Residential Buildings Analysis Tools & Support

2017 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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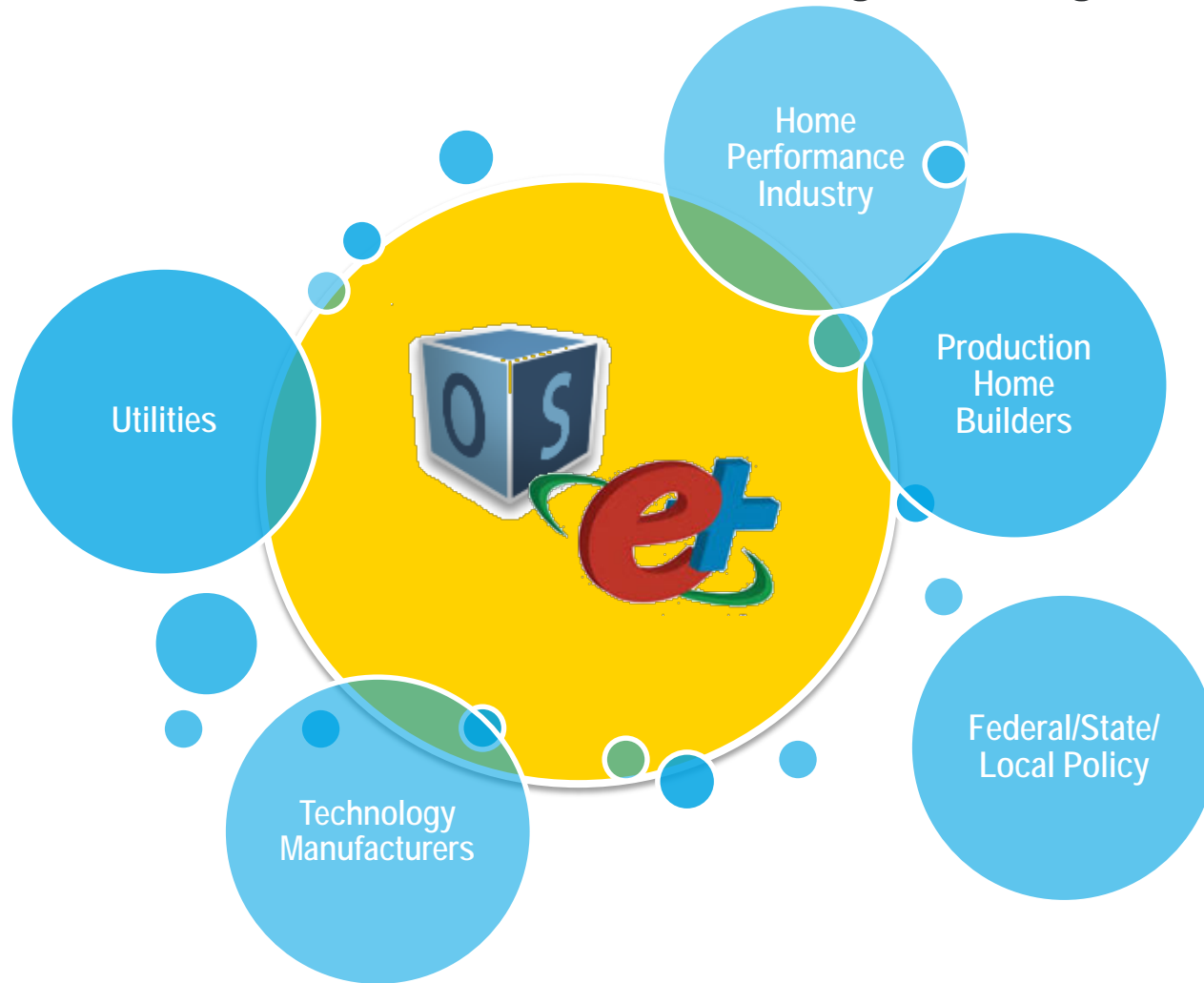
Project Summary

Timeline:

Start date: 10/1/15

Planned end date: TBD

Key Milestones

1. ResStock-OpenStudio Demonstration; 3/15/17
2. Residential OpenStudio measures; 4/28/17
3. OpenStudio/EnergyPlus Releases with Residential Features; 10/31/17

Budget:

Total Project $ to Date:

- DOE RBI: $2,850k
- DOE Non-RBI: $270k
- Cost Share: $990k

Total Project $:

- DOE RBI: $3,615k
- DOE Non-RBI: $705k
- Cost Share: $1,300k

Key Partners:

BPA	DOE ET/CBI/EPSA/OSP
EPA	City of Boulder
RESNET	CPUC
NRCan	Fraunhofer
Tendril	Many Others

Project Outcome:

Foundational open-source capabilities in BTO's flagship energy modeling ecosystem (OpenStudio & EnergyPlus) that are leveraged by efficiency and research programs to evaluate state-of-the-art residential building technologies.

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Purpose and Objectives

Problem Statement:
While residential efficiency programs (e.g., Building America, Home Performance Industry, ENERGY STAR, Zero Energy Ready Home, utilities, implementers) increasingly rely on simulation models to accelerate energy savings, the private sector lacks the resources needed to develop/maintain a sophisticated energy modeling platform that can quickly analyze the latest state-of-the-art residential technologies.

Target Market:
Residential new construction (1.4 quads/decade) and existing homes (10.2 quads).
- Home performance industry: 200,000+ homes rated in 2016 (RESNET)
- Utilities: $3 billion of investment in residential demand side management. (CEE 2015)

Target Audience:
Program implementers, home performance practitioners, utilities, national/state/local government policy makers, production home builders, manufacturers.

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Purpose and Objectives

Impact of Project: Convenient and accurate Building Energy Modeling (BEM) accelerates the adoption of efficiency technologies into the new construction and retrofit marketplaces. Modeling is a vital mechanism for evaluating and marketing the benefits of technology innovations. This project will result in robust, open-source residential building modeling capabilities.

Innovations: Tools, technologies, best practices	**Jobs:** Workforce competent in building science	**Better Buildings:** Lower cost with better comfort, health, safety, durability	**Market Demand:** Consumers/ transaction process that value better buildings	**Big Prize:** • **Stronger Economy** • **Clean Air** • **More Jobs** • **Greater Security**

You Are Here

Near-term success of DOE BEM ecosystem can be measured by the number of users.

Mid-term success is measured by the performance of homes influenced by BEM.

Long-term success is measured by reduction in EUI across residential building sector.*

*BTO Multi-Year Program Plan goal is 35% EUI reduction in the heating, cooling, and water heating end uses in existing single-family homes and 50% reduction in new homes by 2025.

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Approach

Approach:

Research-to-market technology evaluation for DOE/stakeholders:

1. **Develop EnergyPlus-based models** for new/emerging technologies.
2. **Test and validate** models against data and/or other engines.
3. **Publish OpenStudio measures** on the Building Component Library.
4. **Publish OpenStudio workflows** for residential efficiency programs.
5. **Assess technical/economic potential** in ResStock framework.
6. **Disseminate actionable resources** to accelerate market adoption.

Research

to

Market

Key Issues: Lack of consistency, capability, and transparency in residential efficiency programs addressed with open-source models, tools, and workflows.
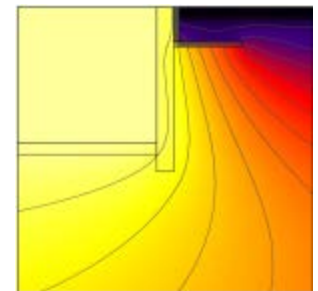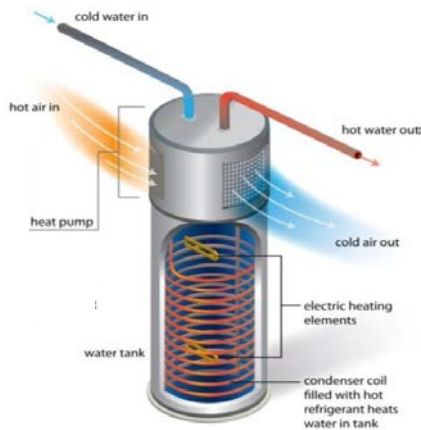
Distinctive Characteristics:
- Establishes open-source analytical foundation for BA residential program
- Leverages many other projects: EnergyPlus, OpenStudio, Efficiency Measures Database, BA Simulation Protocols, HPXML, etc.

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Approach: 1. EnergyPlus Technology Models

Develop EnergyPlus-based models for new/emerging technologies.

✓ New foundation heat transfer model (Kiva)

✓ Enhanced mini-split heat pump (MSHP) model

✓ Enhanced heat pump water heater (HPWH) model

✓ Radiation heat transfer for ducts

✓ Enhanced moisture buffering model (EMPD)

✓ Additional fuel types for HVAC and appliances

❑ Multiple/partial HVAC serving single thermal zone (in progress)

❑ Attic/duct/airflow enhancements (in progress)

cold water in

hot air in

hot water out

heat pump

cold air out

electric heating elements

water tank

condenser coil filled with hot refrigerant heats water in tank

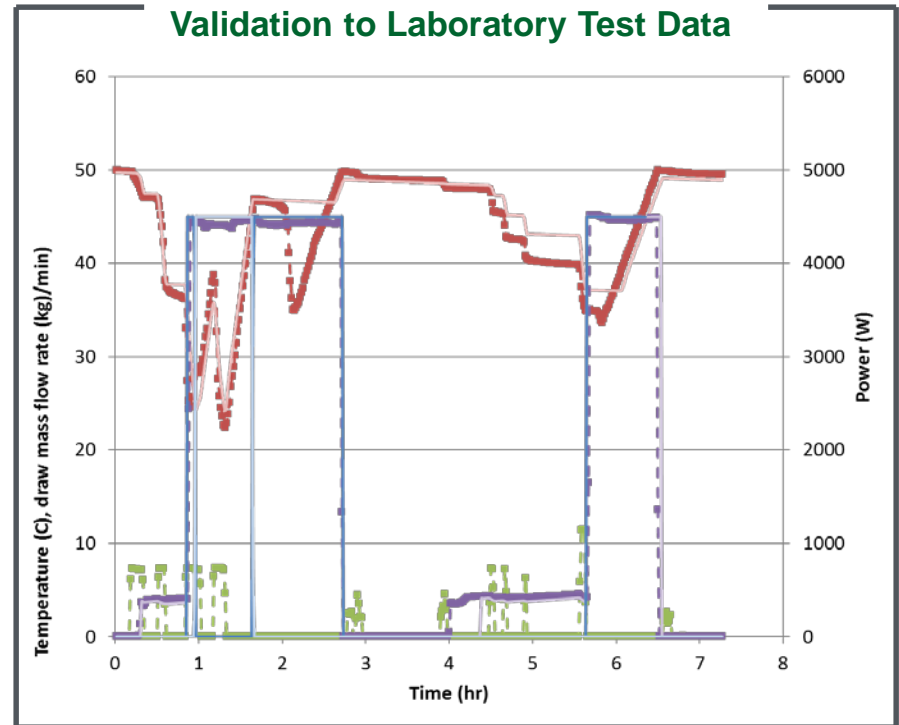U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Approach: 2. Testing and Validation

Test and validate technology models against field and laboratory testing data and/or other simulation engine models.
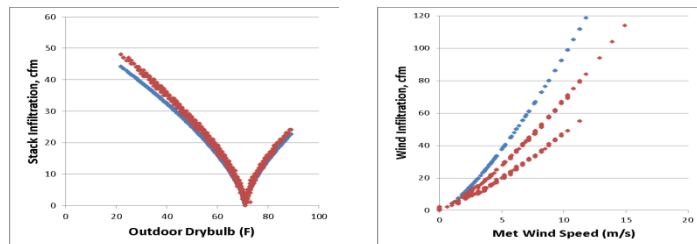
Mini-Split Heat Pump Model Validation to Field Test Data
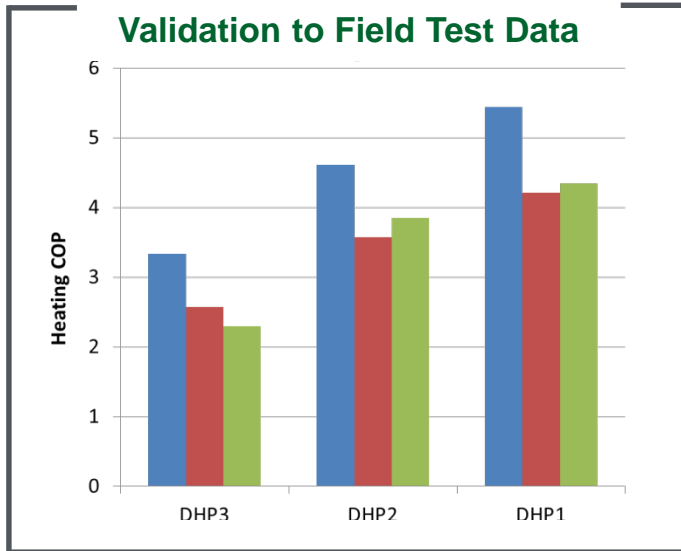
Heat Pump Water Heater Model Validation to Laboratory Test Data

Air Leakage/Infiltration Model Validation to Other Simulation Engine

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Approach: 3. OpenStudio Measures

Publish OpenStudio measures on the Building Component Library.

OpenStudio

- DOE open-source framework
- Simplifies use of EnergyPlus
- Facilitates community development
- Facilitates private sector adoption

Building Component Library

- Public warehouse of measures
- Reduces modeling time and cost
- Maintains quality and consistency
- Contributions by numerous organizations

RADIANT BARRIER CLOTHES WASHERS THERMAL MASS MECHANICAL VENTILATION DUCTS BASEMENTS ERVs/HRVs ORIENTATION SLABS EAVES WALL SHEATHING HOT WATER FIXTURES CRAWLSPACES AIR CONDITIONERS GEOMETRY WATER HEATERS CMU WALLS FURNACES DOORS 90 RESIDENTIAL MEASURES PV BASEBOARD OVERHANGS EXTERIOR FINISH ROOFING MATERIAL ICF WALLS WINDOWS SIP WALLS HOT WATER DISTRIBUTION CLOTHES DRYERS INTERIOR SHADING NEIGHBORS BOILERS HEAT PUMPS DISHWASHERS NATURAL VENTILATION AIR LEAKAGE LIGHTING REFRIGERATORS ATTICS PLUG LOADS COOKING RANGES WOOD STUD WALLS

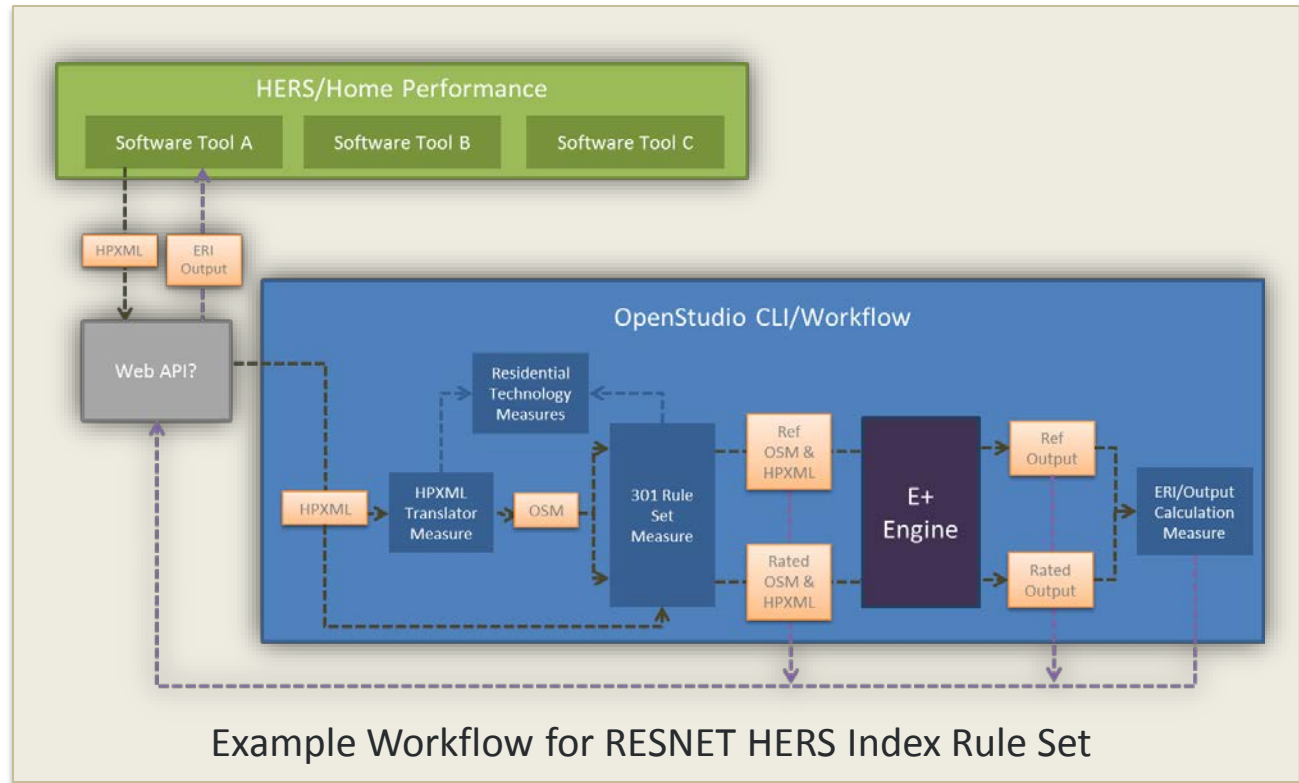U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Approach: 4. OpenStudio Workflows

Publish OpenStudio workflows for use by residential efficiency programs to meet market needs.

Outputs:
- Source Energy
- HERS Rating
- ENERGY STAR
- ZERH
- Code Compliance
- Demand
- Utility Bills
- Utility Cost Tests
- Non-Energy Benefits

Example Workflow for RESNET HERS Index Rule Set

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Approach: 5. Technical/Economic Potential

Assess technical/economic potential in ResStock framework to identify research priorities and target market opportunities.

ResStock: Highly Granular Modeling of the U.S. Single-Family Housing Stock

Building Characteristics

Census Data

Energy Costs

Climate Locations

1000s of statistically representative models

Baseline Buildings

Efficiency Upgrades

Amazon Cloud

EE Supply Curve

Duct Sealing

Total: 17,566 GWh/yr

Approach: 5. Technical/Economic Potential

Assess technical/economic potential in ResStock framework to identify research priorities and target market opportunities.
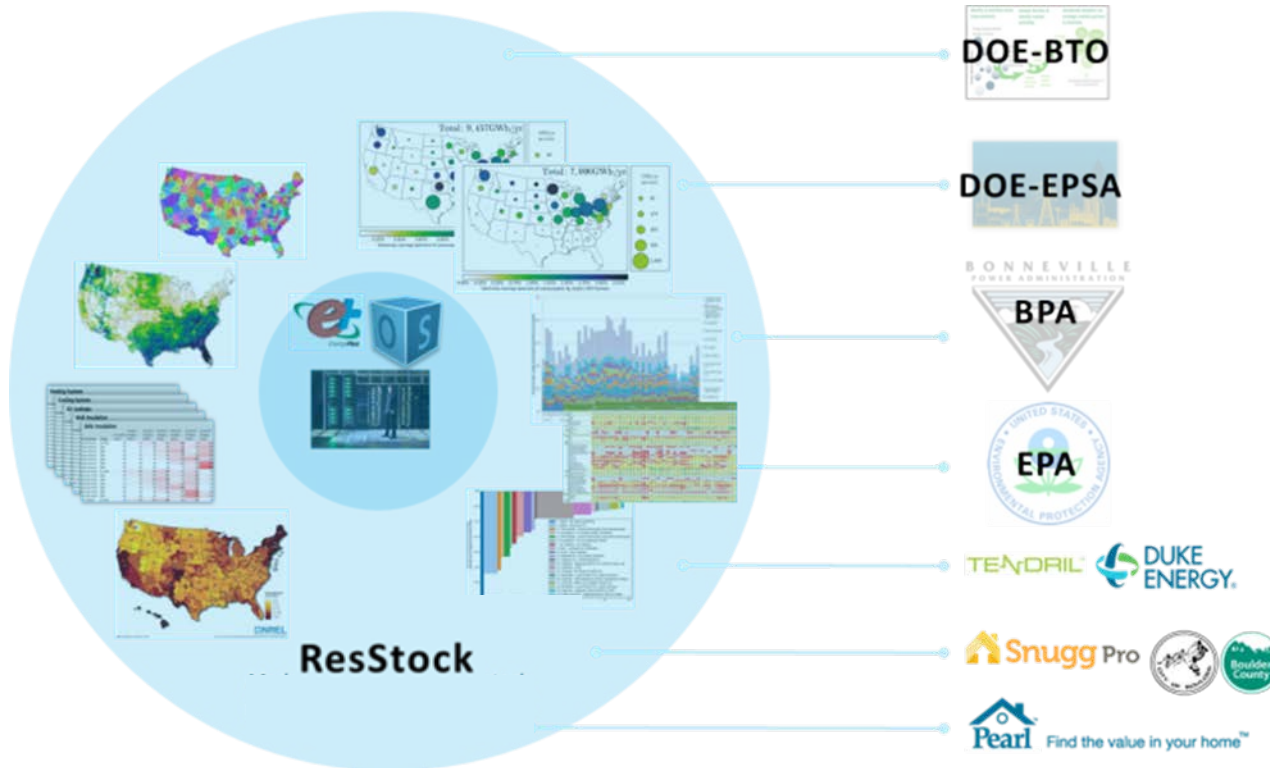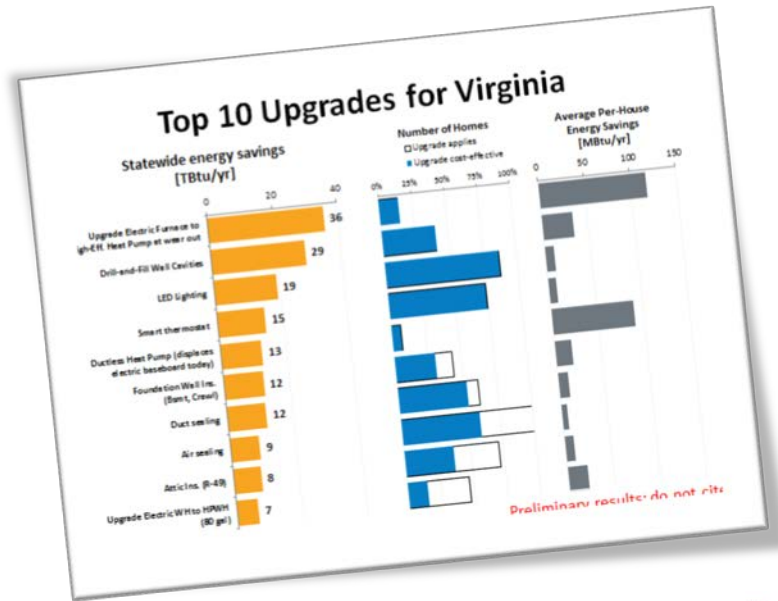
ResStock: Highly Granular Modeling of the U.S. Single-Family Housing Stock

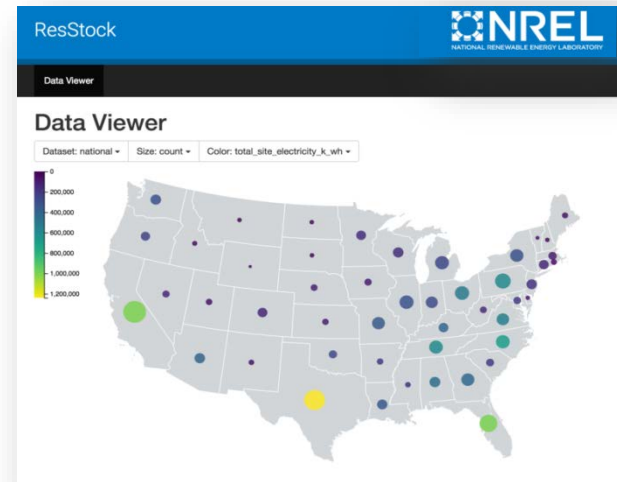**U.S. DEPARTMENT OF ENERGY** | Energy Efficiency & Renewable Energy
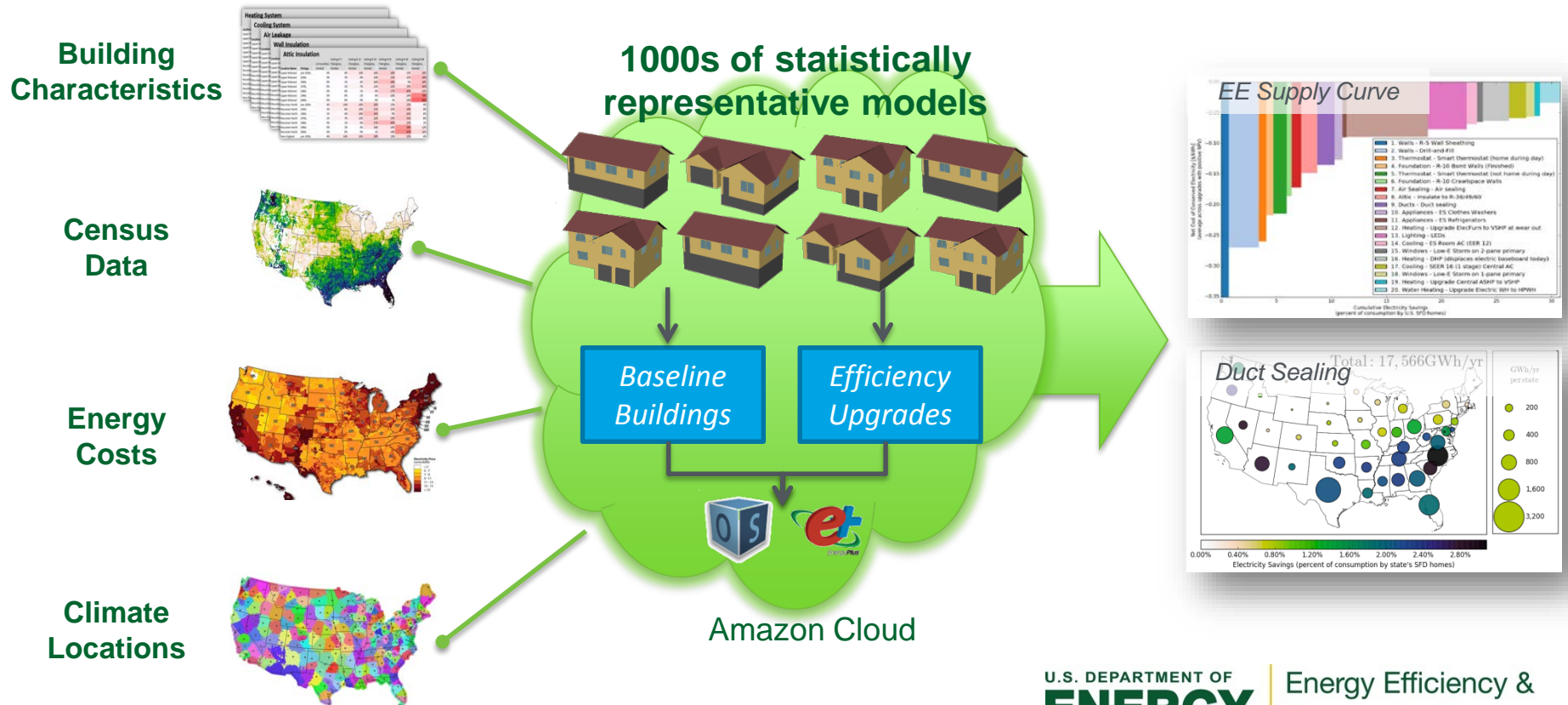
Approach: 6. Actionable Resources

Disseminate actionable resources to accelerate market adoption.
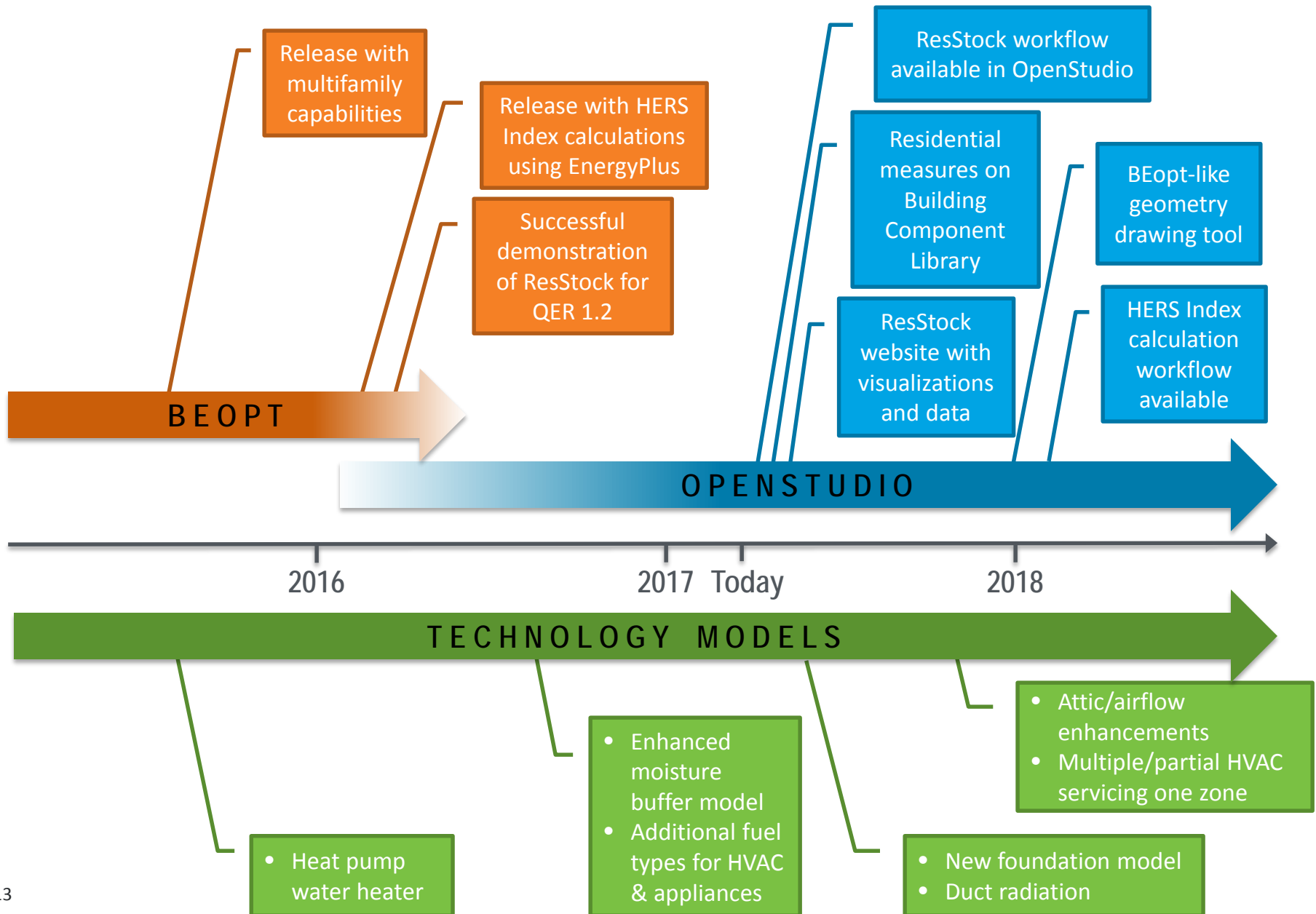
State Fact Sheets for DOE EPSA

Website with Upgrade Results, Housing Characteristics, etc.

Quadrennial Energy Review Second installment

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Progress and Accomplishments

BEOPT (orange arrow) accomplishments:
- Release with multifamily capabilities
- Release with HERS Index calculations using EnergyPlus
- Successful demonstration of ResStock for QER 1.2

OPENSTUDIO (blue arrow) accomplishments:
- ResStock workflow available in OpenStudio
- Residential measures on Building Component Library
- BEopt-like geometry drawing tool
- ResStock website with visualizations and data
- HERS Index calculation workflow available

Timeline: 2016 — 2017 — Today — 2018

TECHNOLOGY MODELS (green arrow) accomplishments:
- Heat pump water heater
- Enhanced moisture buffer model
- Additional fuel types for HVAC & appliances
- New foundation model
- Duct radiation
- Attic/airflow enhancements
- Multiple/partial HVAC servicing one zone

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Progress and Accomplishments

Market Impact:

Public availability of EnergyPlus/OpenStudio/BEopt for the residential sector has resulted in:

- Directly impacting over 45,000 (and indirectly over 1.5 million) homes through BA advanced efficiency demonstration projects.
- 6,500+ downloads, 175,000+ website views, 100+ publications (~2 years for BEopt).
- Use by DOE/BA, utilities, states, builders, manufacturers, universities.
- Stronger national/state/local ZNE goals and building codes.

Potential impact:

- Influence home performance industry and utility programs.

Awards/Recognition:

- EnergyPlus – R&D 100 award
- BEopt – Building America Top Innovation Hall of Fame

Lessons Learned:

Open-source software coupled with longer-term DOE support makes our tools, capabilities, and models more attractive to external entities, resulting in larger investment spread across many parties and increased impact/reach.

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Project Integration and Collaboration

Project Integration:
- Coordination with RESNET to increase consistency/capability of private-sector home performance simulation tools.
- Coordination with BPA to ensure value for power plans and utilities.
- Use of EnergyPlus by BA teams, Race to Zero Student Design Competition participants.

Partners, Subcontractors, and Collaborators:
- **Partners**: BPA, EPA, DOE ET/CBI/EPSA/OSP, City of Boulder, RESNET, Tendril
- **Subcontractors**: Ecotope (technology models), Big Ladder (technology models), Devetry (software development), Neymark & Associates (methods of test), Performance Systems Development (technology models)
- **Collaborators**: OpenStudio & EnergyPlus development teams

Communications:
- **Conference/Forum Presentations:** National & Northwest Home Performance, RESNET Building Performance, ASHRAE/IBPSA SimBuild, ASHRAE Annual, EEBA, ACEEE Summer Study, ACEEE Hot Water Forum, Habitat for Humanity
- **Other:** Building America webinars, DOE Race to Zero webinars, Energy Design Update magazine, Home Energy magazine

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Next Steps and Future Plans

Next Steps and Future Plans:

- Drive OpenStudio/EnergyPlus into the market through promotion, training, support, etc.
- EnergyPlus Models/OpenStudio Measures:
  - Fill missing gaps (e.g., drain-water heat recovery, skylights)
  - Enhance algorithms (e.g., attic/duct modeling via Airflow Network)
  - Incorporate new/emerging technologies
- OpenStudio Workflows:
  - Streamline input via HPXML-to-OpenStudio translation
  - Facilitate geometry input via OpenStudio drawing tool
- Technical/Economic Potential via ResStock:
  - Leverage capabilities for multifamily (and commercial) building sectors
  - Incorporate demand, time-of-savings, and load flexibility
  - Connect to BTO's Scout tool
  - Simplify ease of use via OpenStudio's PAT user interface

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REFERENCE SLIDES

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Project Budget

Project Budget:
Substantial increase of non-RBI funding in first half of FY17 as we begin to promote the residential OpenStudio capabilities and demonstrate value.

Variances: N/A

Cost to Date: In FY17: 30% of DOE, 30% of Cost-share

Additional Funding: BPA (FY15-17), EPA (FY16-17), DOE EPSA/OSP/ET/CBI (FY15-17), Tendril (FY16-17), CPUC (FY15), Misc (FY15-17)
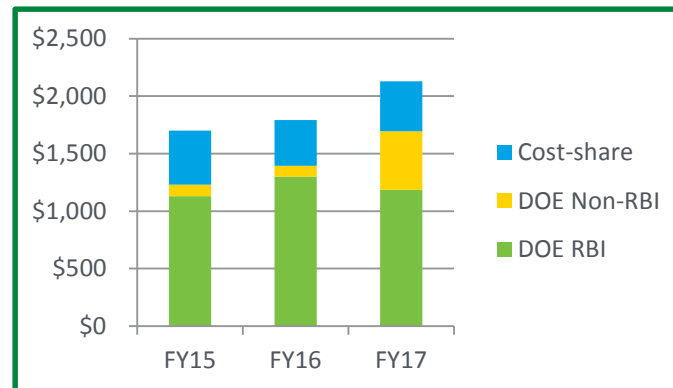
Budget History								
FY 2015 – FY 2016 (past)			FY 2017 (current)			FY 2018 – ? (planned)		
DOE RBI	DOE Non-RBI	Cost-share	DOE RBI	DOE Non-RBI	Cost-share	DOE RBI	DOE Non-RBI	Cost-share
$2,430k	$195k	$865k	$1,185k	$510k	$435k	TBD	TBD	TBD

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Project Plan and Schedule

Project initiation date: FY2015 Q1
Project completion date: Ongoing; specific tasks sunset as appropriate
- Substantial completion of migrating BEopt residential capabilities to OpenStudio
- Most significant milestones shown below

Project Schedule												
	FY2015				FY2016				FY2017			
Task	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Past Work												
FY15 Q3 Milestone: Release of BEopt with Multifamily Capabilities	█	█	◆									
FY15 Q4 Milestone: HERS Index Implementation Using EnergyPlus		█	█	◆								
FY16 Q1 Milestone: Paper on ResStock Value for Use Cases					◆							
FY16 Q2 Milestone: Release of HPXML Data Validator Tool & API					█	◆						
FY16 Q2 Milestone: Paper on Benefits of Calibration via Historical Data					█	◆						
FY16 Q3 Go/No-Go: Significant Progress & Value to Stakeholders							◆					
FY16 Q3 Milestone: ResStock Analysis Results to DOE/EPSA					█	█	◆					
FY16 Q4 Milestones: Releases of EnergyPlus/OpenStudio with Res. Models					█	█	█	◆				
Current/Future Work												
FY17 Q2 Milestone: Design of Res. Features for OpenStudio Drawing Tool									█	◆		
FY17 Q2 Milestone: Demo of ResStock OpenStudio Workflow									█			
FY17 Q3 Milestone: Release of Res. OpenStudio Measures on BCL						█	█		█			
FY17 Q3 Milestone: Release of ResStock Web Interface									█			
FY17 Q3 Milestone: Demo of ResStock Collaborations/Applications						█	█		█			
FY17 Q4 Milestones: Releases of EnergyPlus/OpenStudio with Res. Models									█			
FY17 Q4 STRETCH Milestone: Release of HERS Index Workflow in OpenStudio												
FY17 Q4 Milestone: Release of SEED HPXML Importer										█		
FY18 Q1 Milestone: Release of OpenStudio Drawing Tool with Res. Features									█	█		