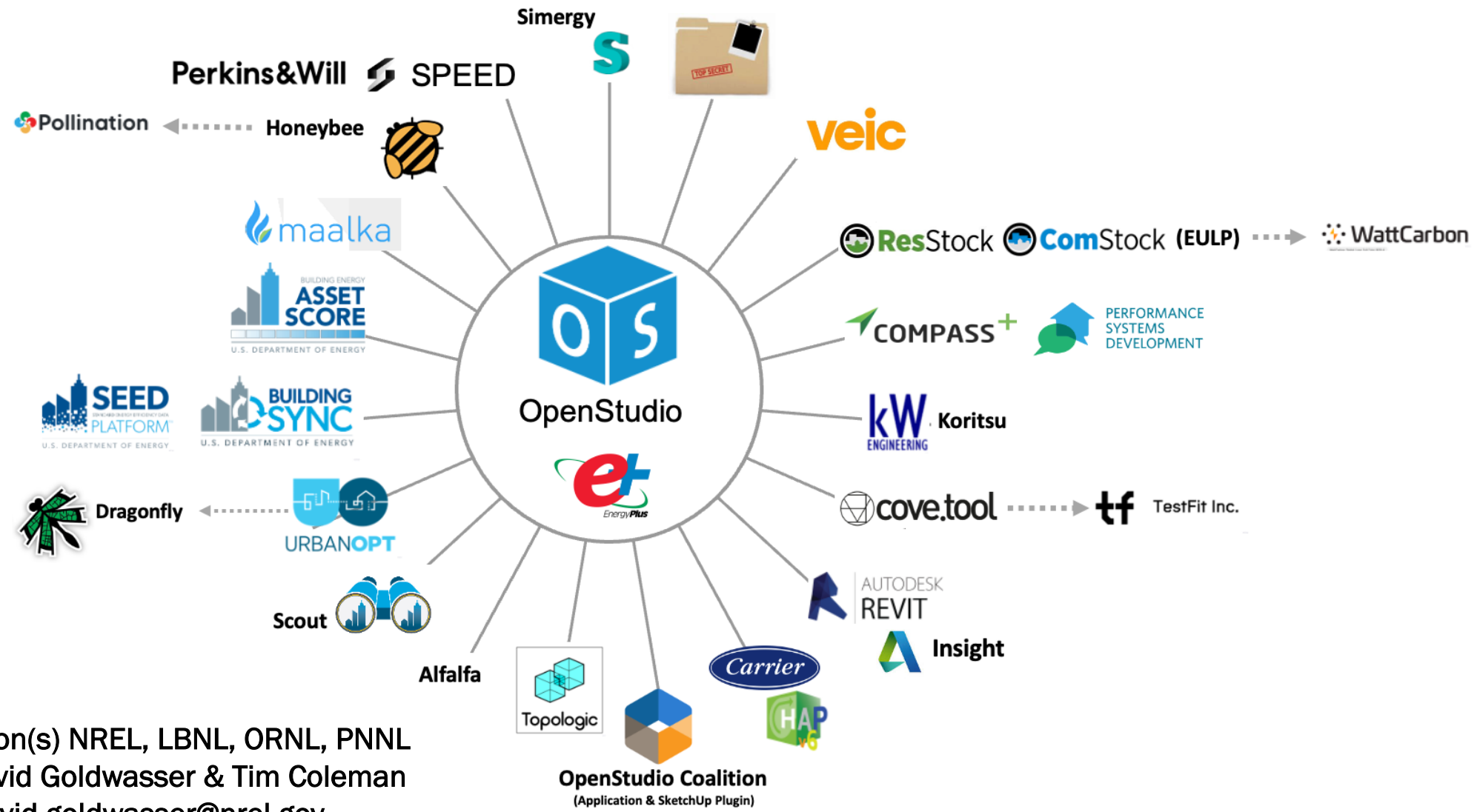# OpenStudio development, maintenance, and support

Performing Organization(s) NREL, LBNL, ORNL, PNNL
PI Name and Title: David Goldwasser & Tim Coleman
PI Tel and/or Email david.goldwasser@nrel.gov
WBS#: 3.5.5.26

Project summary

Objective and outcome

BEM is a key decision support tool for energy efficiency, demand flexibility, and electrification at the building and building stock levels.

The OpenStudio SDK maximizes the value of BEM by enhancing the productivity, consistency, and transparency with which it is applied. OpenStudio enables BEM experts to encapsulate domain and process knowledge in such a way that makes it usable by a range of stakeholders.

Team and Partners

NREL: Project Mgt. & Core Development

LBNL: Load Flexibility Measures

ORNL: SDK Performance Improvements

PNNL: OpenStudio Standards Development

Stats (FY23)

Performance Period: 10/1/22 – 9/30/23

DOE budget: $1,800k

Milestone 2: OpenStudio SDK 3.6.0 Major Public Release

Milestone 3: OpenStudio SDK 3.7.0 Major Public Release

The Problem

Most engineered products are modeled before they are built

- Airplanes, cars, computer chips, televisions, toasters, table saws, electric razors, non-electric razors...
- Individual building components too: windows, chillers, water heaters, dishwashers, ...

Buildings are a unique type of product with big impacts, including energy impacts

- But modeling applies here too; Building Energy Modeling (BEM) has many use cases
  - Design, HVAC sizing, code compliance, incentive calculations, product development, policy analysis

Buildings are not mass produced -- there are similarities, but each one is bespoke

- BEM must be cost effective on an individual building basis, can't amortize over millions of units
- BEM cannot be the domain of a few experts, it must be accessible to diverse professionals
  - Architects, mechanical engineers, control engineers, code officials, standards bodies, policy makers
- But BEM is a deep discipline and requires expertise ...

How to apply BEM (cost) effectively at scale? In many different use cases?

Our Solution: a BEM amplifier – OpenStudio

EnergyPlus probably needs very little introduction

- Comprehensive features, vetted, designed for integration into other products
- Input is extremely verbose -- 1000s of lines of text to describe a building.
- Graphical user interfaces help but still limited by human user.

OpenStudio is a "software development kit (SDK)" for BEM, specifically for EnergyPlus. It helps people write software to automate BEM/EnergyPlus workflows.

- Application Programming Interface (API) for accessing EnergyPlus inputs and outputs
- Code that uses this API can make (big) changes to EnergyPlus models quickly … and repeatedly!

OpenStudio enables **BEM experts** to write code that can create and modify EnergyPlus models. Expert knowledge (not to mention manual labor) is encapsulated so that it can be used by a much larger group of professionals … over and over!

70%: This special sauce is called OpenStudio Measures

API and Measures is 70% of what you need to know about OpenStudio

```
#  An OpenStudio Measure is a script that applies a
   specific transformation to a building model.

#  This one is simple, adding overhangs to south-facing
   windows. A more complicated Measure creates a baseline
   building model using the ASHRAE 90.1 Appendix G
   procedure.

#  Measures encapsulate significant BEM knowledge and
   expertise (and code!!), and are the technology behind
   OpenStudio's workflow automation, large-scale
   simulation, and extensibility (vendors and users can
   write their own). They provide significant added value
   to BEM.
```
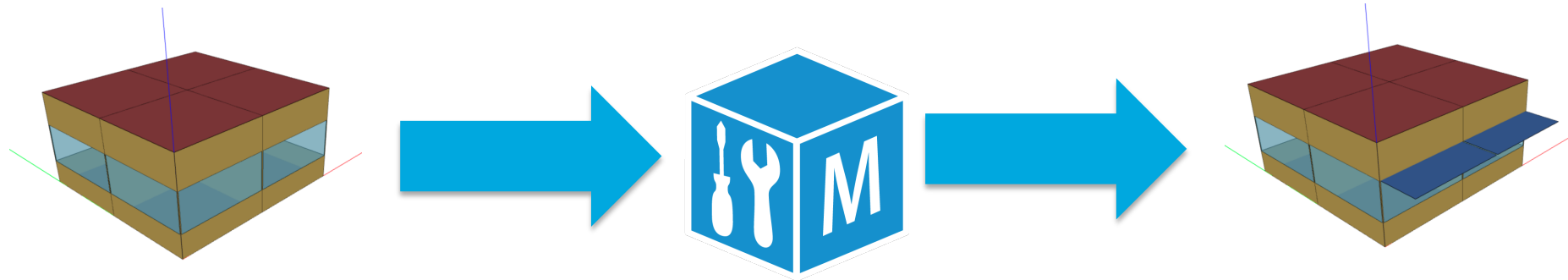
What does an OpenStudio Measure look like?

OpenStudio "understands" energy models

And makes changes easy

```ruby
# add overhang on south facing windows with a proj factor of 1
def run(model, runner, user_arguments)
  model.getSubSurfaces.each do |s|
    next if not s.outsideBoundaryCondition == "Outdoors"
    next if not s.subSurfaceType == "FixedWindow"
    orientation = OpenStudio::convert(s.azimuth,"rad","deg").get
    if orientation > 135 && orientation < 225
      s.addOverhangByProjectionFactor(1,0) #proj factor, offset
    end
  end
  return true
end
```
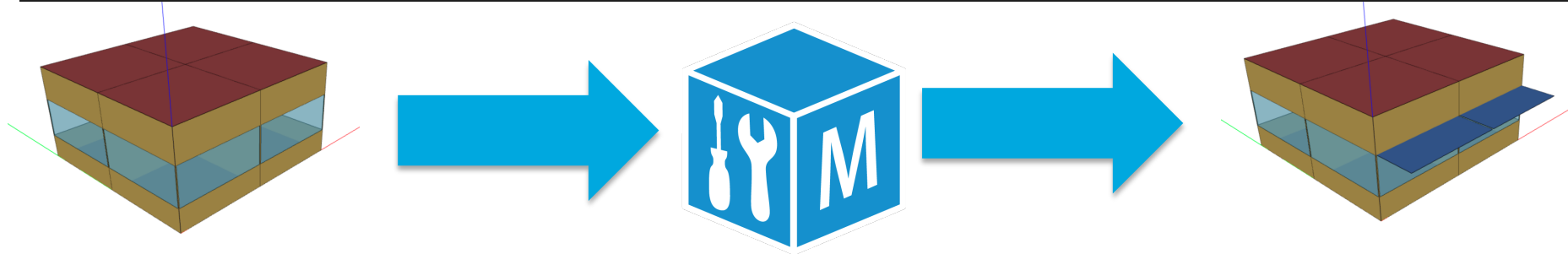
+ 10%: Building Component Library (BCL)

Building Component Library (BCL) https://bcl.nrel.gov/

- A versioned online repository of Measures and "Components"
    - OpenStudio Components: Model information such as a light definition, chiller, wall material, etc
- Experts can share with BEM community … BEM community can build and share on top of that
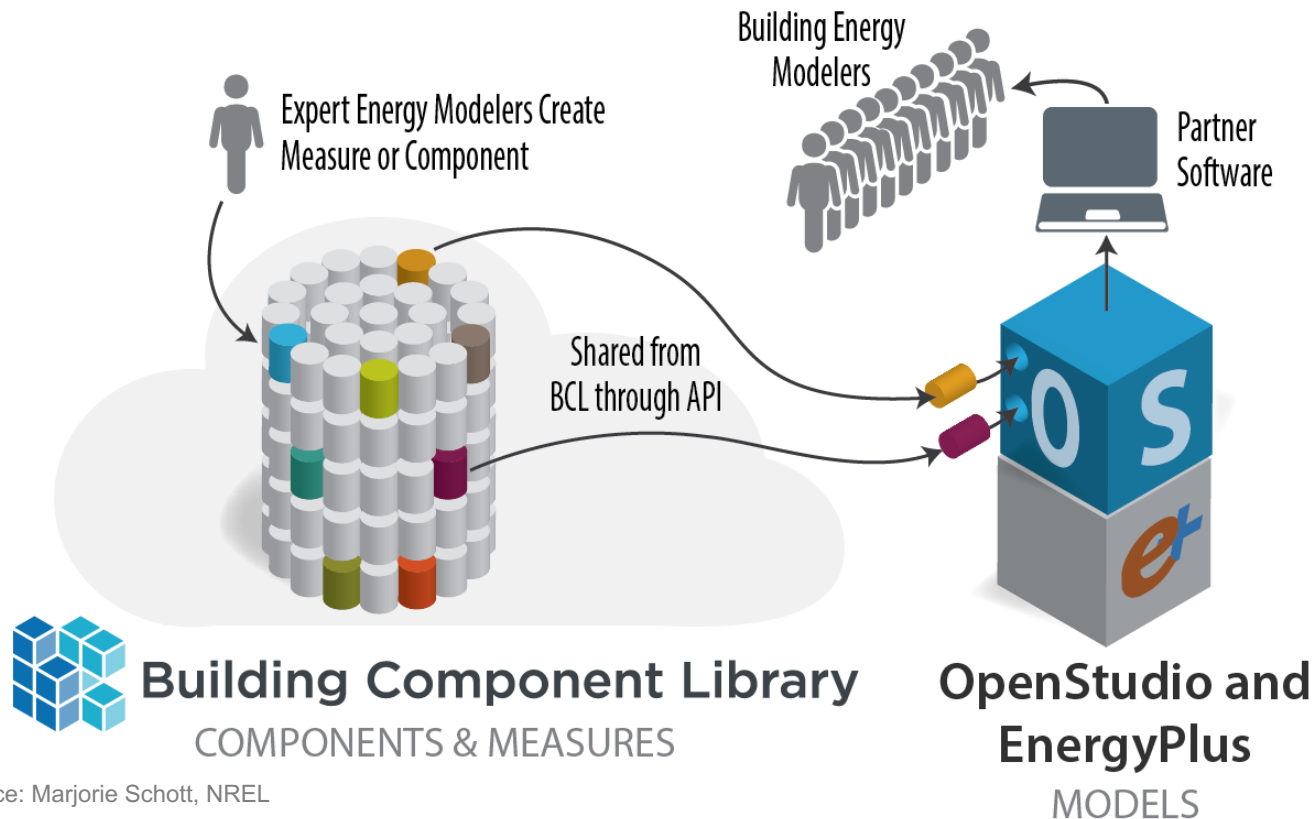

Source: Marjorie Schott, NREL

BCL 2.0 (released Oct. 2021)

- Versioning and provenance with git
- Collaborative Measure development
- Simplified management and approvals
- Ready for applications like Revit MEP

+ 10%: OpenStudio-Standards (first generation)

- **Many analysis use cases apply to entire building stocks**
  - Code development, program planning, deemed savings calculations, regional/national impact analysis, technology road-mapping, research, education ... e.g., ResStock, ComStock
  - Historically used "prototype" or "reference" models that represent classes of buildings by type
  - Familiar DOE/PNNL/ASHRAE commercial and residential prototype models
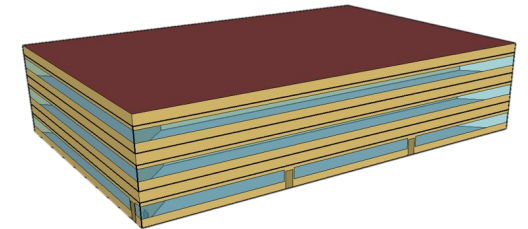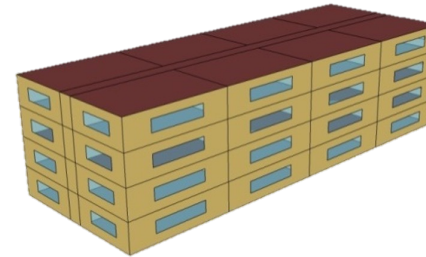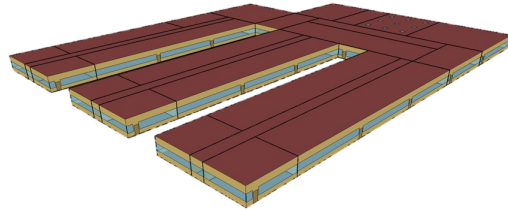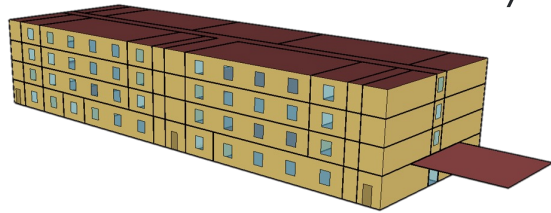
- **OpenStudio-Standards (first generation)**
  - Measures and content for creating ASHRAE prototypes
    - Specify building-type, climate zone, and code vintage
    - Tables map high-level specs to constructions, COPs, etc.
  - Added some new types (LBNL & ORNL)
    - Religious, data-center, skyscraper, college dorm, ...

OpenStudio-Standards (current generation)

- **It became clear that building models from high-level specs is more useful than just choosing from finite ASHRAE prototype building types.**
  - Example: ResStock and ComStock use 100,000s of models to represent diverse US stock

```
I want a hotel with retail and
restaurant spaces on the first floor
```

```
Default hours of operation for hotel
and retail, 12-11p for restaurant
```

```
50% street parking, and ext. lighting
levels based on high activity zone
```

```
Electric heating (hydronic
distribution) and SWH, gas for
kitchen
```

```
ASHRAE 90.1-2019 for envelope, loads,
and system efficiencies
```

Voila!

Pacific Northwest
NATIONAL LABORATORY
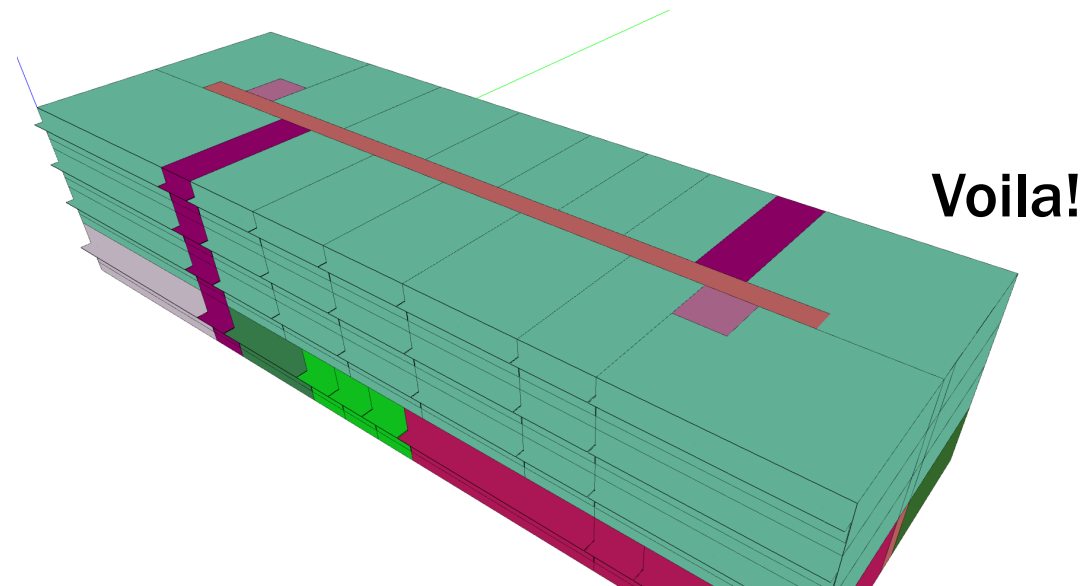
Recently completed
- Custom space type ratio
- ASHRAE 90.1-2016, 90.1-2019 added
- Take any model as input, produce 90.1-2019 Appendix G baseline

+ 10%: OpenStudio Analysis Framework (OSAF)

- **Humans are limited in time and ability to evaluate many building alternatives**
- **OSAF has algorithms for exploring many options at scale, impossible for humans**
- **Individual building/portfolios:**
  - design optimization, calibration
- **District scale analysis:**
  - measure impact analysis, program planning, code updates

Recent Progress
- Integrated URBANopt / REopt (for district scale modeling)
- Better support for Amazon, Google, and Microsoft cloud
- Interactive tutorials and documentation on how to create these workflows without a GUI.
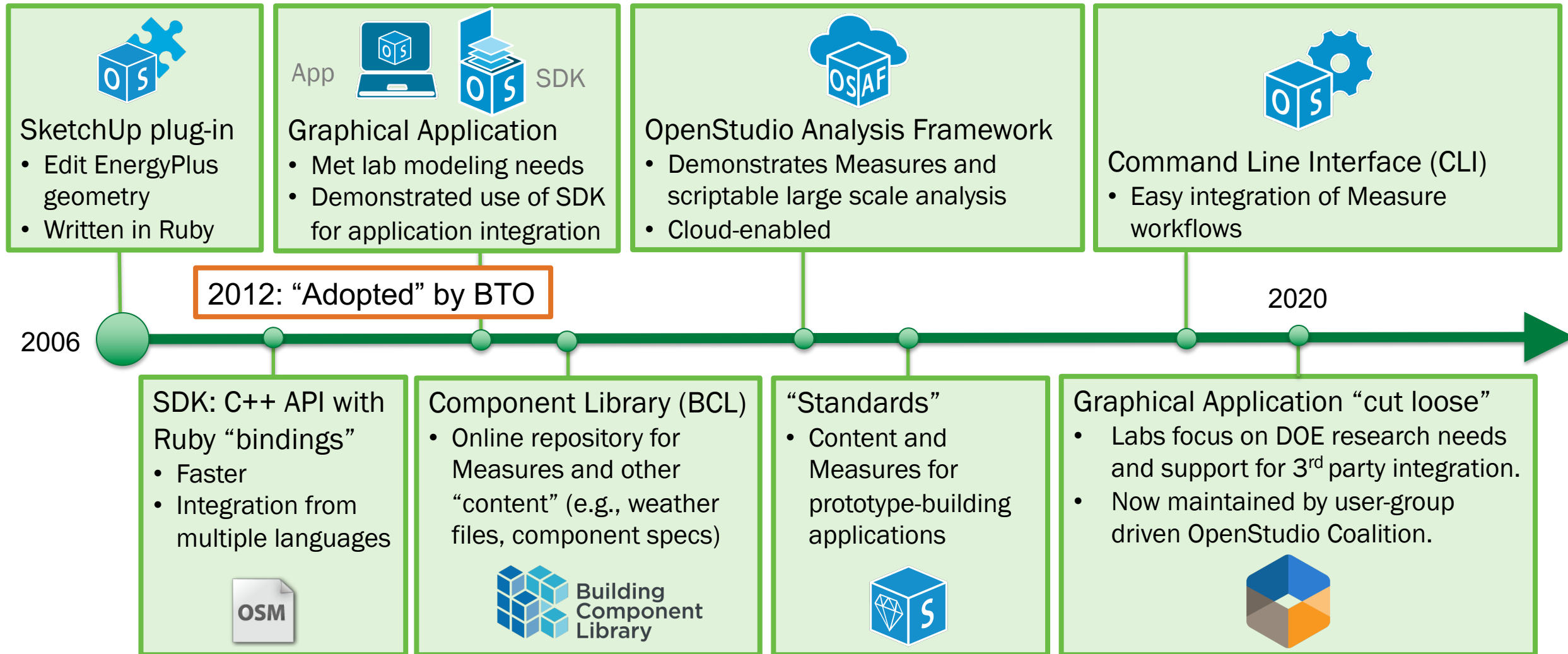 - https://github.com/NREL/docker-openstudio-jupyter

Future Work
- Workflow for Spawn
- Advanced calibration workflows
- Integrated ML / AI workflows

Approach and Timeline

SketchUp plug-in
- Edit EnergyPlus geometry
- Written in Ruby

Graphical Application (App / SDK)
- Met lab modeling needs
- Demonstrated use of SDK for application integration

OpenStudio Analysis Framework
- Demonstrates Measures and scriptable large scale analysis
- Cloud-enabled

Command Line Interface (CLI)
- Easy integration of Measure workflows

2012: "Adopted" by BTO

2006 ————————————————————————————————————► 2020

SDK: C++ API with Ruby "bindings"
- Faster
- Integration from multiple languages

OSM

Component Library (BCL)
- Online repository for Measures and other "content" (e.g., weather files, component specs)

Building Component Library

"Standards"
- Content and Measures for prototype-building applications

Graphical Application "cut loose"
- Labs focus on DOE research needs and support for 3rd party integration.
- Now maintained by user-group driven OpenStudio Coalition.

Vision: an open-source platform to support BEM vendors (and BTO needs)

It's working
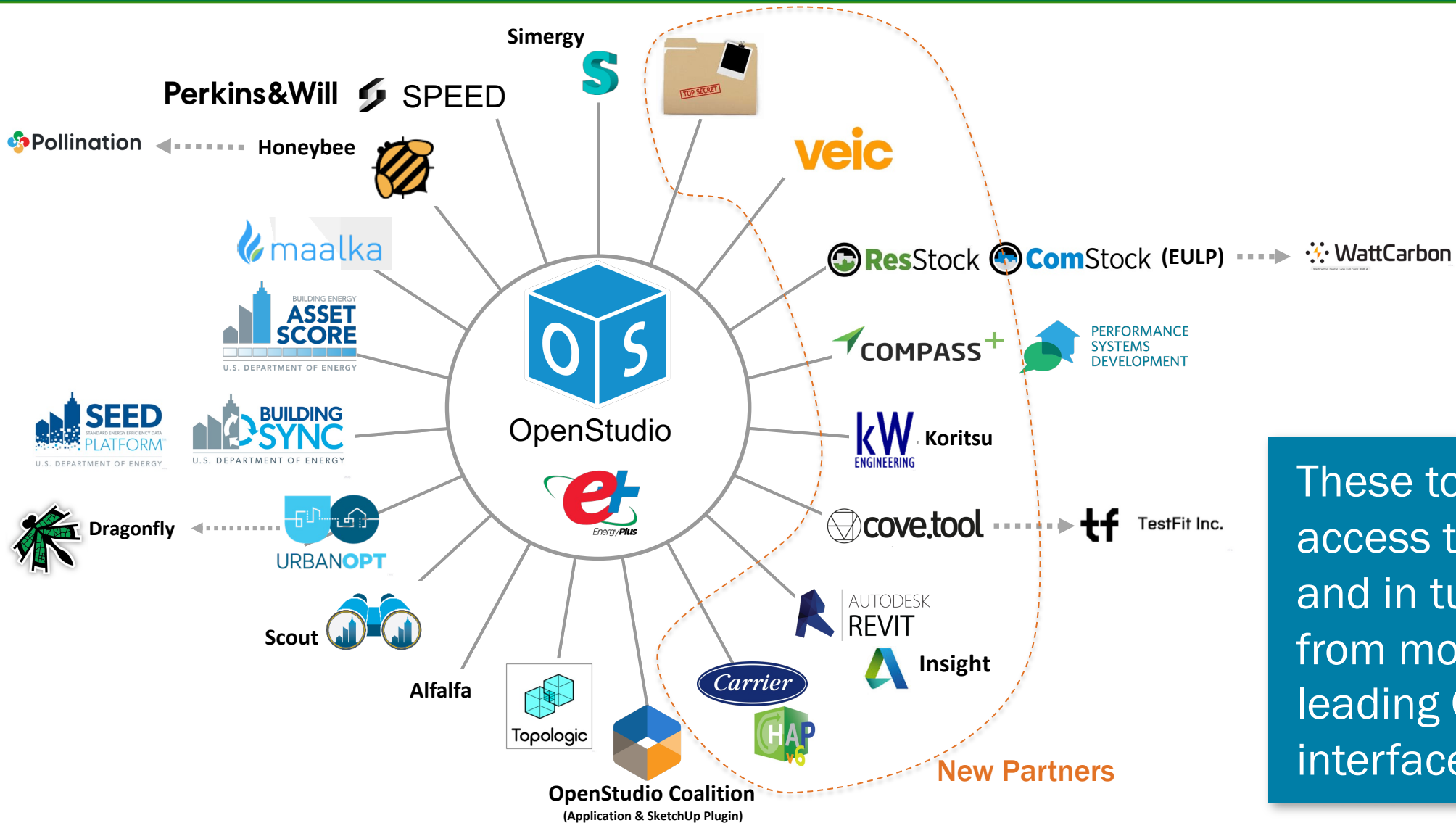
These tools provide access to OpenStudio, and in turn EnergyPlus, from more than 10 leading CAD/BIM interfaces

(selection of some of tools leveraging the OpenStudio SDK)

There is now even a second tier

Pollination

Perkins&Will   SPEED   Simergy

Honeybee

maalka

BUILDING ENERGY
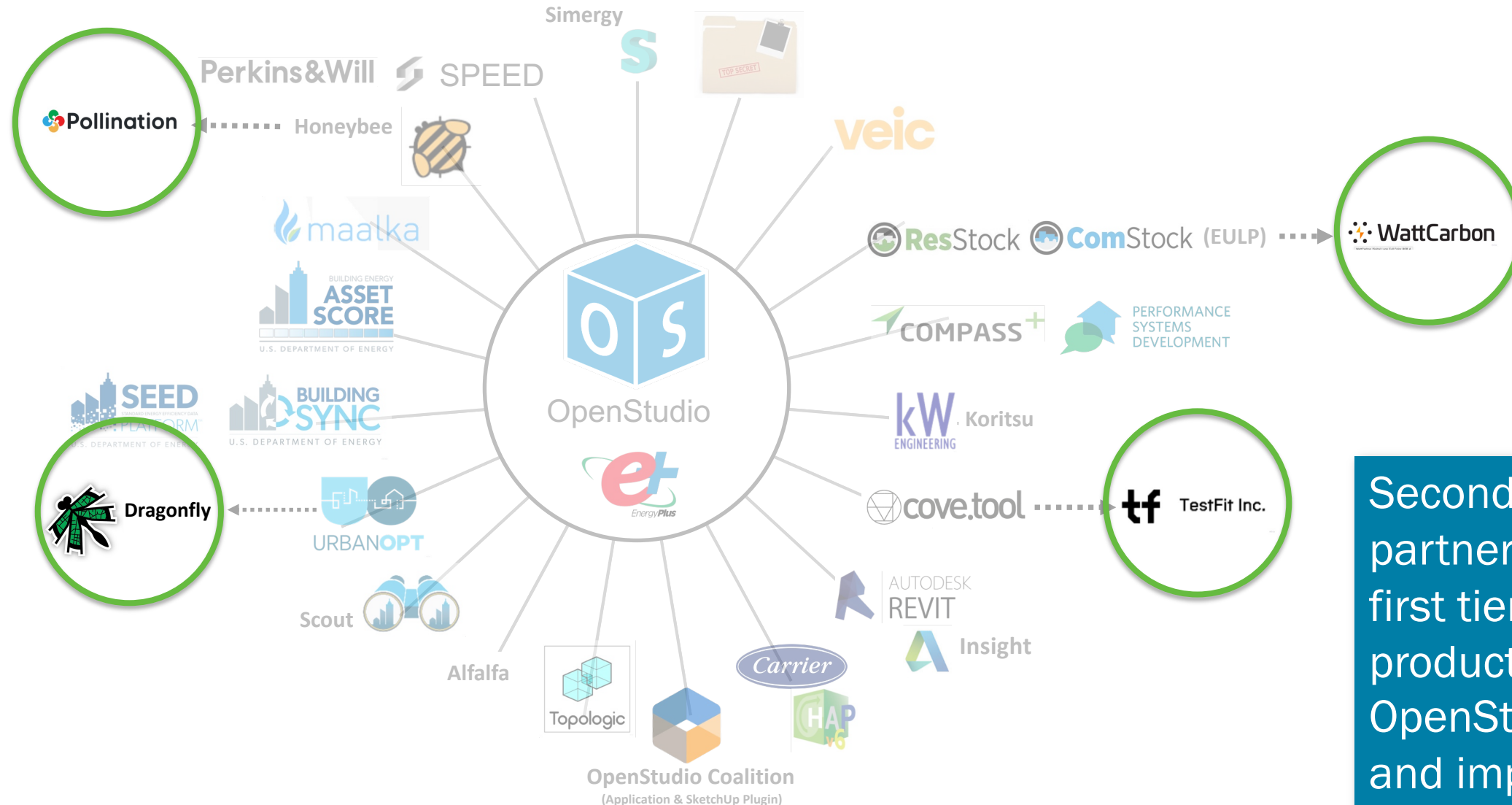ASSET SCORE
U.S. DEPARTMENT OF ENERGY

SEED PLATFORM
U.S. DEPARTMENT OF ENERGY

BUILDING SYNC
U.S. DEPARTMENT OF ENERGY

Dragonfly

URBANOPT

Scout

Alfalfa

Topologic

OpenStudio Coalition
(Application & SketchUp Plugin)

Carrier

HAP

OpenStudio

EnergyPlus

veic

ResStock   ComStock   (EULP)   WattCarbon

COMPASS⁺   PERFORMANCE SYSTEMS DEVELOPMENT

kW ENGINEERING   Koritsu

cove.tool   tf   TestFit Inc.

AUTODESK REVIT

Insight

Second tier indirect partners that build on first tier partners' products amplify OpenStudio adoption and impact.

(selection of some of tools leveraging the OpenStudio SDK)

This is what the community is saying!

Utility Companies:
The results of the EULP research effort will be tremendously helpful to Seattle City Light, allowing us to improve our load modeling of future residential and commercial electrification related to electric vehicles, heat pumps, and other end uses.

*Michael Hamilton,
Seattle City Light*

Utility DM Consultants:
This dataset will be a very valuable resource for the utility demand side management industry.

*Justin Spencer
Apex Analytics*

This is incredible. I've been wanting someone to do this since I started at NYSERDA, and here it is already completed.

*James Geppner, RetrofitNY
Senior Project Manager*

BEM Industry:
We are excited to help our city and utility clients understand the local impacts of building electrification... with much more confidence than previously available methods such as California DEER or DOE prototype models.

*Mudit Saxena.
CEO & President,
XeroHome / Vistar Energy Inc.*

Technology Developers:
At Lunar Energy, we develop hardware and software products to enable whole-home electrification. We're excited to engage with this critical dataset to help guide our product direction.

*Randol Aikin,
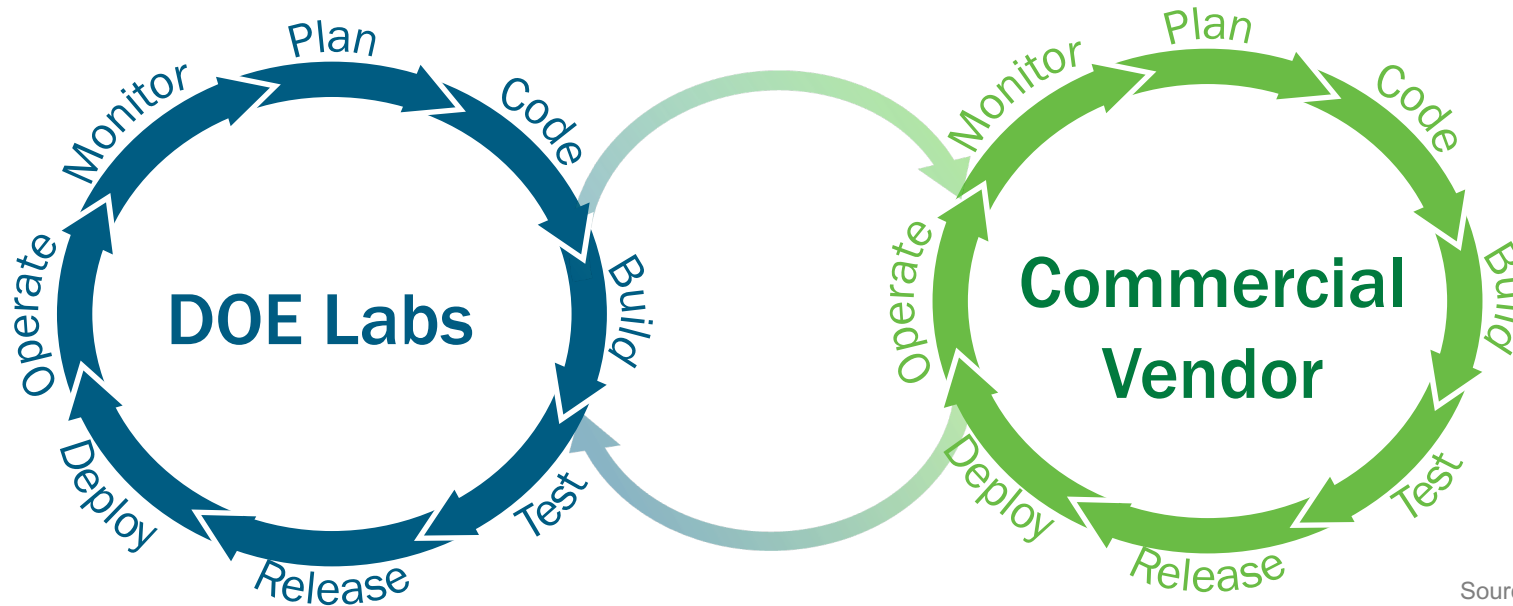Techno-Financial Modeling Lead
Lunar Energy*

Approach: commercial-grade software development

Source: Marjorie Schott, NREL

Use software industry best practices for robust and maintainable software

- Agile development.
- Continuous integration (CI) with unit, regression, and performance testing.
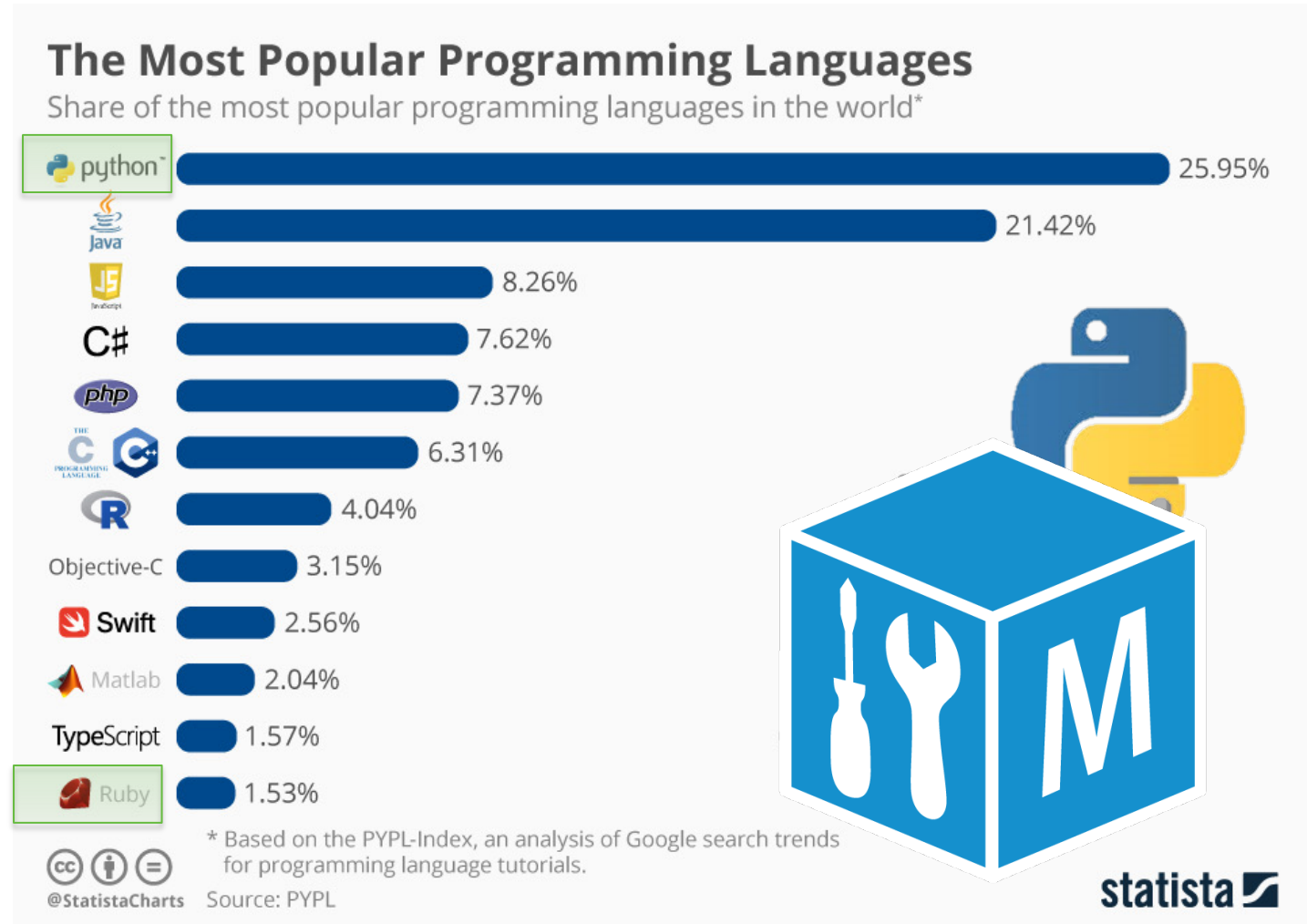- Consistent frequency and timing of releases.

Non-negotiable for commercial clients

- Can't break software other people are using and relying on for their business!
- These practices now used by EnergyPlus and other DOE software projects

Big New Feature: Python Measures

Measure ecosystem based on Ruby (SketchUp plug-in language)

- Good choice in 2007 but aged poorly
- Python has more libraries and is more heavily used in Architecture, Engineering, and Construction (AEC).
- Python Measures is one of the most requested features by both practitioners and researchers.
- Will be available in OpenStudio 3.6.0 (May 12th 2023)!
- Mixed Ruby-Python workflows!
- Required significant re-architecting, but things are more modular now!

The Most Popular Programming Languages
Share of the most popular programming languages in the world*

Language	Share
python	25.95%
Java	21.42%
JavaScript	8.26%
C#	7.62%
php	7.37%
C / C++	6.31%
R	4.04%
Objective-C	3.15%
Swift	2.56%
Matlab	2.04%
TypeScript	1.57%
Ruby	1.53%

* Based on the PYPL-Index, an analysis of Google search trends for programming language tutorials.

@StatistaCharts Source: PYPL

statista

Progress: GEB Measures!

FY 21-22

- Adjusted thermostat setpoints
- **Pre-cooling**
- Pre-heating
- Reduce MELS
- Reduce lighting loads
- EV smart charging
- Water tank with TES
- DCV

- Occupancy-driven lighting
- Reporting metrics
- Change to HPWH
- Reduce DHW Usage
- Adjust DHW setpoint
- Shading control
- Electrochromic Windows
- Time averaged ventilation
- Rooftop PV System

FY 23

- Reduce exterior lighting
- Ceiling fan
- TES for food storage
- Natural ventilation

- Night ventilation
- Dynamic coating for roofs/walls
- Radiative cooling

https://github.com/LBNL-ETA/Openstudio-GEB-gem

Pre-cooing GEB measure
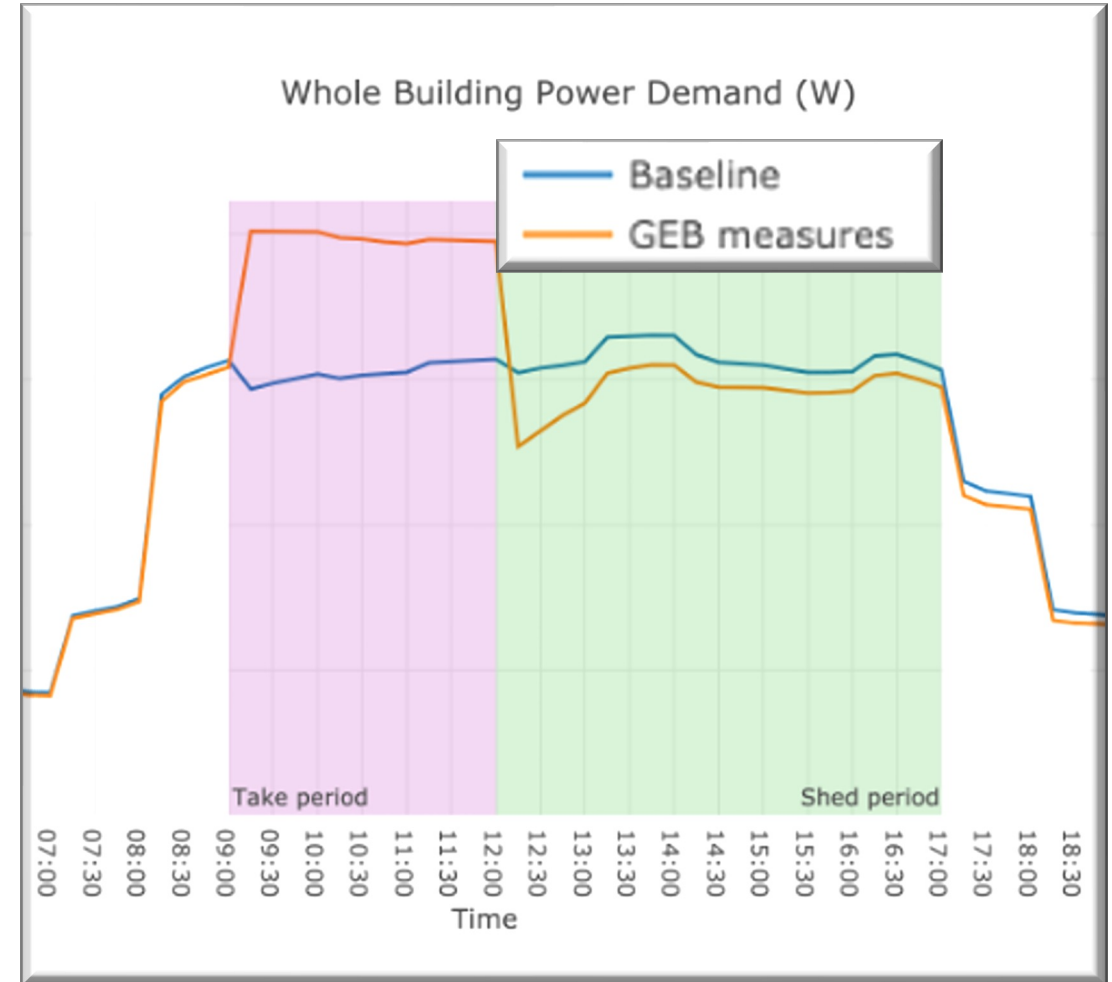
Pre-cooling in off peak hours lowers(sheds) demand in the afternoon.

BERKELEY LAB

Current focus: improve OpenStudio performance

Performance of OpenStudio model generation is critical to Industry Adoption

- Makes their software more responsive and enhances user experience.

- Reduces computing cost on large scale simulations

Software Profiling

- Identifies the portions of the program code that are most heavily used

- Allows the work to focus on the parts of the code that are most impactful

- We have identified large real-world baseline models that demonstrate hotspots

Profile → **Identify** → **Prioritize** → **Improve**

OAK RIDGE
National Laboratory

Summary

Problem: Good BEM requires deep expertise, but to maximize impact BEM must be accessible to many different professionals working on many different use cases

Solution: OpenStudio helps encapsulate BEM expertise so that it can be shared and built upon to make BEM more productive, consistent, and transparent

THANK YOU

Kyle Benne (for David Goldwasser and Tim Coleman)

kyle.benne@nrel.gov (david.goldwasser@nrel.gov)

REFERENCE SLIDES

Project Execution

Milestone	Description	FY23				FY24
		Q1	Q2	Q3	Q4	Q1
1.a	OpenStudio SDK 3.5.0 Major Public Release	██				
1.b	Progress Update Email on Development Activities and Defects	██	██			
1.c	OpenStudio SDK 3.6.0 Major Public Release		██	██		
1.d	Progress Update Email on Development Activities and Defects			██	██	
Go/No Go	Support for Python EMS – decide technical implementation	██				
2.a	OpenStudio SDK 3.7.0 Major Public Release				██	██

Team

- Project Management
- Software Development for SDK, PAT, Server, Measures, FloorSpaceJS
- CI, Deployment (Releases)
- Third Party Development Support and Academic Outreach

- Load Flexibility Measures and Prototype Spaces

- SDK Performance Improvements and Prototype Spaces

- OpenStudio Standards Development and Prototype Spaces