Comparative Analysis of ASHRAE Building EQ As-Designed, Building Energy Asset Score, and ASHRAE 90.1 Performance Rating Method

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Contribution Number	6149
Presentation Date	2017-0X-0X
Presentation Time	XX:00

BUILDING SIMULATION 2017

AUGUST 7-9 • SAN FRANCISCO

Learning Objectives

- Understand the difference between asset rating and operational ratings

- Get an insight of the methodologies behind DOE and ASHRAE asset ratings

- Learn about the side-by-side comparisons of models from multiple rating systems

- Understand reasons for disagreements between the rating systems

ASHRAE's Building Energy Quotient

Charles Eley

Ratings Types

Asset Rating

- Simulated energy use based on standard modeling assumptions
- Independent of operational and occupancy variables
- Improved only by upgrading building fabric or systems

Building EQ As Designed

- Other Examples:
  - DOE Asset Score
  - 90.1 Performance Cost Index
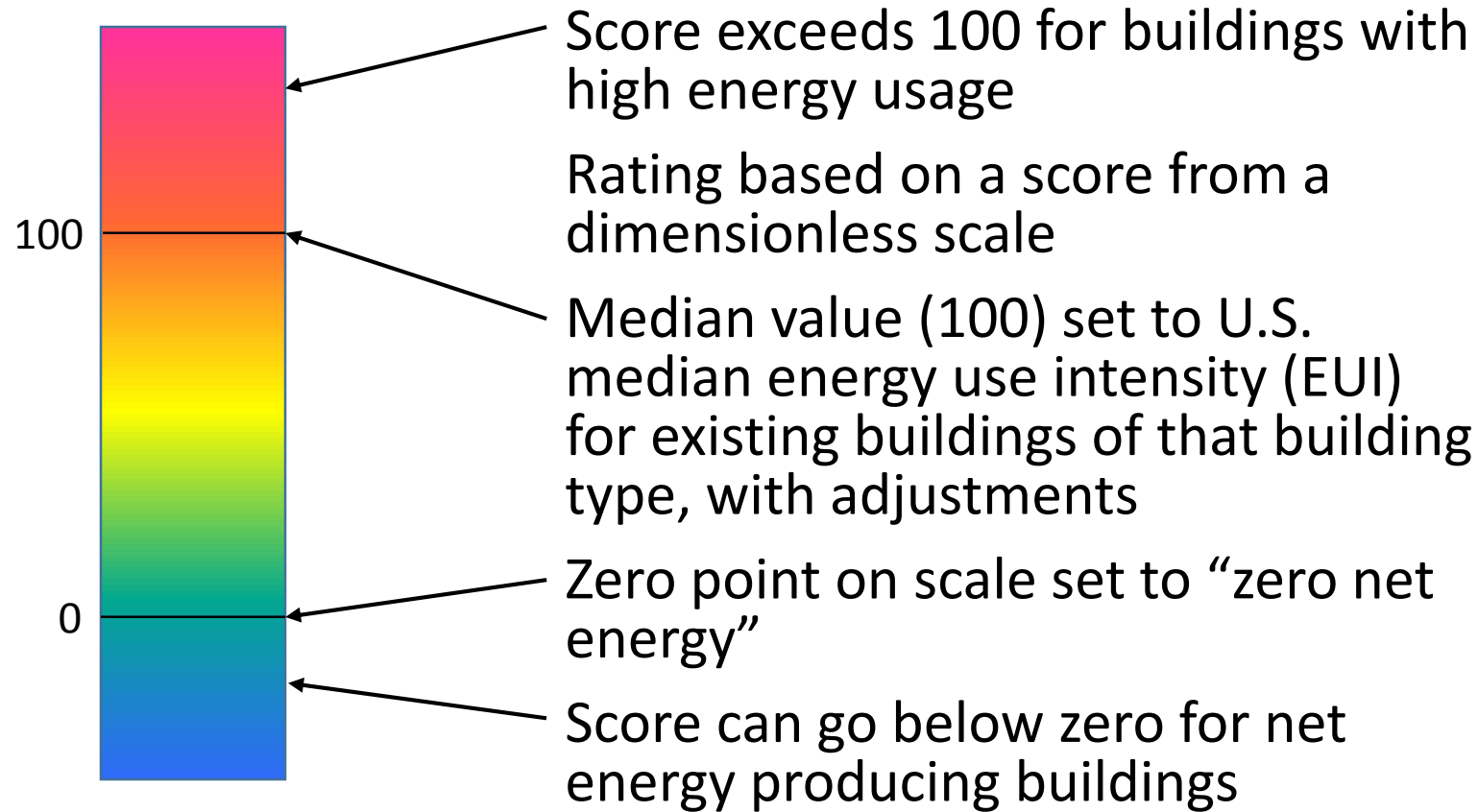
Operational Rating

- Actual metered energy consumption
- Influenced by operational and occupancy variables
- Improved by upgrading building fabric, systems, or operating procedures

Building EQ In Operation

- Other Examples:
  - ENERGY STAR Portfolio Manager

Building EQ Scale

Score exceeds 100 for buildings with high energy usage

100

Rating based on a score from a dimensionless scale

Median value (100) set to U.S. median energy use intensity (EUI) for existing buildings of that building type, with adjustments

0

Zero point on scale set to "zero net energy"

Score can go below zero for net energy producing buildings

Building eq™ POWERED BY ASHRAE

Building EQ As Designed Score

$$(\text{EUI}_{\text{simulated}} / \text{EUI}_{\text{baseline}}) \times 100$$

- Baseline EUI is based on CBECS median for the building type, corrected for location
- Uses standardized modeling inputs of building operating parameters (COMNET*)
  - Occupancy, plug and process loads, schedules, setpoints
  - Depend on building and space type
- EUIs calculated for source energy using US national site-to-source factors

* COMNET Commercial Buildings Energy Modeling Guidelines and Procedures

Building eQ POWERED BY **ASHRAE**

Modeling Inputs

That Affect Rating

- Building Envelope
- HVAC system type
- Cooling type
- Heating Type
- Service water heating
- Fuel types
- Lighting systems
- Other energy efficiency measures

That are Neutral

- Plug Loads
- Occupancy
- Ventilation Rates
- Processes
- Schedules – includes lights, receptacles, HVAC Operating hours, HVAC set points, domestic hot water use, refrigeration, elevators, etc.
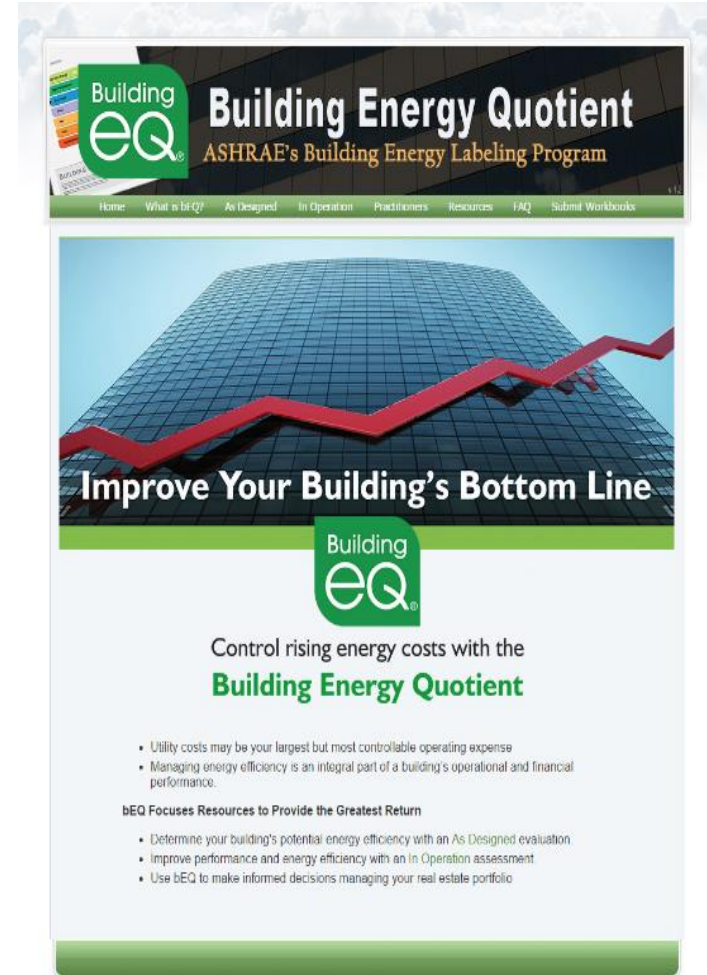
Building eQ
POWERED BY ASHRAE

Rater Credentials

- Building Energy Modeling Professional (BEMP)
  - Evaluate, choose, use, calibrate, and interpret results of energy modeling software when applied to building and systems energy performance and economics.
  - Competence to model new and existing buildings and systems with their full range of physics.
- Licensed design professional in jurisdiction

ASHRAE's Building EQ

- Voluntary rating/labeling program
- Complements other green building and energy rating/labeling programs
- Provides a way to benchmark performance
- Greater differentiation for high performing buildings and emphasis on zero net energy
- Can be a tool to stimulate adoption of high perfromance building techniques

ASHRAE's Building EQ

- Allows for comparison of As Designed (asset) and In Operation (operational) ratings
- Consistent energy rating method for both existing building and new construction programs
- Unified system for assessing assets and operations
- Allows for comparison between buildings with different operational variables
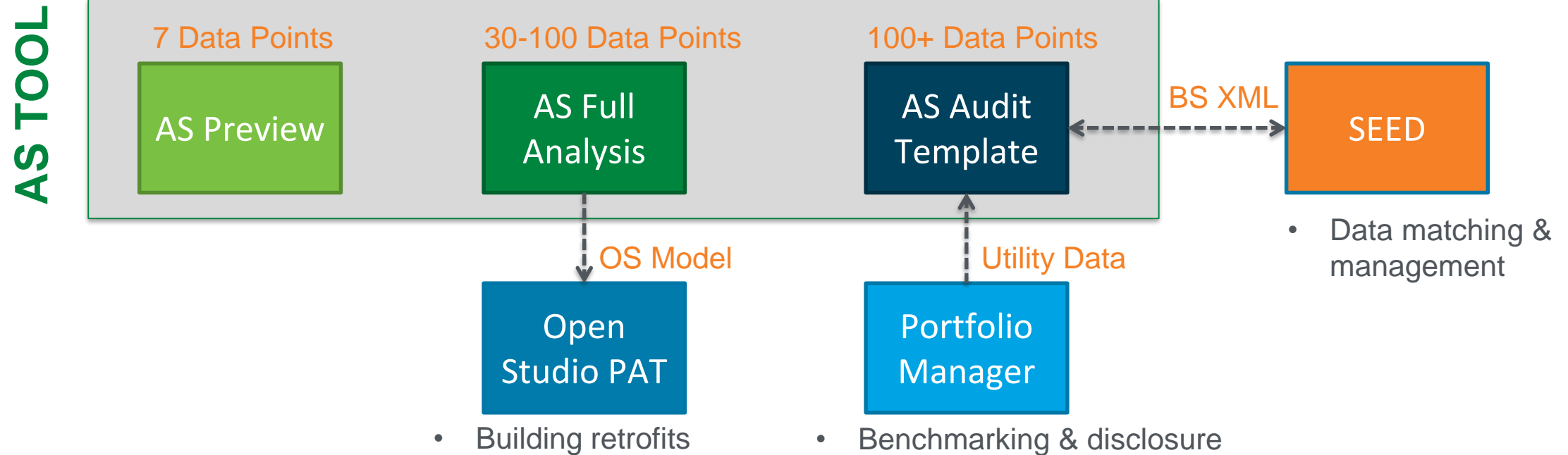
Building Energy Asset Score

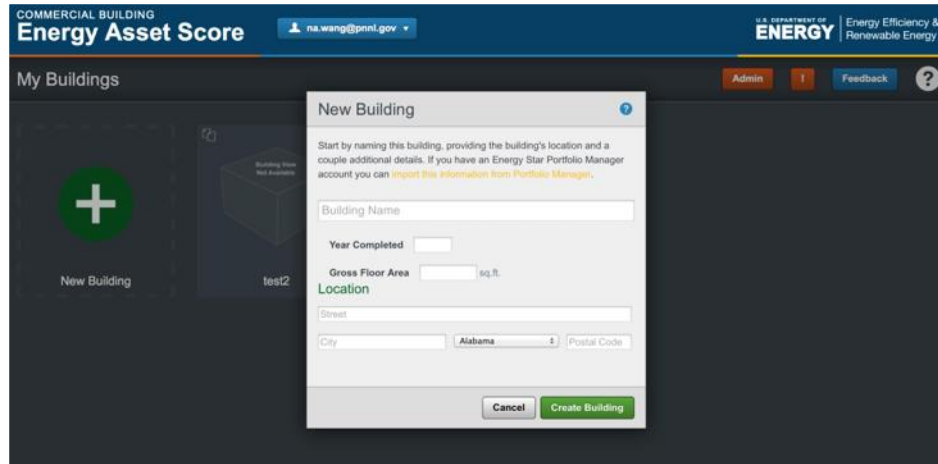WANG, Ph.D.
nora.wang@pnnl.gov

PACIFIC NORTHWEST NATIONAL LABORATORY
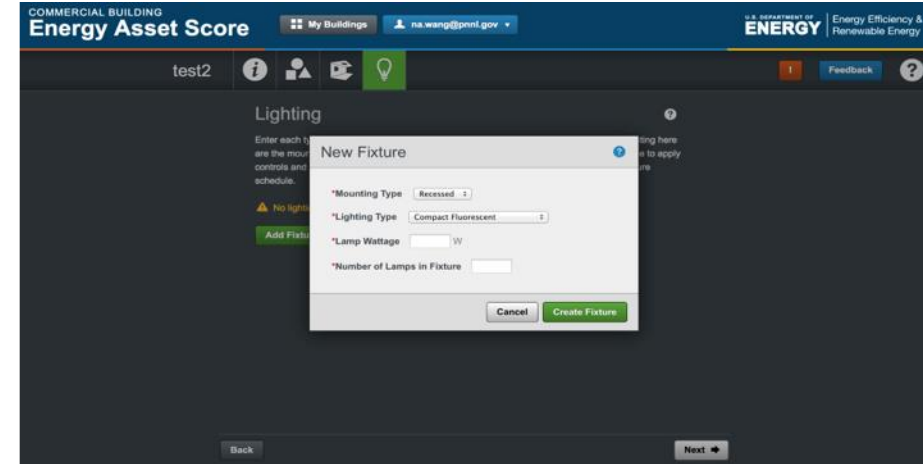
System Approach

- Screening & prioritization for EE programs

- Asset valuation
- Green building certifications
- Incentives & rebate programs

- Energy audit or retuning

AS TOOL

7 Data Points
AS Preview

30-100 Data Points
AS Full Analysis

100+ Data Points
AS Audit Template

BS XML

SEED

- Data matching & management

OS Model
Open Studio PAT

Utility Data
Portfolio Manager

- Building retrofits
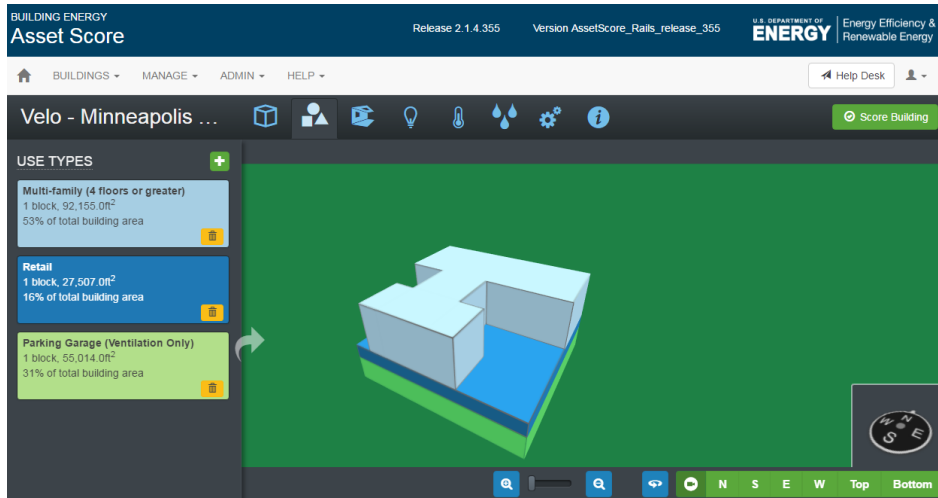
- Benchmarking & disclosure
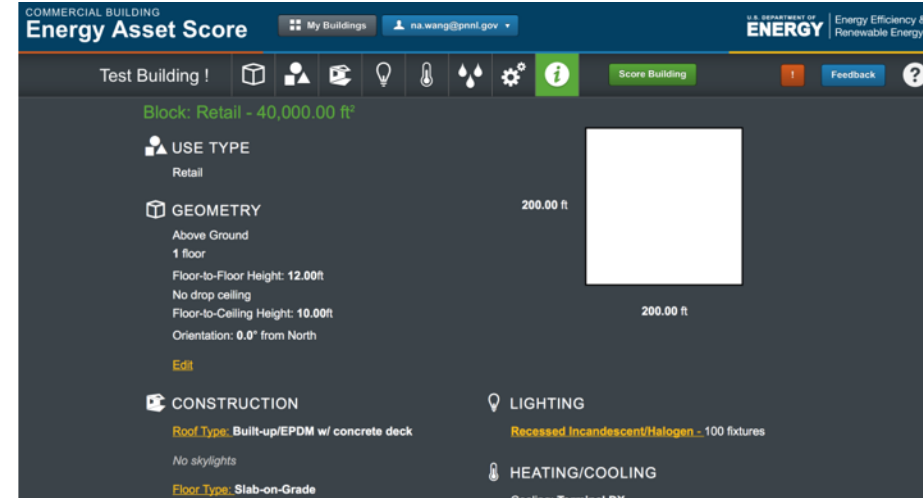
Asset Score Tool

1. Create a new building and enter basic building information

2. Identify building use type(s) and create an inventory of your building features (HVAC, windows, etc.)

3. Create 3-D block(s) of your building and apply use type(s) and features to your building block(s)

4. Score your building and receive your Asset Score Report

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Climate Adjustment

▶ Buildings are scored based on adjusted EUI.

▶ A set of weather coefficients for heating, cooling, and fan energy use was developed for each weather station (1020 TMY3 weather stations).

▶ 90.1 prototype buildings were used to weather coefficients.

$$\check{N}EUI^{heating}_{site\ m} = EUI^{heating}_{site\ m} \times Coefficient^{heating}_{site\ m}$$

$$\check{N}EUI^{cooling}_{site\ m} = EUI^{cooling}_{site\ m} \times Coefficient^{cooling}_{site\ m}$$

$$\check{N}EUI^{fan}_{site\ m} = EUI^{fan}_{site\ m} \times Coefficient^{fan}_{site\ m}$$

$$\check{N}EUI^{total}_{site\ m} = \check{N}EUI^{heating}_{site\ m} + \check{N}EUI^{cooling}_{site\ m} + \check{N}EUI^{fan}_{site\ m}$$
$$+ EUI^{plug\ loads}_{site\ m} + EUI^{lighting}_{site\ m} + EUI^{load\ n}_{site\ m}$$

Scoring Scales

► A progressive binning method was used to establish an appropriate scale for each use type.

► 90.1 Prototype Buildings were used as base models to develop EUI distributions, which were turned into score look-up tables.

► No baseline is needed for scoring a building.

EUI	Score	Increments
70	10.0	
80	9.5	10
90	9.0	10
100	8.5	10
110	8.0	10
120	7.5	10
130	7.0	10
140	6.5	10
150	6.0	10
160	5.5	10
175	5.0	15
190	4.5	15
205	4.0	15
220	3.5	15
235	3.0	15
250	2.5	15
270	2.0	20
290	1.5	20
310	1.0	20

Office Score
On a 10 Point Scale

Mean	5.525
StDev	1.536
N	35415

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Scoring A Building

	EUI		Asset Score
	(Kbtu/ft^2)	(MJ/m^2)	
	70	795	10.0
	80	909	9.5
	90	1,022	9.0
	100	1,136	8.5
	110	1,249	8.0
	120	1,363	7.5
	130	1,476	7.0
	140	1,590	6.5
	150	1,704	6.0
	160	1,817	5.5
	175	1,987	5.0
	190	2,158	4.5
	205	2,328	4.0
	220	2,499	3.5
	235	2,669	3.0
	250	2,839	2.5
	270	3,066	2.0
	290	3,294	1.5
	310	3,521	1.0
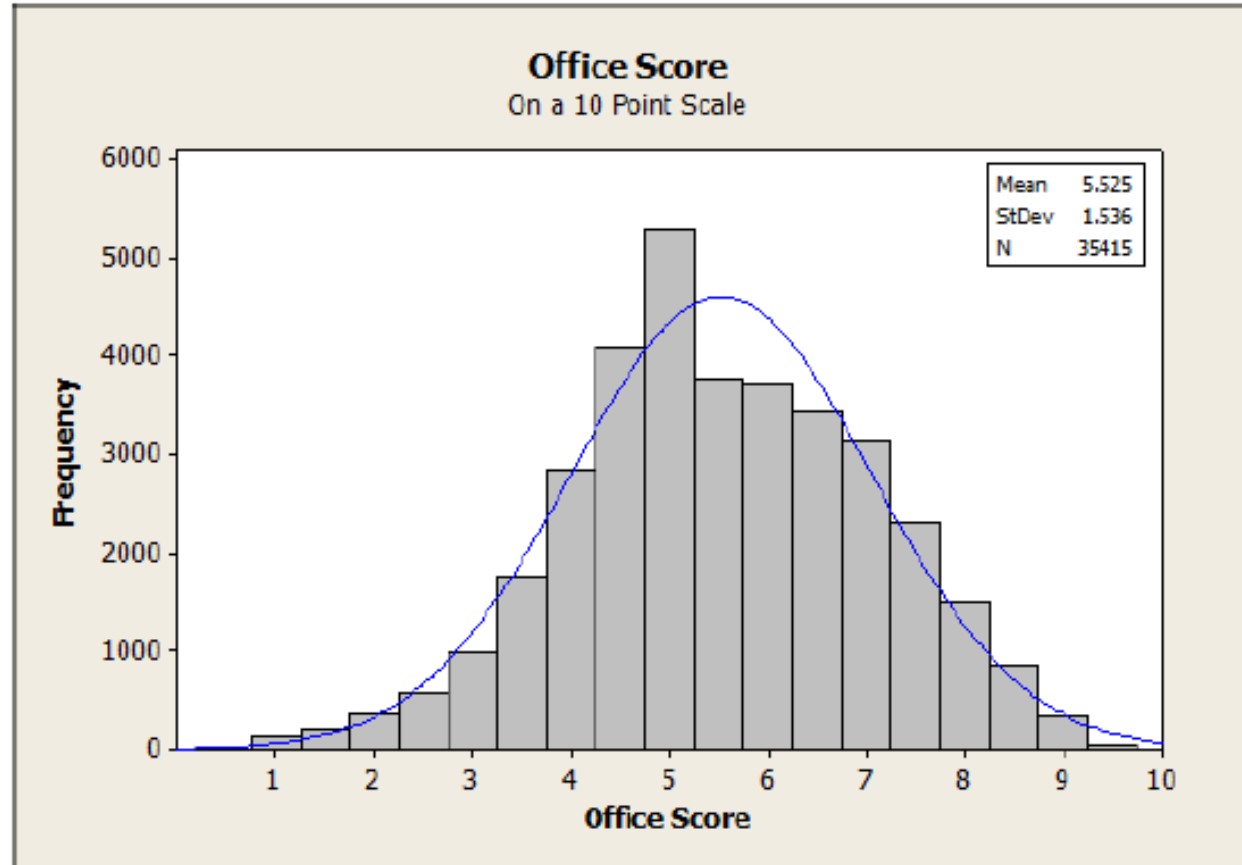
Step 1: Model Source EUI
Example:
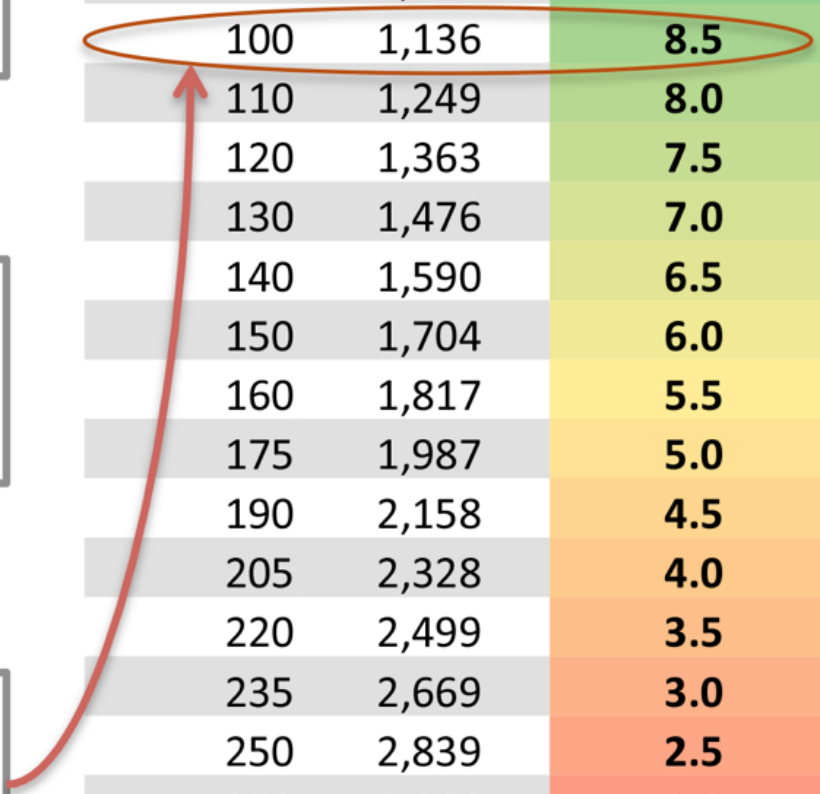*Source EUI = 1,249 MJ/m^2 (110 kBtu/ft^2)*

Step 2: Adjust EUI for Climate
Example:
Adjusted Source EUI = 1,136 MJ/m^2 (100 kBtu/ft^2)

Step 3: Convert Adjusted EUI to Asset Score
Example:
Asset Score = 8.5

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Asset Score Report

The Asset Score generates a report with the following information:

- 10-point score based on the EE of the building envelope and the mechanical, electrical, and service hot water systems

- EE assessment of the building's individual systems

- Total estimated building energy usage and energy use by end use under standard operating conditions

- Opportunities to upgrade building efficiency, and a "potential" energy efficiency score based on identified upgrades

Thank You

Adoption:	January 2016	February 2017
Buildings Scored	825	1735
Sq.ft. Valuated	83 million	186 million
Sq.ft. in Progress	155 million	169 million
States	30	45
User Accounts	792	1716

▶ Asset Scoring Tool
   buildingenergyscore.energy.gov/

▶ Resources: https://buildingenergyscore.energy.gov/resources

▶ Publications:

• Wang, N., Makhmalbaf, A., Srivastava, V., & Hathaway, J. (2016). Simulation-based coefficients for adjusting climate impact on energy consumption of commercial buildings. *Building Simulation: An International Journal.* DOI: 10.1007/s12273-016-0332-1.

• Wang, N., Goel, S., Makhmalbaf, A., & Long, N. (2016). Development of building energy asset rating using stock modelling in the USA. *Journal of Building Performance Simulation.* DOI:10.1080/19401493.2015.1134668.

ASHRAE Standard 90.1 2016 Performance Rating Method and Comparative Analysis of the Asset Ratings

Maria Karpman

90.1 2016 Performance Rating Method: General Approach
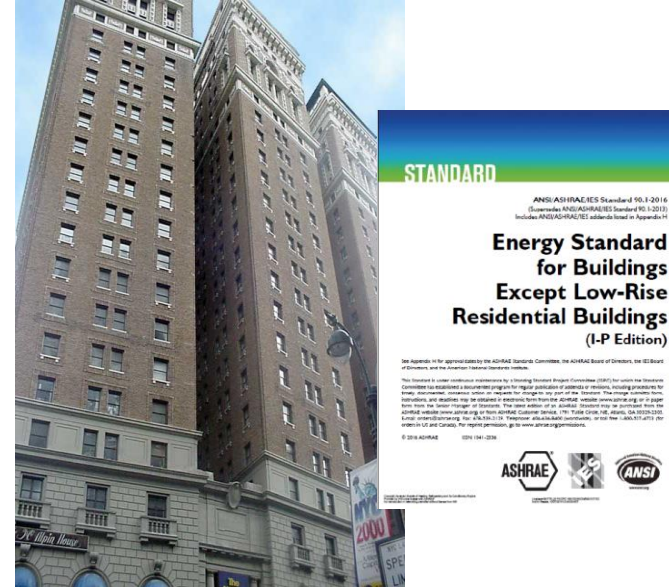
Proposed Building Model	**Baseline Building Model**
Reflects building design or existing systems and components	Virtual building configured as described in 90.1 Appendix G and meeting ~ 90.1 2004

- Same operating conditions typical for the building type, or as expected for the project
  - Same utility rates and weather file, appropriate for the project
  - Modeled in a simulation tool compliant with 90.1 Appendix G

Performance Rating Method: Scale

$$Performance\ Cost\ Index\ (PCI) = \frac{Proposed\ Building\ Energy\ Cost}{Baseline\ Building\ Energy\ Cost}$$

PCI

1.00 ← Baseline (~ 90.1 2004)

0 ← ~Net Zero
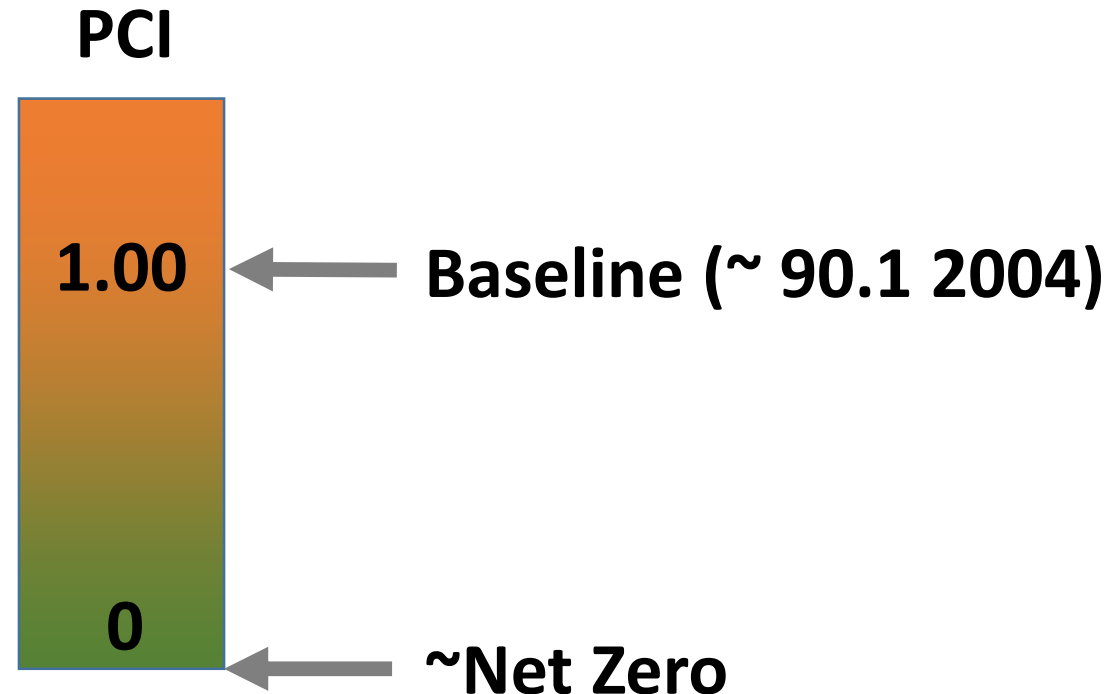
Comparative Analysis Study

- Undertaken in the framework of the National Labeling Group (NLG) convened by NYSERDA to investigate feasibility, develop, and implement a nationally recognized ubiquitous building energy label utilizing <u>existing asset and operational rating systems</u>

- The comparative analysis focused on verifying the general agreement between selected rating systems, and feasibility of mapping to a generic score

Tested Rating Systems

Asset Ratings

- **ASHRAE Building Energy Quotient (bEQ) As Designed**

- **DOE Asset Score**

- **ASHRAE Standard 90.1 Performance Rating Method (PRM, Appendix G)**

Operational Ratings

- **ASHRAE Building Energy Quotient (bEQ) In Operation**

- **EPA Energy Star Score**
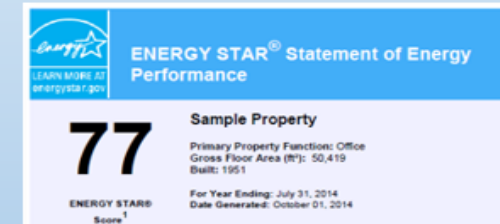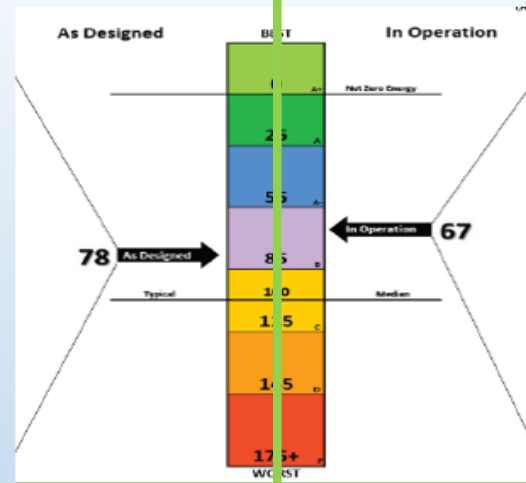
Methodology

- Tested office and multifamily buildings as representing commercial and residential sectors

- Climate zones 4A (heating dominated) and 2A (cooling dominated)

- Use "theoretical" buildings based on the Progress Indicator Models (PNNL), and Reference Building Models (NREL)

- Vintages meeting 90.1 2004 & 2013, pre-1980, and high performance options.

High-rise Apartment (HR MF)

84,360 ft²; 10 floors

Mid-rise Apartment

33,700 ft²; 4 floors

Small Office

5,500 ft²; 1 floor

Medium Office Prototype

53,600 ft²; 3 floors

Large Office

498,600 ft²; 12 floors; Includes Data Center
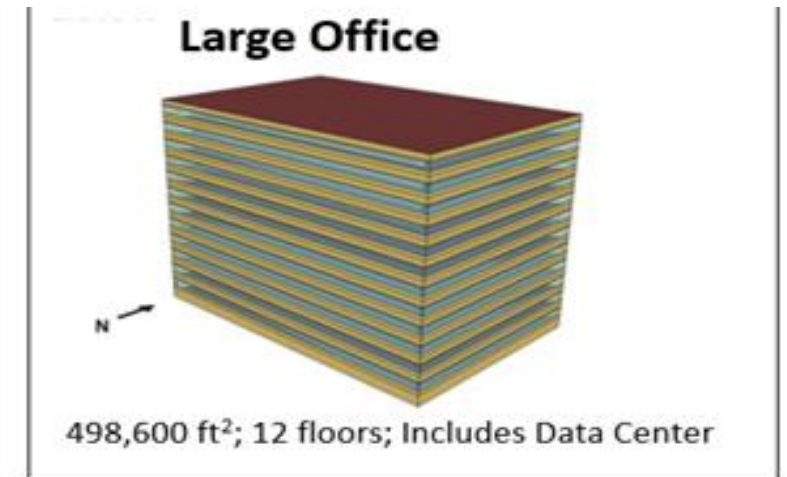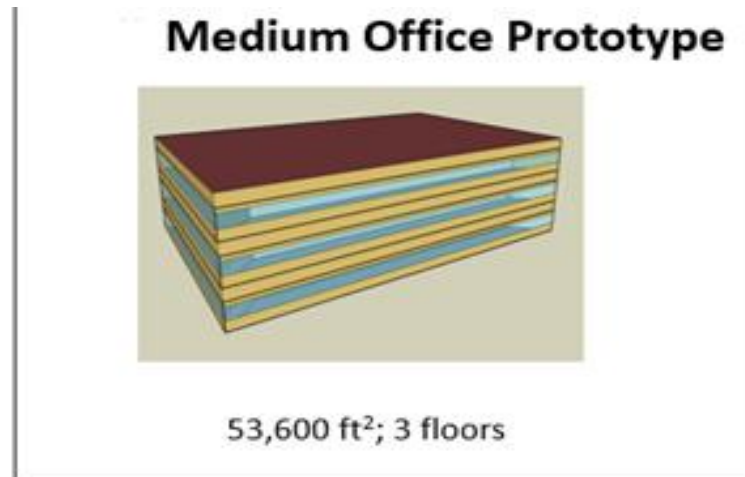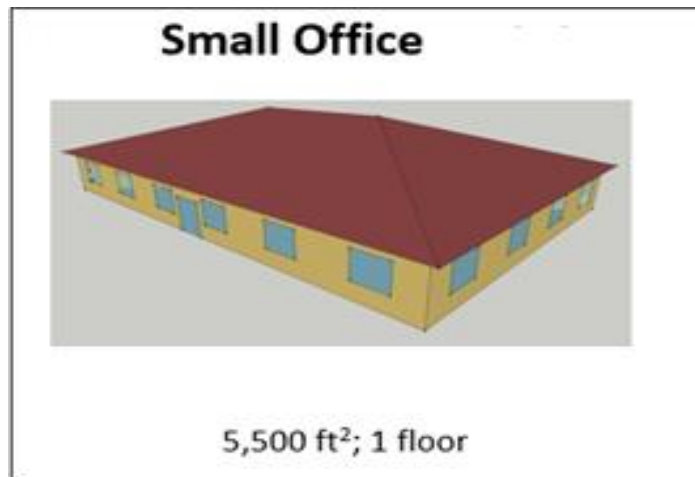
High-rise Apartment Test Cases

#	Climate Zone	90.1 Vintage	HVAC	Test Case Label
1	4A	Exceeds Passive House	BB & RTU & ERV	4A - PH
2	4A	2013	BB & RTU	4A - 2013 - BB & RTU
3	4A	2013	WSHP	4A - 2013 - WSHP
4	2A	2013	WSHP	2A - 2013 - WSHP
5	4A	2004	BB & RTU	4A - 2004 - BB & RTU
6	4A	2004	WSHP	4A - 2004 - WSHP
7	4A	2004	PTAC	4A - 2004 - PTAC
8	2A	2004	PTHP	2A - 2004 - PTHP
9	2A	2004	WSHP	2A - 2004 - WSHP

WSHP: Continuously running Water Source Heat Pumps
PTAC: Continuously running Packaged Terminal Air Conditioners with HW gas boilers
ERV: Energy recovery ventilators in each apartment and on corridor RTU
BB & RTU: HW baseboards + cycling room ACs + continuous exhaust fans in apartments, RTU in corridors

Relative Ranking of Test Cases

BEST ⬇ **WORST** ⬇

	1	2	3	4	5	6	7	8	9
BEAS									
	4A - PH		4A - 2013 - WSHP		2A - 2004 - WSHP	4A - 2013 BB & RTU	4A - 2004 - BB & RTU	4A - 2004 - WSHP	
	2A - 2004 - PTHP		4A - 2004 - PTAC					2A - 2013 - WSHP	
bEQ As Designed									
	4A - PH	4A - 2013 - BB & RTU	4A - 2004 - BB & RTU	2A - 2013 - WSHP	4A - 2004 - PTAC	2A - 2004 - PTHP	4A - 2013 - WSHP	2A - 2004 - WSHP	4A - 2004 - WSHP
PRM									
	4A - PH	4A - 2013 - BB & RTU	4A - 2004 - BB & RTU	2A - 2013 - WSHP	4A - 2004 - PTAC		4A - 2013 - WSHP	2A - 2004 - WSHP	4A - 2004 - WSHP
					2A - 2004 - PTHP				

Reasons for Disagreement: Definition of Asset

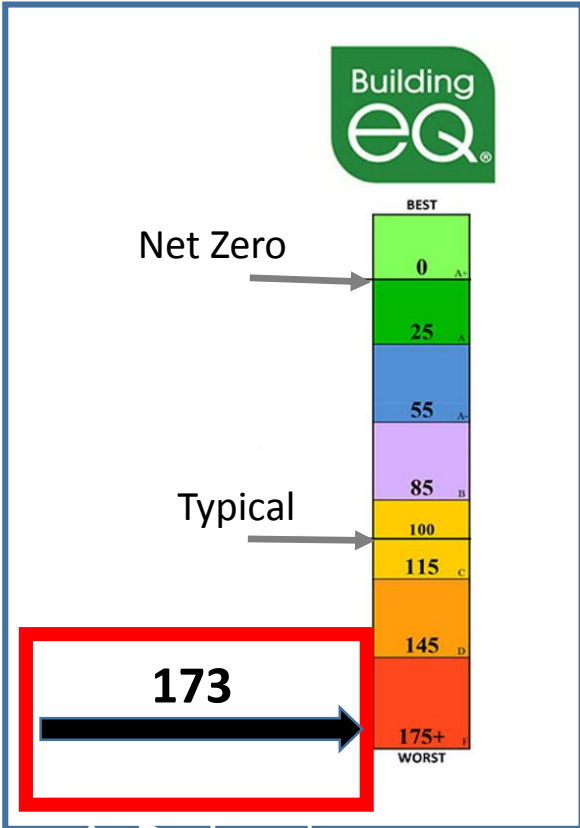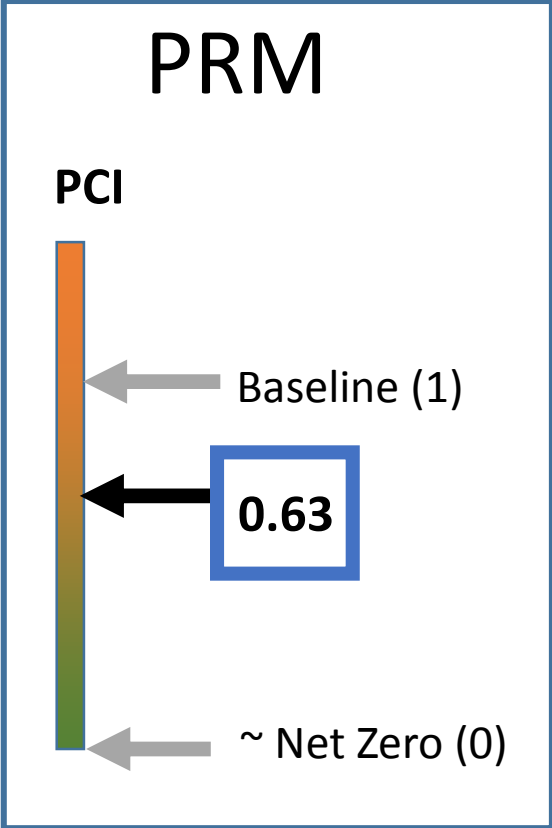|	4A - PH - BB & RTU & ER	2A - 2004 - PTHP	ASSET?		
			BEAS	bEQ	PRM
Infiltration cfm/ft^2 @ 75Pa	0.04; as tested	0.40 (default)	No*	Yes	Yes
ERV in apartments	Yes	No	No**	Yes	Yes
Apartment fan energy and control	Cycling window ACs	Continuously running PTHPs	No***	Yes	Yes
Low flow fixtures	Yes	No	Yes	No	Yes****
Apartment lighting	0.5 W/SF (as installed)	0.45 (default)	Yes, all	Yes, hardwired	Yes, hardwired
Energy Star ® appliances	Yes	No	No	No	Yes****

* Plan to add in future

** Envisioned as asset, but Asset Score Tool could not capture zone-level ERV.

***Envisioned as asset, but Asset Score Tool could not capture cycling window AC.

**** Modeled as asset, following EPA for Energy Star High Rise Multifamily program Simulation Guidelines, as allowed by PRM for above-code applications.

Rating Scores of "4A-PH" Test Case

BUILDING ENERGY ASSET SCORE — OVERALL BUILDING SCORE

Current Score: **7.0**

1 — Uses MORE Energy … 10 — Uses LESS Energy[2]

High-Efficiency

PRM

PCI

Baseline (1)

0.63

~ Net Zero (0)

Building eQ

BEST

Net Zero → 0 (A⁺)

25 (A)

55 (A⁻)

85 (B)

Typical → 100

115 (C)

145 (D)

173 →

175+ (F)

WORST
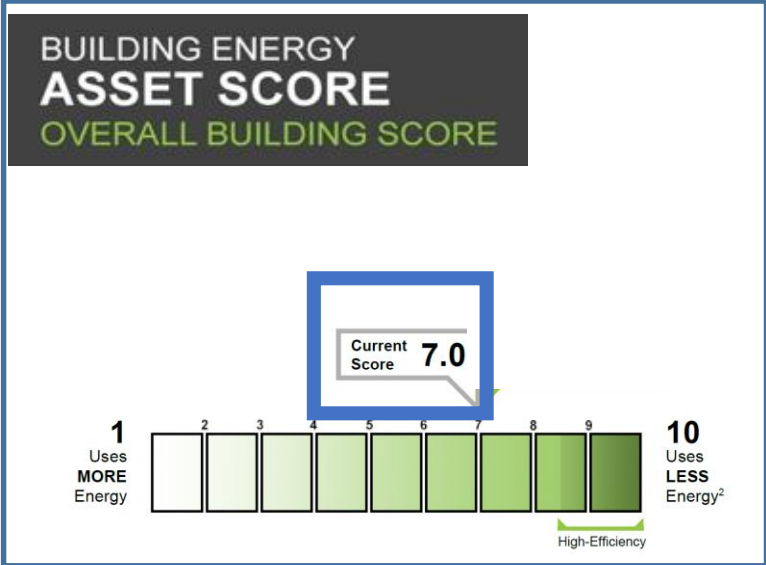
Why did bEQ give the failing grade to the project that it ranked as the best?

Reasons for Disagreement: Baseline and Scale

bEQ as Designed PH-MF Source EUI

bEQ Baseline EUI

Legend:
- Hot Water
- Heating
- Fans
- Pumps
- Cooling
- Lighting
- Misc. Equipment
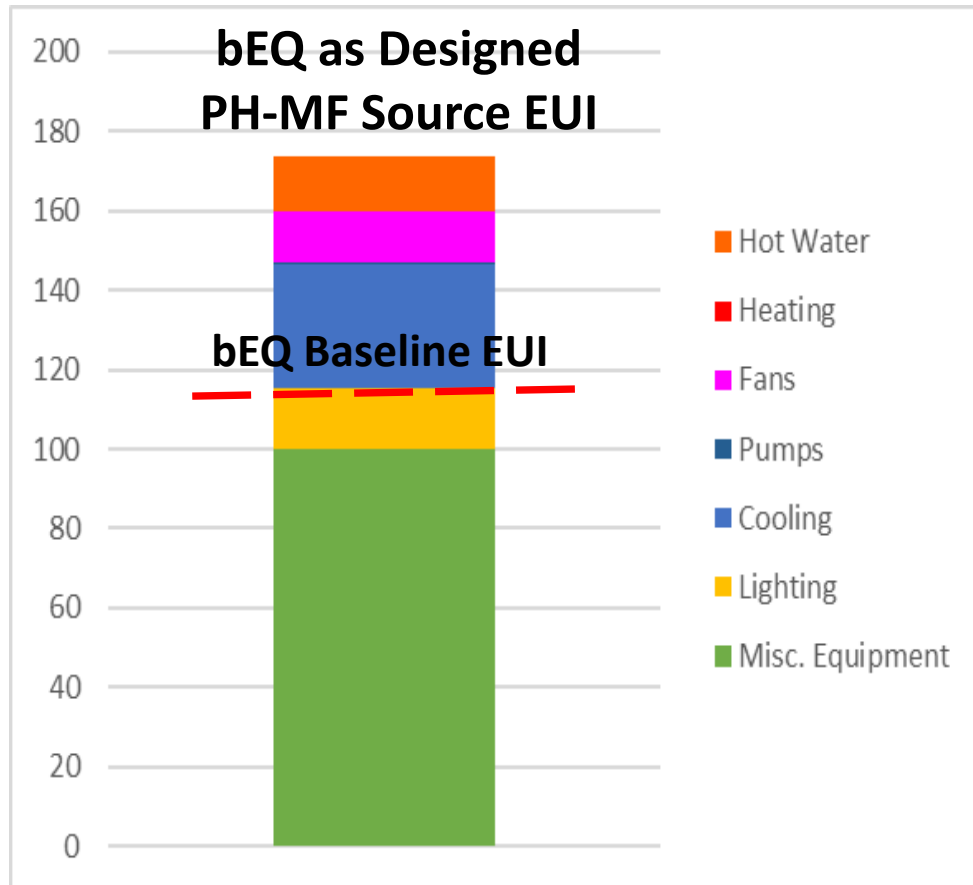
- COMNET receptacle and refrigeration loads account for 80%+ of the bEQ Baseline EUI.

- Different sources disagree on the typical annual energy use of miscellaneous equipment

COMNET   PNNL MF HR Prototype   EPA Energy Star MF HR   Passive House Institute (PHI)
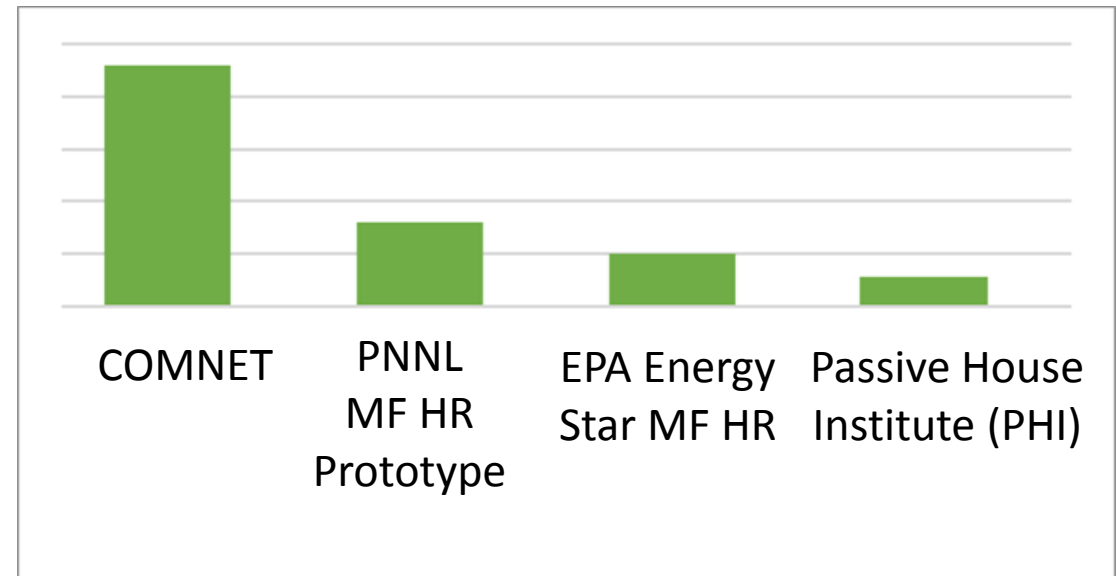
PRM Approach to the Operating Conditions

- Baseline and Proposed Design models use the same modeling assumptions.

- PCI is the ratio of the Proposed to the Baseline Energy Cost, so perhaps operating conditions "cancel out"?
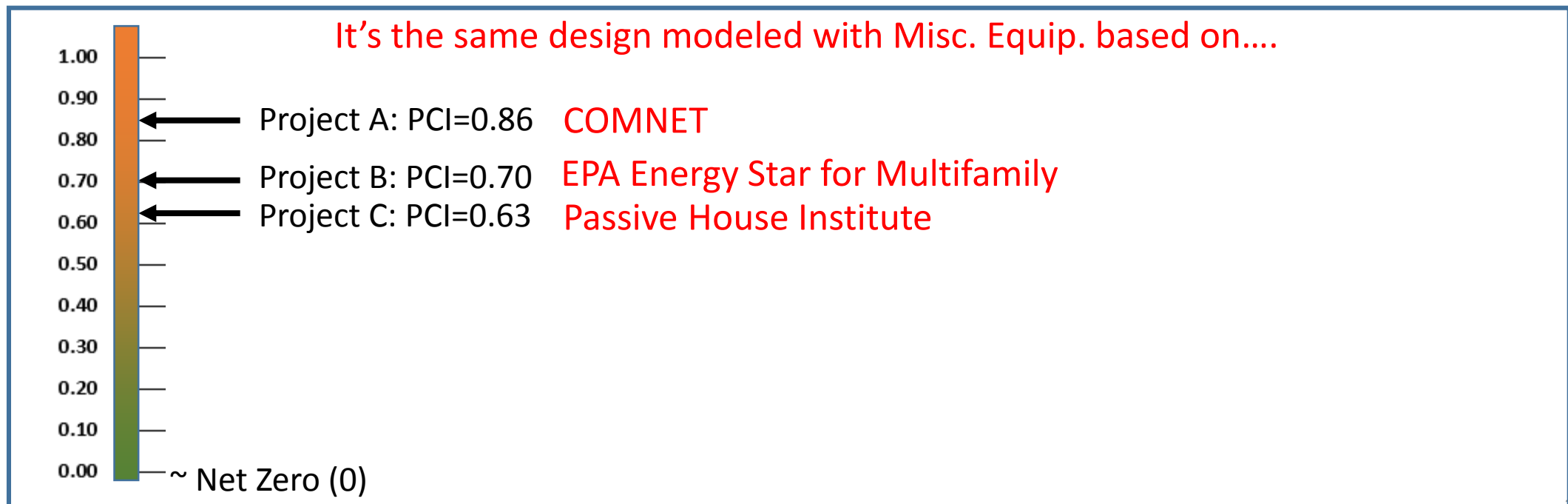
Which of the three projects is more efficient?

It's the same design modeled with Misc. Equip. based on….

1.00

0.90

Project A: PCI=0.86 COMNET
0.80

0.70 Project B: PCI=0.70 EPA Energy Star for Multifamily
Project C: PCI=0.63 Passive House Institute
0.60

0.50

0.40

0.30

0.20

0.10

0.00 ~ Net Zero (0)

Why is General Agreement between the Rating Systems Important?

- Significant unexplained disagreements undermine credibility of the asset rating concept.

Rating System A   Rating System B

- Adopters increasingly want to allow multiple compliance options

Pay for Performance Program New Construction

Chose Path

- bEQ As-Designed
- 90.1 PRM

MULTIFAMILY NEW CONSTRUCTION PROGRAM

➢ Performance Path with Energy Star (PRM)
➢ Passive House Institute US (PHIUS)
➢ Passive House Institute (PHI)
➢ Prescriptive Path
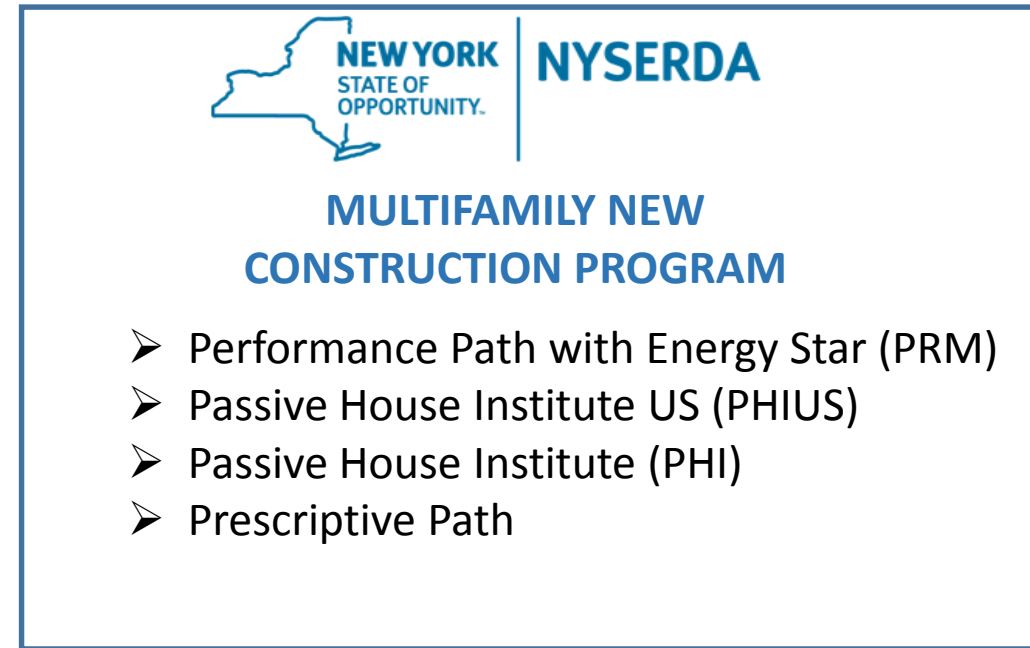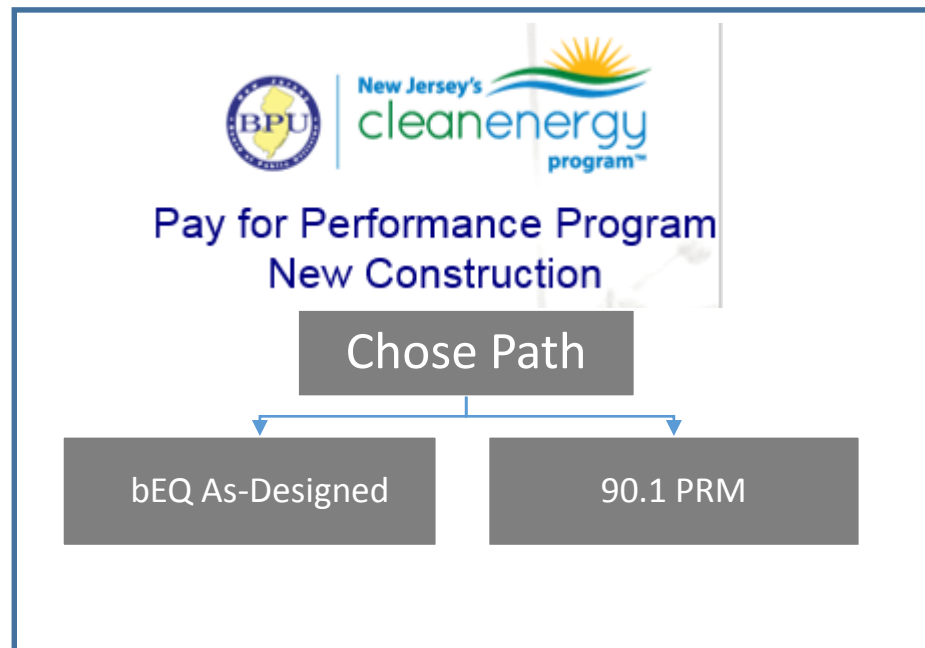
Takeaways

➢ Adopters will benefit from an independent entity developing requirements and overseeing validation and testing of the rating systems.

➢ It appears possible and desirable to align asset definition between the rating systems, such as based on the aspects of design regulated by Standard 90.1.

➢ There should be a matrix comparing asset definitions in each rating system, to help adopters make educated decisions when selecting the rating system(s), and correctly interpret the scores.

➢ Sample recommendations to the rating system developers:

bEQ As Designed: Review COMNET modeling assumptions and schedules to ensure reasonable scoring

BEAS: Enhance Asset Score Tool (AST) support of common configurations and high performance buildings; troubleshoot AST functionality.

PRM: Lack of prescribed operating conditions hinders the use of PRM for asset ratings, and creates opportunities for gaming

PANEL DISCUSSION
and
Q & A

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Charles Eley   *Eley Consulting*

Nora Wang   *Pacific Northwest National Laboratory*