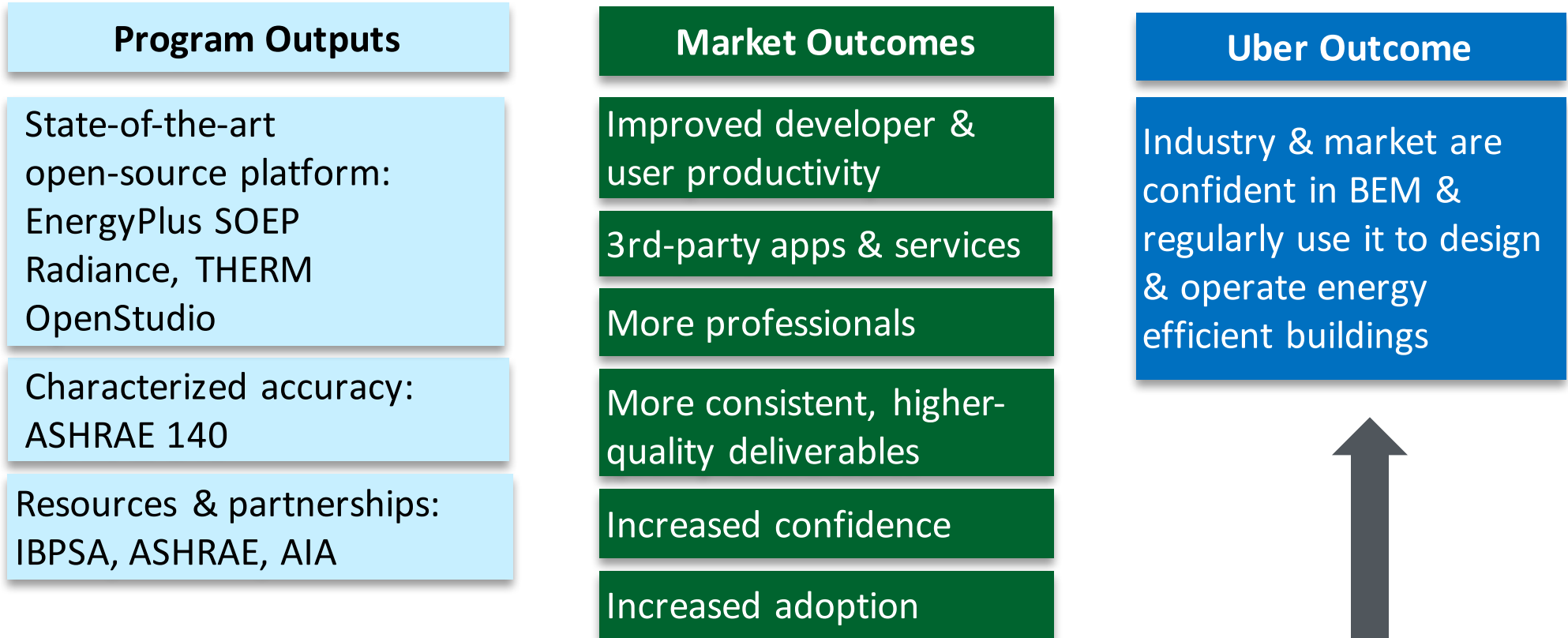
Project Name	% Modeling Fees vs Gross Fees	Annual Modeled Energy Cost Savings	Payback on Modeling Fees in MONTHS
Office Building	0.7%	\$122,876	2
Office Building	0.5%	\$306,692	1
Justice Center	0.8%	\$350,000	3
Convention Hotel	0.6%	\$233,791	1
Regional Hospital	2.4%	\$3,300,000	1
Government Office Building	3.3%	\$186,000	4
Government Building 20	1.1%	\$224,276	2
Cancer & Critical Care Tower	0.6%	\$853,013	3
Institutional Research Center	0.6%	\$340,000	3
Energy Institute	2.5%	\$169,432	7
Institutional Research Facility	1.0%	\$302,169	1
Science Teaching and Research Facility	0.8%	\$419,599	1
Corporate Headquarters	1.0%	\$239,835	4

Source: HOK

## BEM in design

- Potential to save 0.7 quad/year by 2030
- Payback << 1 year and sometimes instantaneous
- <https://energy.gov/eere/buildings/articles/shockingly-short-payback-energy-modeling>

# Logic Model, MYPP, and Goals



$$\begin{array}{|c|} \hline \text{Design \& operation} \\ \hline \text{EUI reduction} \\ \hline \end{array} \times \begin{array}{|c|} \hline \text{App \# \&} \\ \hline \text{productivity} \\ \hline \end{array} \times \begin{array}{|c|} \hline \text{Professional \#} \\ \hline \text{\& productivity} \\ \hline \end{array} \times \begin{array}{|c|} \hline \text{Industry} \\ \hline \text{confidence} \\ \hline \end{array} = \begin{array}{|c|} \hline \text{\% GSF designed} \\ \hline \text{and/or operated} \\ \hline \end{array}$$

## 2020 goals

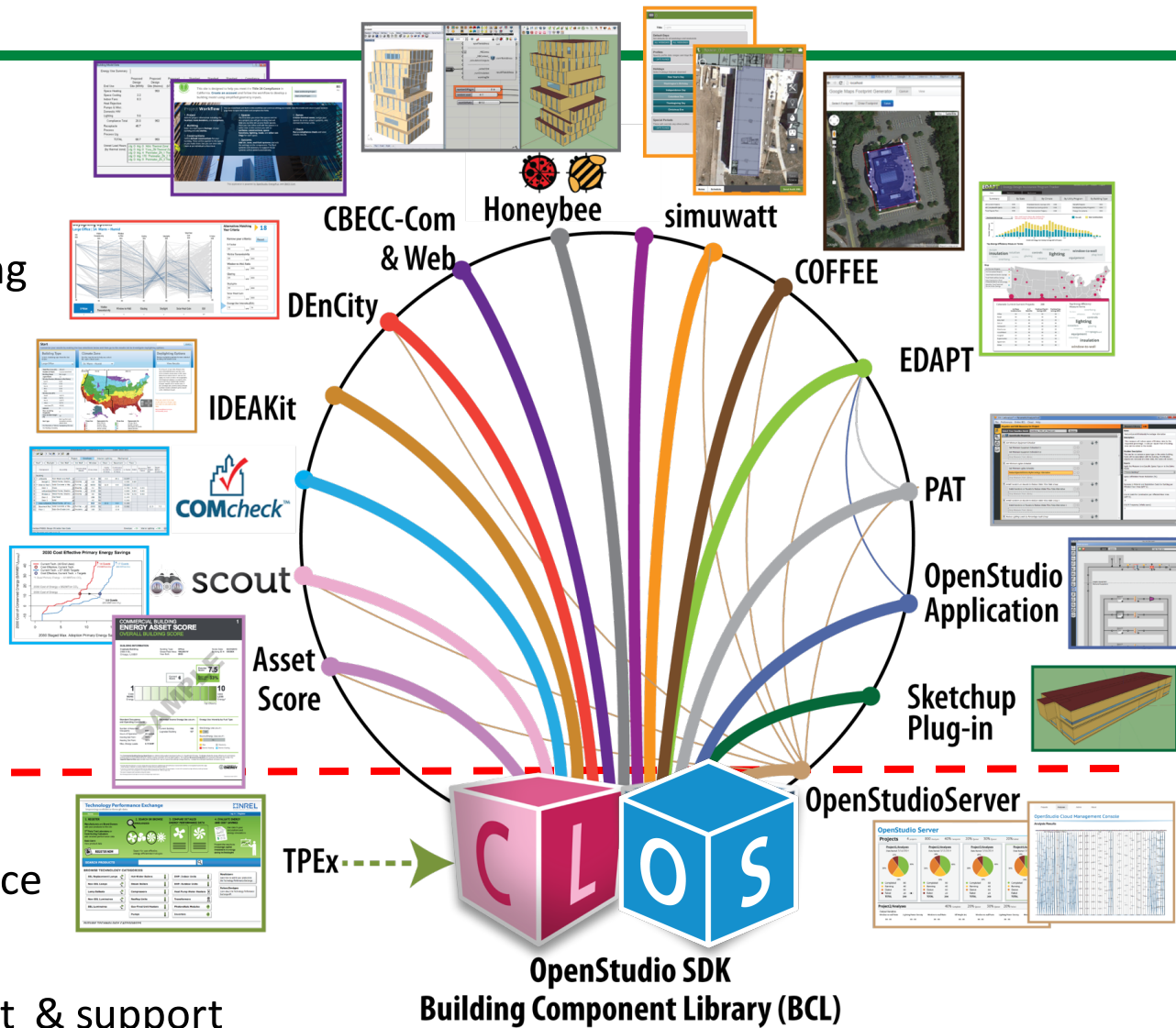
- BEM for new construction GSF: 70% (now: 76%), EnergyPlus: 5% (7%)
- Savings over code: EnergyPlus: 20% (20%)
- 3<sup>rd</sup>-party EnergyPlus tools: 12 (8)

# The Dream-catcher

## Apps: use-case specific

- Open-source or proprietary
- Public, private, or mixed funding

## BEM industry adapting to (& adopting) open-source!



## Platform: general

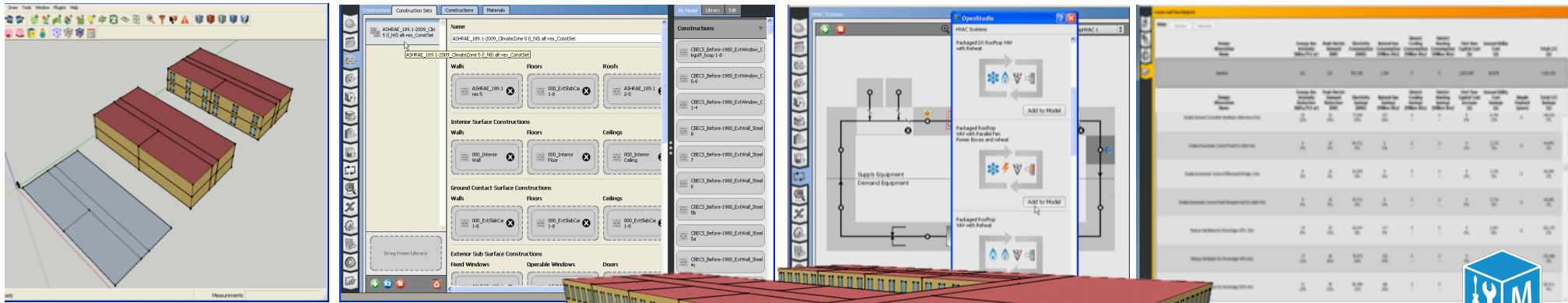
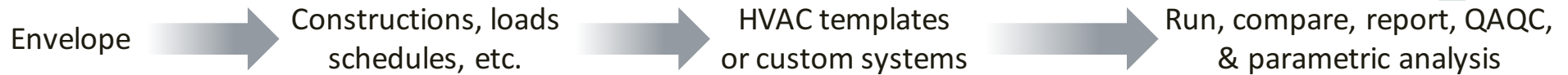
- Commercial-friendly open-source
- State-of-the-art capabilities
- Commercial-grade development & support
- Long-term commitment
- Public funding – transparency & impartiality matter!
- Focus BTO resources here



U.S. DEPARTMENT OF  
**ENERGY**

Energy Efficiency &  
Renewable Energy

# The Platform: EnergyPlus & OpenStudio



## EnergyPlus ([energyplus.net](http://energyplus.net))

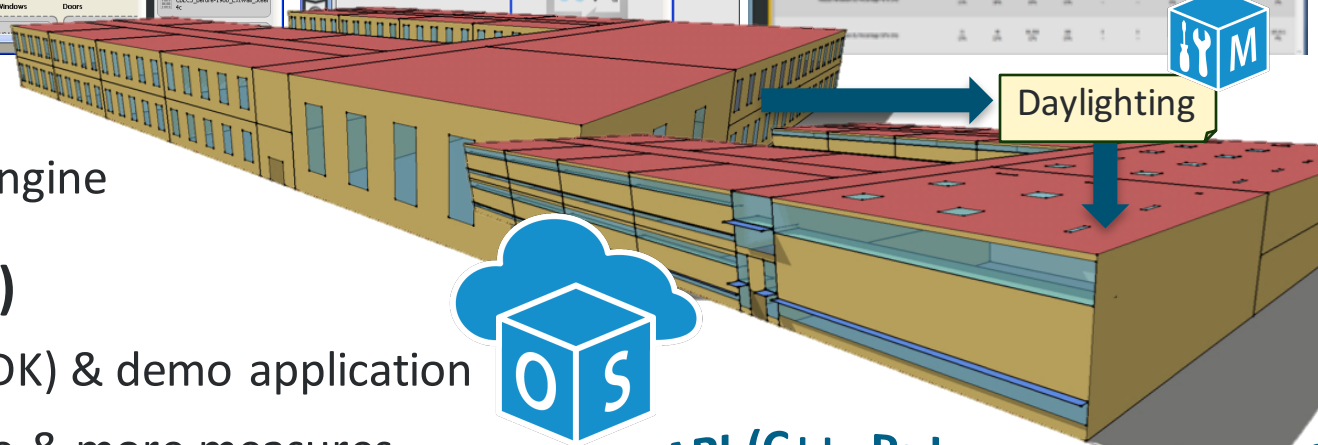
- Industry leading simulation engine

## OpenStudio ([openstudio.net](http://openstudio.net))

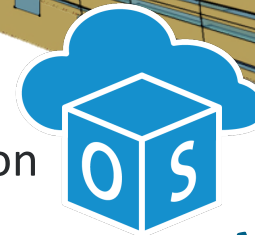
- Software development kit (SDK) & demo application
- Measures, Amazon EC2 image & more measures

## High-value package

- Great offering to market partners (vendors, utilities, etc.)
- Helps streamline BTO's own BEM work
- Serves as template for other BTO BEM projects



Daylighting



API (C++, Ruby, Python, JS, C#)



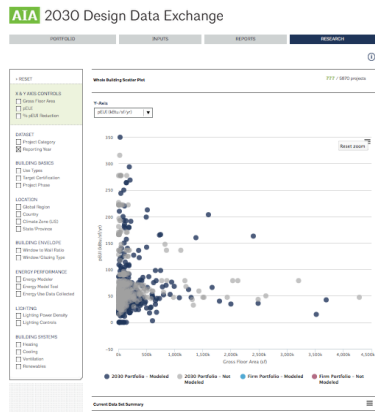
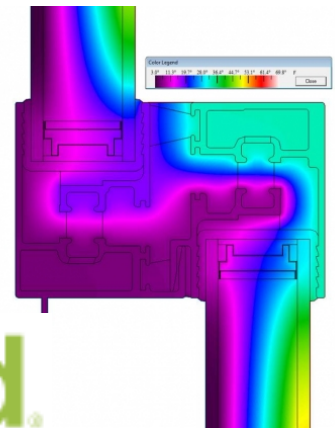
# Today's Agenda

## Program updates (me)

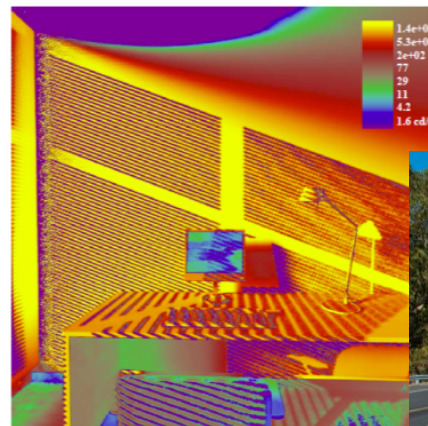
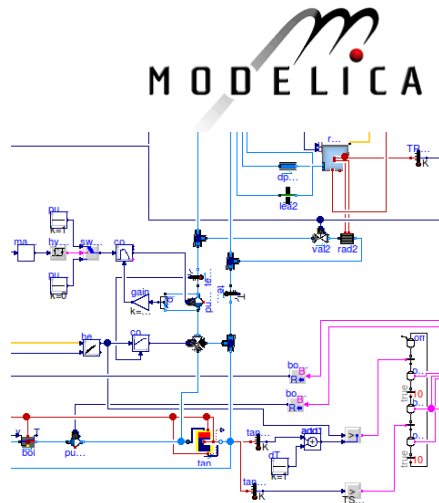
- EnergyPlus and OpenStudio updates – not being reviewed this year
- Program accomplishments & future directions

## Reviews of other projects in portfolio (PIs)

- AIA 2030 DDX – benchmark and tracking BEM in design
- Spawn-of-EnergyPlus (SOEP) – next-generation simulation/controls product
- Validation & Uncertainty Characterization – ground truth
- Fenestration: THERM – thermal characterization of facades
- More fenestration: Radiance – detailed lighting simulation
- NRG & Lucid – helping small businesses develop new capabilities



MODELICA



lucid.

NRGsim   
Energy Systems Simulation



# EnergyPlus Updates



## Data Center

- ITE, CRAC, controls

## Residential

- Ground-coupling, integrated heat-pumps, multiple air-systems per zone, duct radiation
- V8.7 (March 2017) will be MVP (minimum viable product) for residential modeling

## JSON input

- First step in modernizing input, output & error handling

## DOAS configurations

## Shading speedups

## Hybrid Modeling!

**TRAIN INFORMATION** 9:22 time

Time	Number	Train	To	From	Status	Track
9:30	2150	ACELA EXPRESS	BOSTON	WASHINGTON	5mins LATE	8
9:30	1549	METRO-NORTH	GRAND CENTRAL	NEW HAVEN	ON TIME	8
10:10	170	REGIONAL	BOSTON	WASHINGTON	20mins LATE	8
10:10	1551	METRO-NORTH	GRAND CENTRAL	NEW HAVEN	ON TIME	14
10:30	470	REGIONAL	SPRINGFIELD	NEW HAVEN	ON TIME	8
10:43	171	REGIONAL	WASHINGTON	BOSTON	ON TIME	8
10:57	1555	METRO-NORTH	GRAND CENTRAL	NEW HAVEN	ON TIME	8
• SHORELINE EAST TO OLD SAYBROOK DEP 1PM AND 210PM						
• HAVE ALTERNATE BUS TRANSP FROM GREYHOUND BUS LOT						

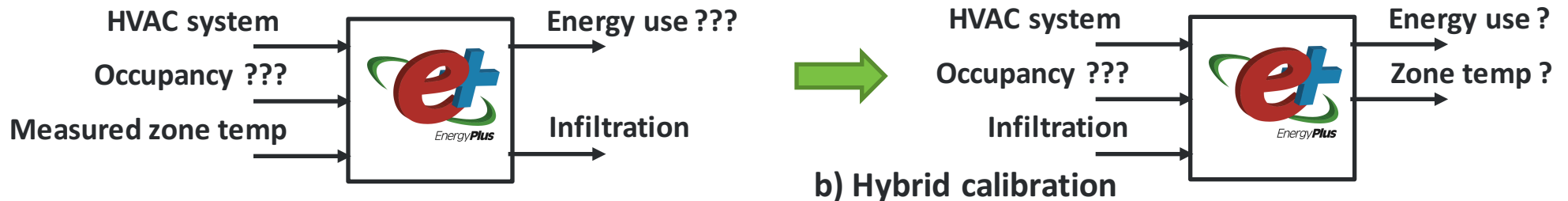
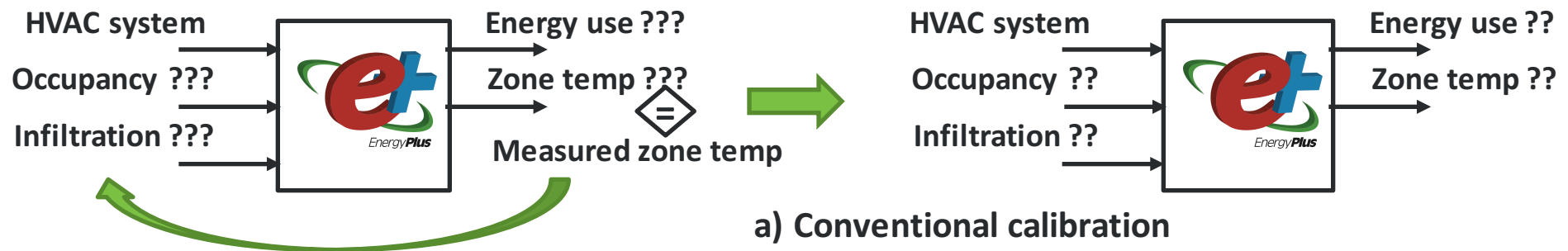
solarisc.udine.italy

# EnergyPlus Updates – “Hybrid Modeling”



## Better Name: “Selective Inverse Modeling” or “Hybrid Calibration”

- Conventional heat-balance (HB) equation calculates zone temperature time series
- Zone temperature time series easy to obtain from BAS & smart thermostats
- Invert HB to take temperature as input ... and calculate one traditional input as output
- Useful when said input is harder to obtain than zone temperature, e.g., infiltration

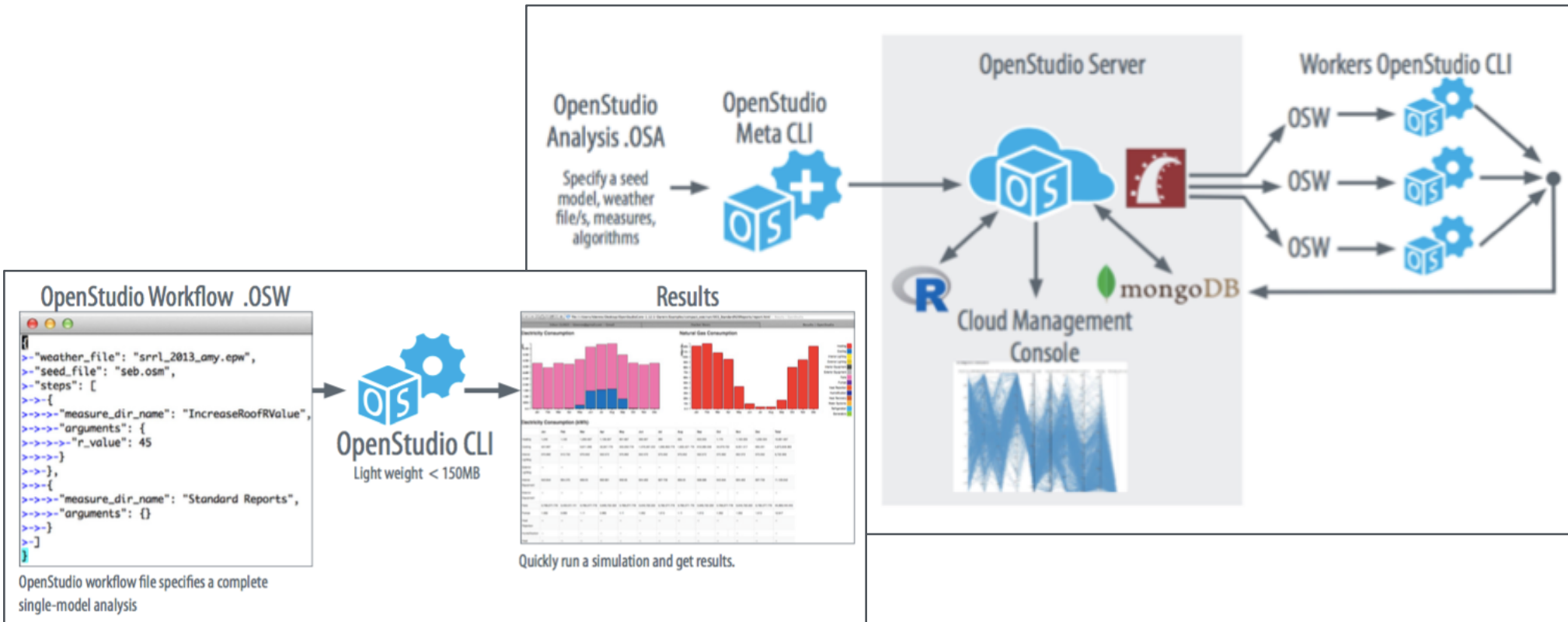


- More accurate than conventional calibration ... and can be combined with it!
- S-H. Lee & T. Hong, “Hybrid Modeling”, Building Simulation 2017.





# OpenStudio Updates – OpenStudio 2.0



## Developer-centric re-factor of OpenStudio 1.X

- Two new file formats: OSW (single model workflows), OSA (large scale analysis)
- Command Line Interface (CLI) – 150 MB self-contained OSW execution machine
- Meta-CLI – OSA → (many) OSW translation machine
- Server 2.0 – elastic, multi-cloud image, runs locally also
- Modular installer – install only the pieces you want
- [.../articles/finally-major-update-openstudio](https://www.energy.gov/articles/finally-major-update-openstudio)



# OpenStudio Updates – PAT 2.0

Name	Seed Model	Location or Weath...	Description	Set Window To W...	Reduce Lighting L...	Rotate
Baseline	Test2.osm	USA_CO_Golden-N...		None	None	None
WWR 0.1	Test2.osm	USA_CO_Golden-N...		WWR 0.1	None	None
WWR 0.2	Test2.osm	USA_CO_Golden-N...		WWR 0.2	None	None
WWR 0.3	Test2.osm	USA_CO_Golden-N...		WWR 0.3	None	None
LPD 50%	Test2.osm	USA_CO_Golden-N...		None	LPD 50%	None
Rot 90	Test2.osm	USA_CO_Golden-N...		None	None	Rot 90



Name	Seed Model	Location or Weath...	Description	Set Window To W...	Reduce Lighting L...	Rotate
Baseline	Test2.osm	USA_CO_Golden-N...		None	None	None
WWR 0.1	Test2.osm	USA_CO_Golden-N...		WWR 0.1	None	None
WWR 0.2	Test2.osm	USA_CO_Golden-N...		WWR 0.2	None	None
WWR 0.3	Test2.osm	USA_CO_Golden-N...		WWR 0.3	None	None
LPD 50%	Test2.osm	USA_CO_Golden-N...		None	LPD 50%	None
Rot 90	Test2.osm	USA_CO_Golden-N...		None	None	Rot 90

Run Run Locally Server Status ✓

Run Entire Workflow Stop Server View Server

Analysis completed

Analysis ID f5a4783d-786f-47fc-8ca9-4e2a02fc27c1 Status completed

Name	Last Run	Run Time	Status	NAs	Warnings	Errors
Baseline	12/1/2016	00:00:50	completed Success	0	0	0
WWR 0.1	12/1/2016	00:00:50	completed Success	0	0	0
WWR 0.2	12/1/2016	00:00:49	completed Success	0	0	0

Reports Summary Table

### Summary Table

Name	Measures	Energy Use Intensity (kBtu/ft2-yr)	Peak Electric Demand (kW)	Electricity Consumption (kWh)	Natural Gas Consumption (Million Btu)	District Cooling Consumption (Million Btu)	Di C (N
Baseline	view_model	88.4	66.10091	202,528.6	775.4	129.7	9t
Name	Measures	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)	Di Si (N
Rot 90	rotate_building	-3.4 -4%	-0.2 0%	-448.1 0%	-0.6 0%	7.9 6%	-7 -7
LPD 50%	reduce_lighting_loads_by_percentage	5.2 6%	12.2 18%	40,827.5 20%	-48.8 -6%	29.6 23%	-2 -2
WWR 0.3	set_window_to_wall_ratio_by_facade view_model	-3.0 -3%	0.2 0%	450.5 0%	-1.2 0%	13.3 10%	-7 -7

## New front-end

- Qt → electron.io (JavaScript in browser)
- Local or web applications
- No dependences (every system has a browser)
- How we will do UI from now on

# OpenStudio Updates – OpenStudio-Standards



## openstudio-standards “gem” ([rubygems.org/gems/openstudio-standards](http://rubygems.org/gems/openstudio-standards))

- Functions for creating & applying ASHRAE 90.1 constructions, schedules, systems, etc.
- Data (insulation levels, equipment efficiencies, etc.) in Excel Spreadsheet

### 1) Create DOE Prototype Building

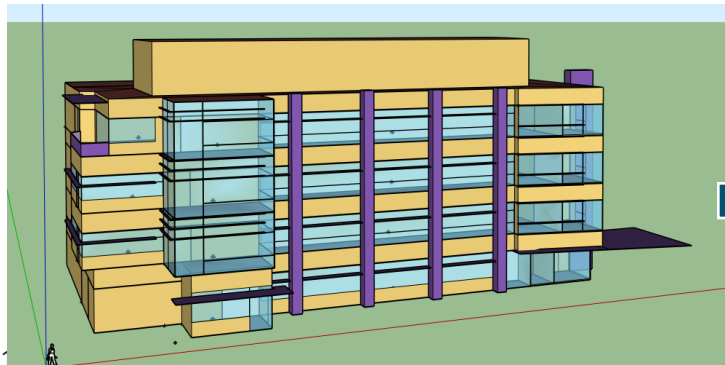
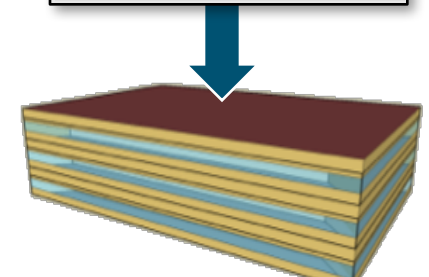
- { Type, CZ, Code-Version } → Prototype-Model

### 2) Create Performance Rating Method Baseline Building

- { Type, CZ, Code-Version, Model } → “Appendix G” Baseline-Model
- Adaptable to other codes: Canada NECB, India ECBC, IECC? Title 24?
- Reduces tedium, confusion, inconsistency, and “cheating”
- Moves effort towards more creative, constructive BEM tasks
- [.../articles/new-openstudio-standards-gem-delivers-one-two-punch](http://.../articles/new-openstudio-standards-gem-delivers-one-two-punch)



<b>Name</b>	Create DOE Prototype Building
<b>Description</b>	Creates the DOE Reference Building Models as starting points for other analyses.
<b>Modeler Description</b>	
<b>Inputs</b>	
Select a Building Type.	MediumOffice
Select a Vintage.	90.1-2013
Select a Climate Zone.	ASHRAE 169-2006-5B



<b>Name</b>	Create Performance Rating Method Baseline Build
<b>Description</b>	Creates the Performance Rating Method baseline building. For 90.1, this is the Appendix G aka LED Baseline. For India ECBC, this is the Appendix D Baseline. Note: for 90.1, this model CANNOT be used.
<b>Modeler Description</b>	
<b>Inputs</b>	
Standard	90.1-2013
Building Type.	SmallOffice
Climate Zone.	ASHRAE 169-2006-2A



# Program Summary & Plans

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## Core funding

- ET: \$4,600k – EnergyPlus, SOEP, ASHRAE 140, Empirical Validation, Fenestration Tools
- CBI: \$1,500k – OpenStudio
- CC: \$500k – AIA 2030, Scout, “Decision Science”

## Starts and stops

- Two BENEFIT projects ending: grey-box RTU models, selective inverse modeling
- Three BENEFIT projects starting: MOISTHERM, OpenBuildingControl, Data Center Toolkit
- Two CBI FOA projects starting: OpenEfficiency, BayREN BRICR

## Forward Emphasis

- Control/operations applications → EnergyPlus-to-SOEP resource shift
- Connectivity with (BTO) data ecosystem
- Connectivity with fenestration/envelope modeling ecosystem
- District- and urban-scale (LDRD) → better communities alliance (BCA)
- More, smaller competitive awards
- Leveraging external resources

# Additional Reading & Writing

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## Since last peer review

- EnergyPlus & OpenStudio exceeding 35,000 downloads per version
- New annual-simulation products from Autodesk & Sefaira
- Re-launch of simuwatt energy auditor
- Launch of NEEA/BetterBricks SPARK
- California utility eTRM moving to EnergyPlus/OpenStudio
- Scout alpha & beta
- New fellow, Janet Reyna ([janet.reyna@ee.doe.gov](mailto:janet.reyna@ee.doe.gov)): large-scale modeling, data-ecosystem



## Resources

- Website: [.../building-energy-modeling/](http://.../building-energy-modeling/) (updated content including “BEM 101” series)
- Blog: [.../end-use-breakdown-building-energy-modeling-blog](http://.../end-use-breakdown-building-energy-modeling-blog)
- MYPP: [.../downloads/multi-year-program-plan](http://.../downloads/multi-year-program-plan) (updates in progress)
- Revised RD&D Roadmap: coming soon-ish
- Email: [amir.roth@ee.doe.gov](mailto:amir.roth@ee.doe.gov)