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Unlocking the Savings Potential in Small Commercial Buildings

2016 ACEEE National Symposium on Market Transformation

March 21, 2015

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Mark Stutman - Demonstration Program Manager, Penn State mbstutman@engr.psu.edu

Chris Baker - Principal, NBI chrisb@twgi.com

Today's Panel

- Ralph DiNola, NBI: Moderator
- Mark B. Stutman, Penn State
- Chris Baker, The Weidt Group

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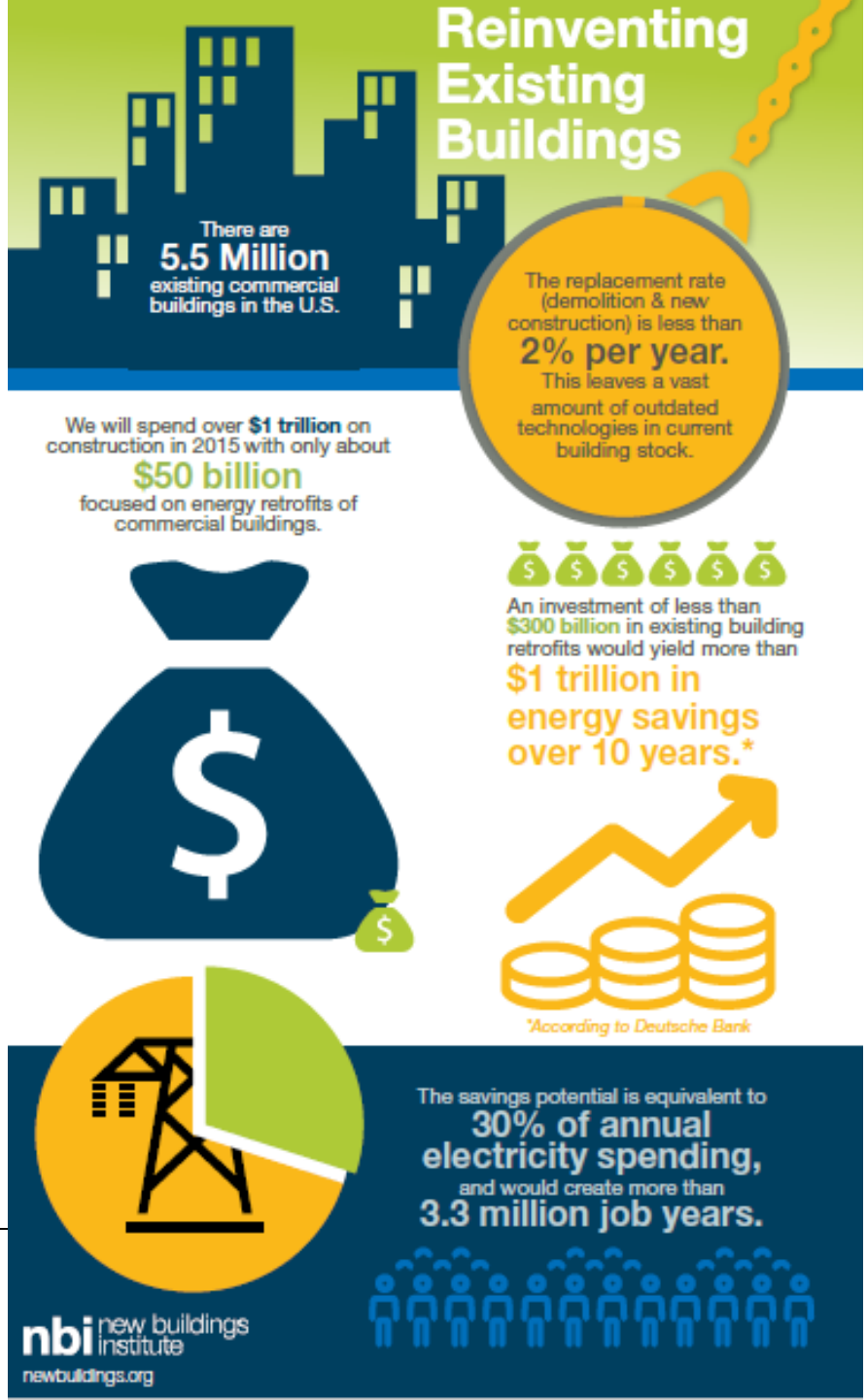
The Importance of Existing Buildings

1. Make real estate transactions a mechanism for upgrading the existing building stock
2. Reserve federal incentives for building retrofits to zero net energy
3. Modify Title 42 federal preemption of local and state equipment standards to ensure reasonable standards are available to meet state and local energy goals.



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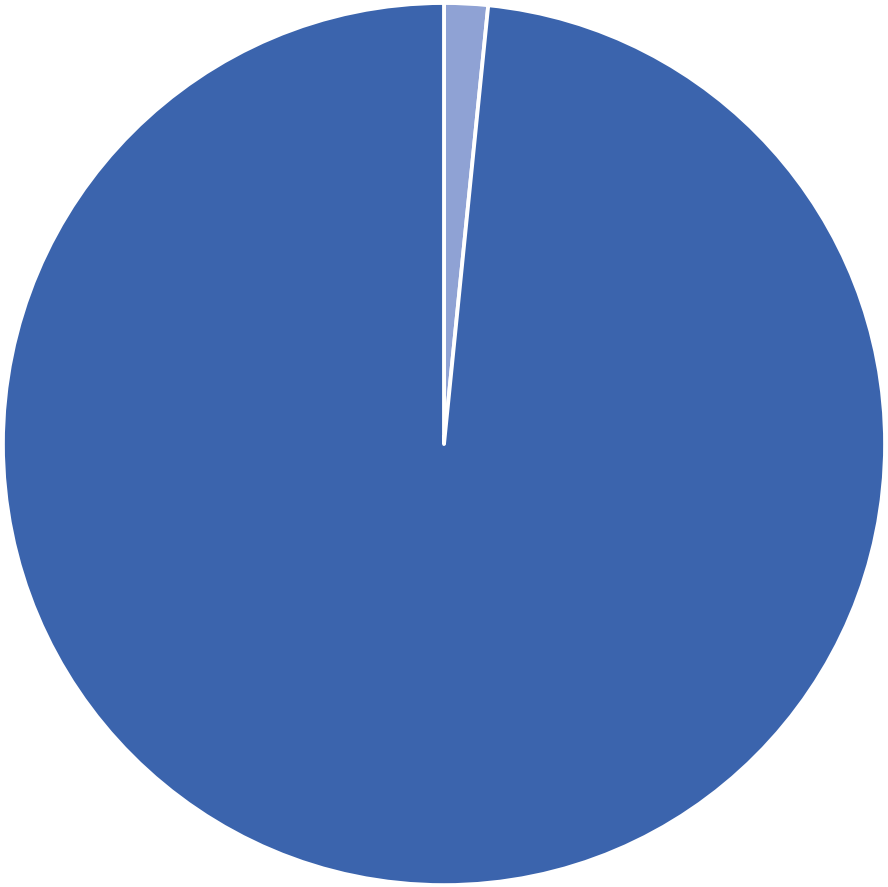
Context: Commercial Buildings

98.6% Existing

- 5.6 million commercial buildings exist in the United States
- 78,500 new or replacement per year
- ~ 90% under 25,000 sf



(EIA, 2012)

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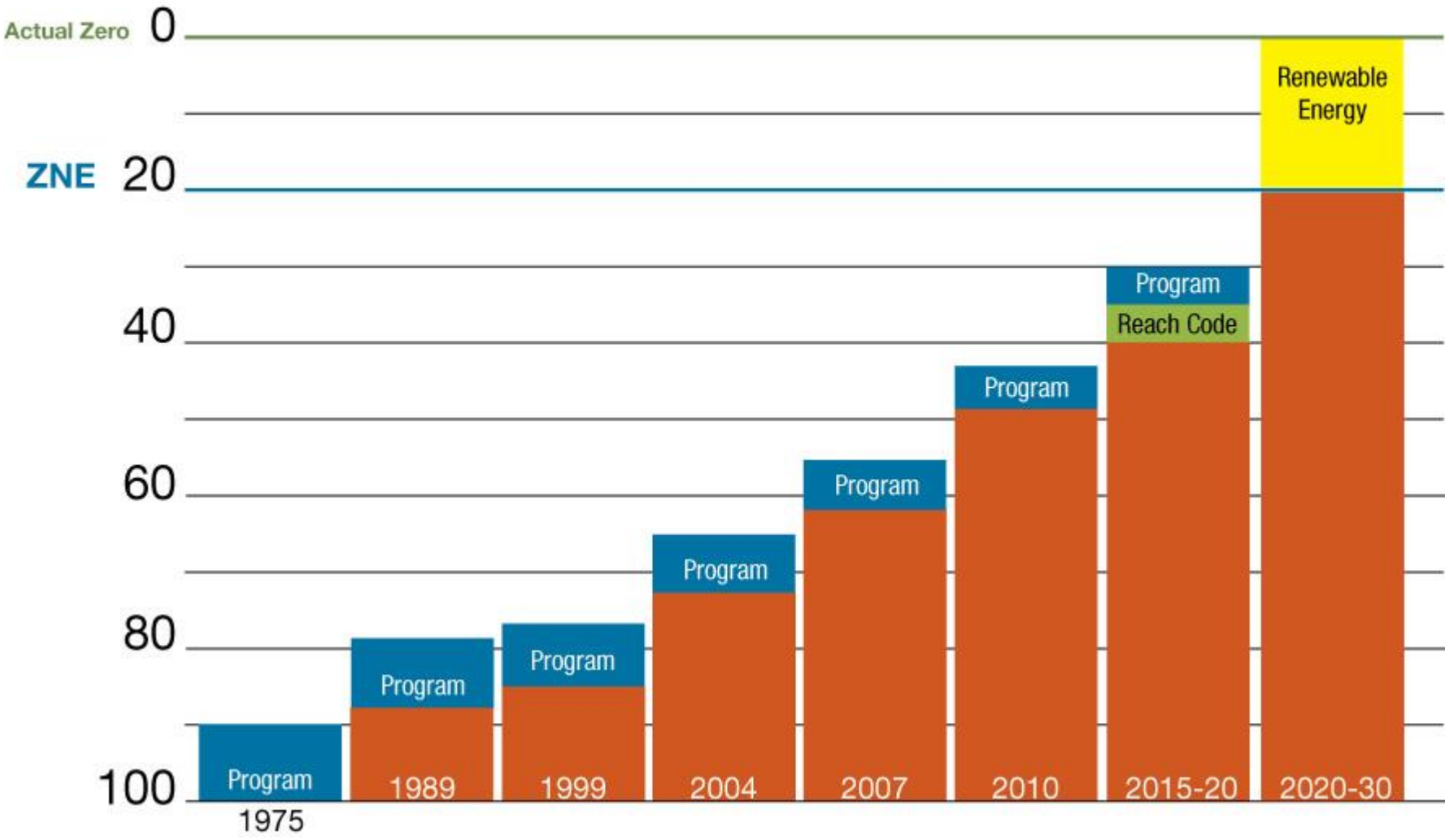
Advancing Policy to Zero



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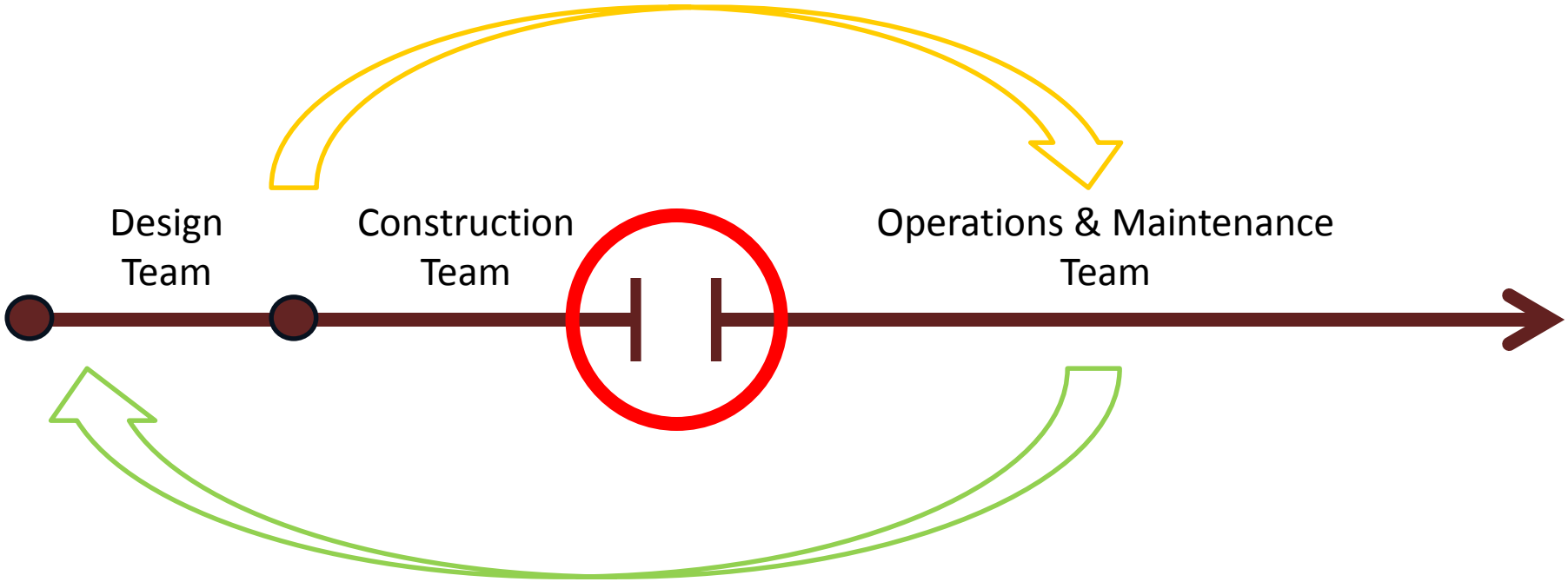
Design for Operations

Integrating operations team into the design process



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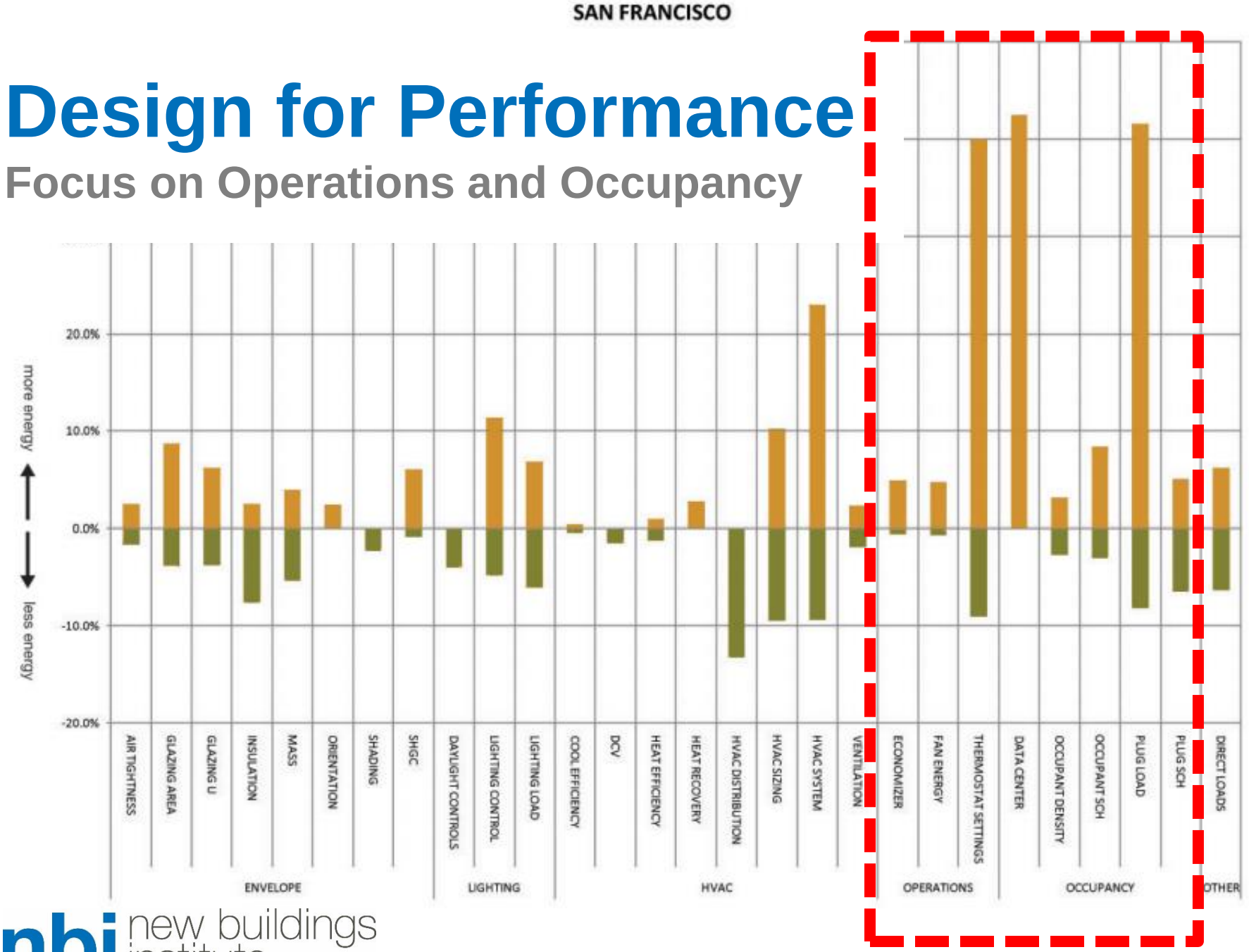
Design for Performance

Focus on Operations and Occupancy



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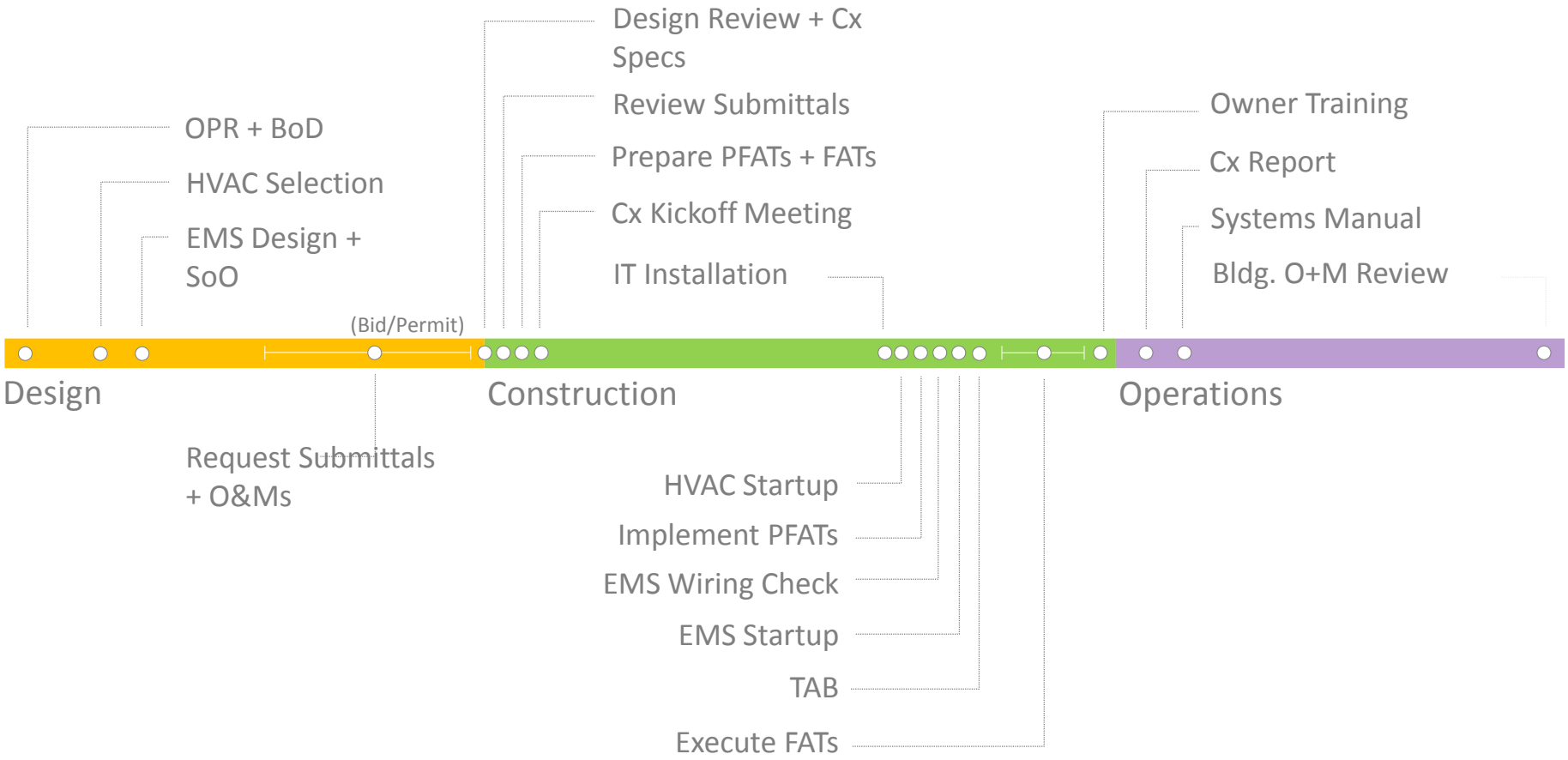
http://newbuildings.org/sites/default/files/SensitivityAnalysisReport.pdf

Build to the Design

Commissioning: ensuring persistence performance



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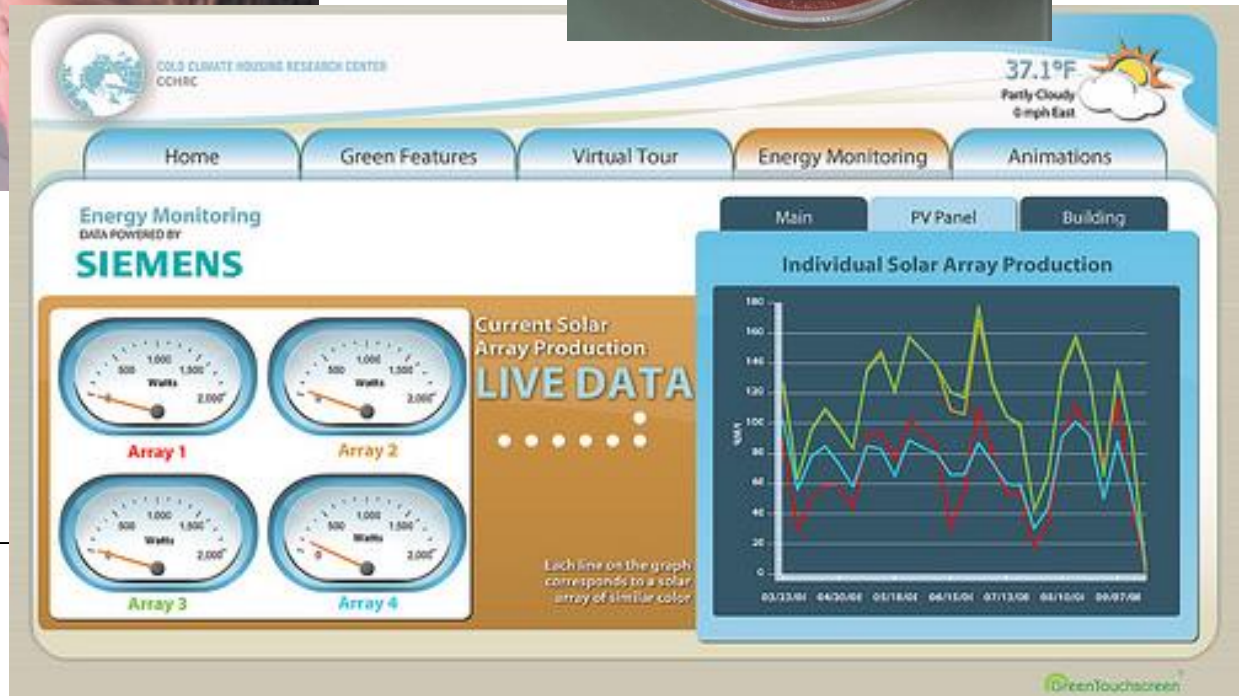
Engage Occupants
Measure and Verify Performance



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Solutions

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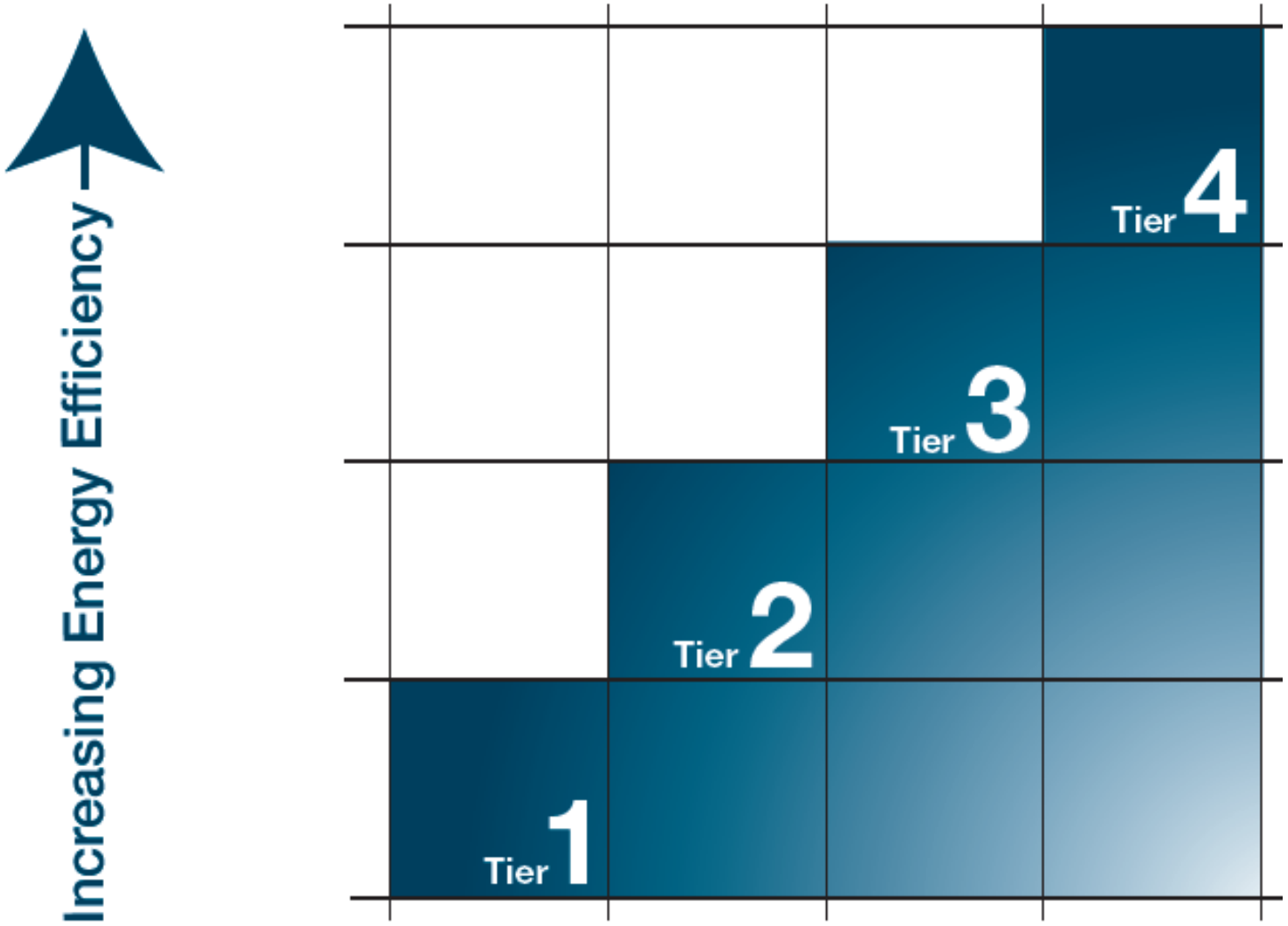
Tiers of Efficiency



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Energy Savings by Tier

Approximate Range of Savings from Advanced Buildings Requirements

Base Code and Year		Range of Savings		
ASHRAE 90.1	IECC	Tier 1	Tier 2	Tier 3
2004	2006	20-30%		
2007	2009	15-25%	25-35%	35-40%
2010	2012	n/a	15-25%	25-35%

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LEED v4

NORTHEAST COLLABORATIVE FOR HIGH PERFORMANCE SCHOOLS

architecture 2030

CITY OF BOULDER

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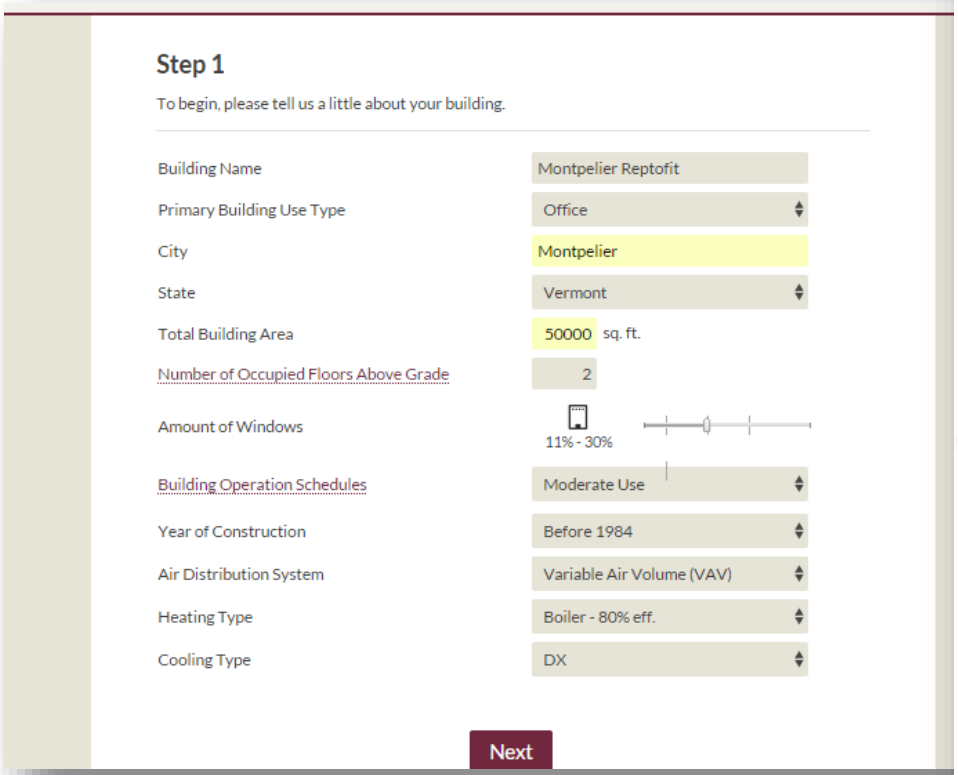
Retrofit Savings Estimator

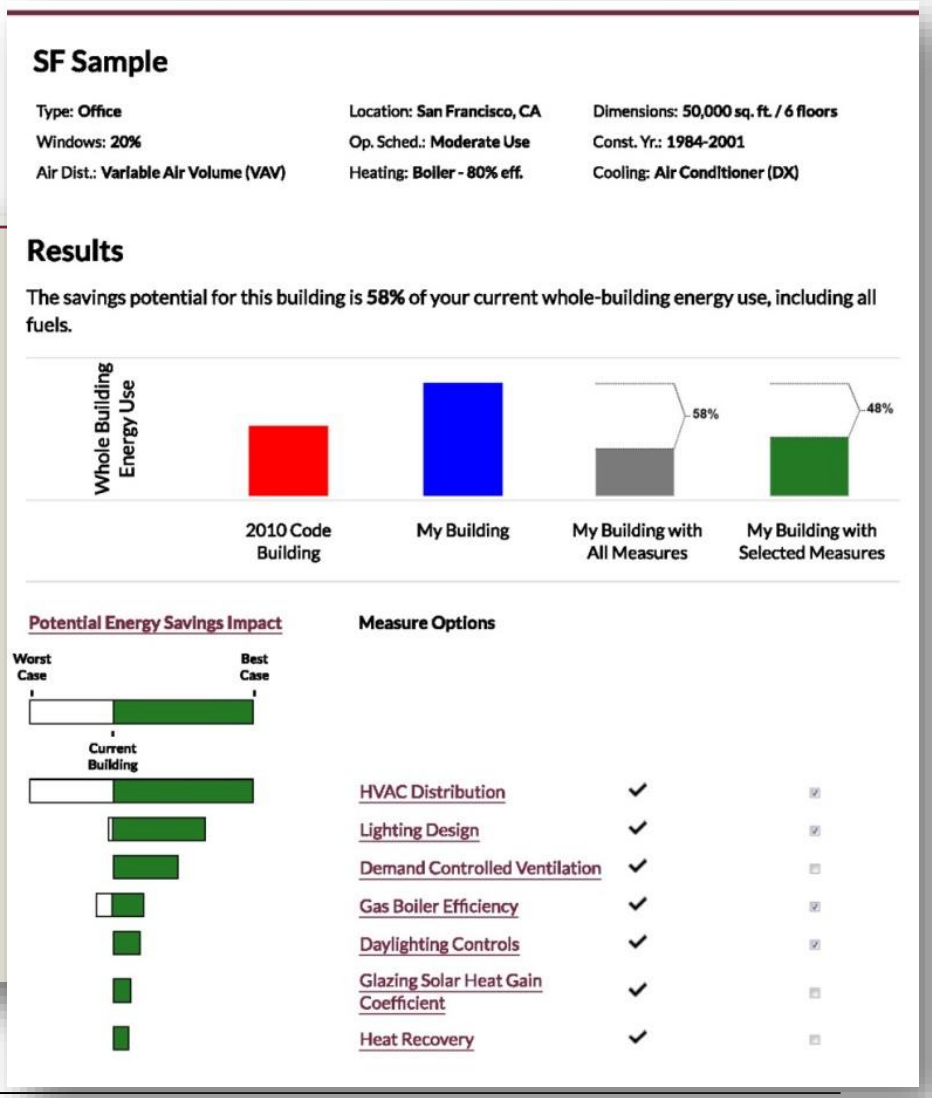
- Simplified Web-Based Energy Simulation Model for Existing Buildings
- Intended for building owners, property managers, third parties
- Developed in collaboration with The Weidt Group

RSE: Prototype-Based Model

Large database of prototype buildings enables **real-time** simulation analyses to compare **customized** measure packages and estimate whole-building **impacts.**

RSE: Data & Customization





http://nbideepretrofittool.twgi.com/

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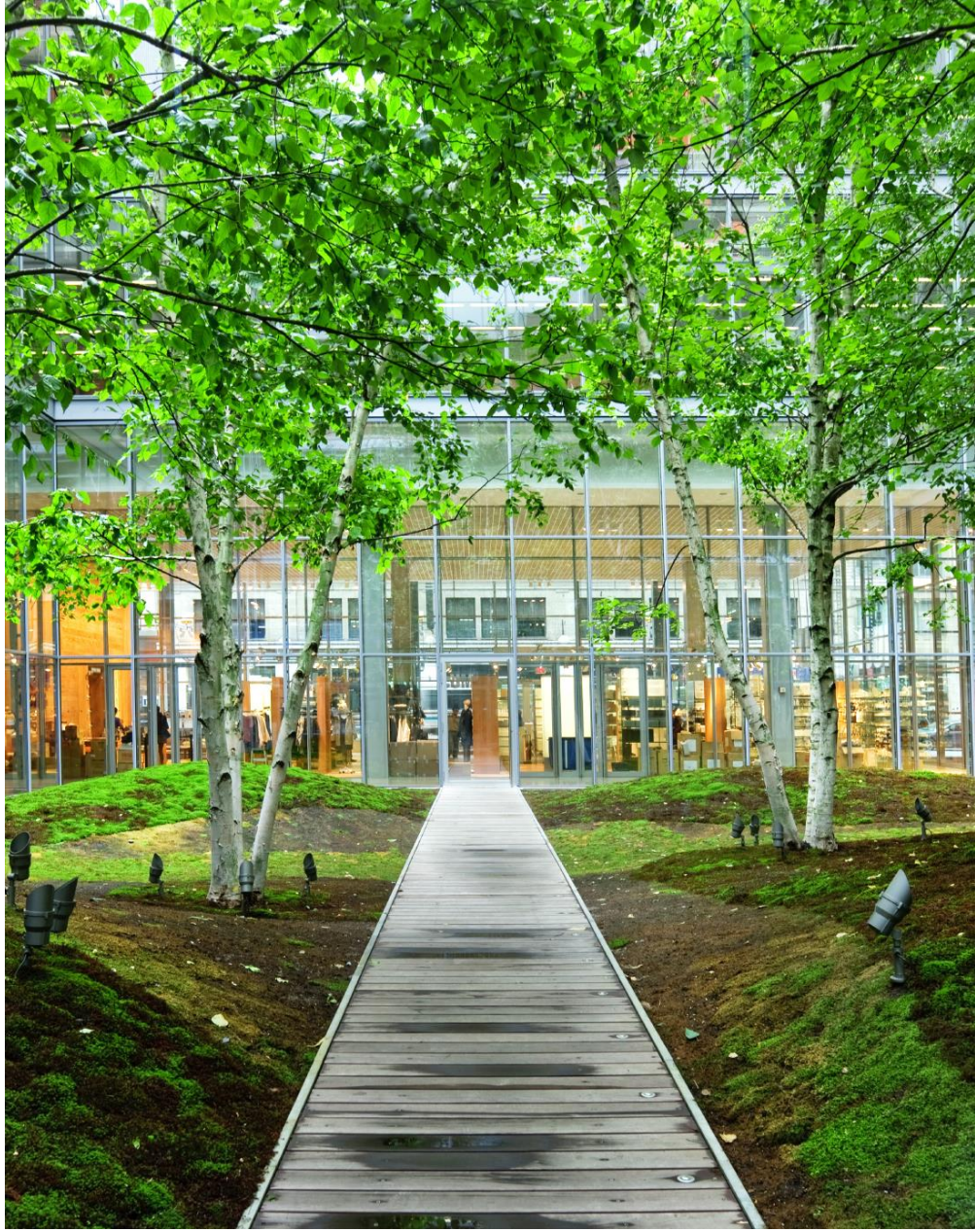
advanced buildings

FirstView®

Virtual Energy Auditing & Advanced Benchmarking



Contact: Alexi Miller, P.E.
alexi@newbuildings.org

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advanced buildings

Simple Inputs for Deep Insight

- Inputs:
  - 1 year of monthly utility bills
    - All fuels – electric, gas, other
  - Basic Building Info:
    - Location
    - Building size
    - Building type

- Energy Star Portfolio Manager Integration
  1. PM bulk data exports to spreadsheet
  2. NBI cleans, validates, checks data
  3. NBI creates bulk set of FirstView inputs

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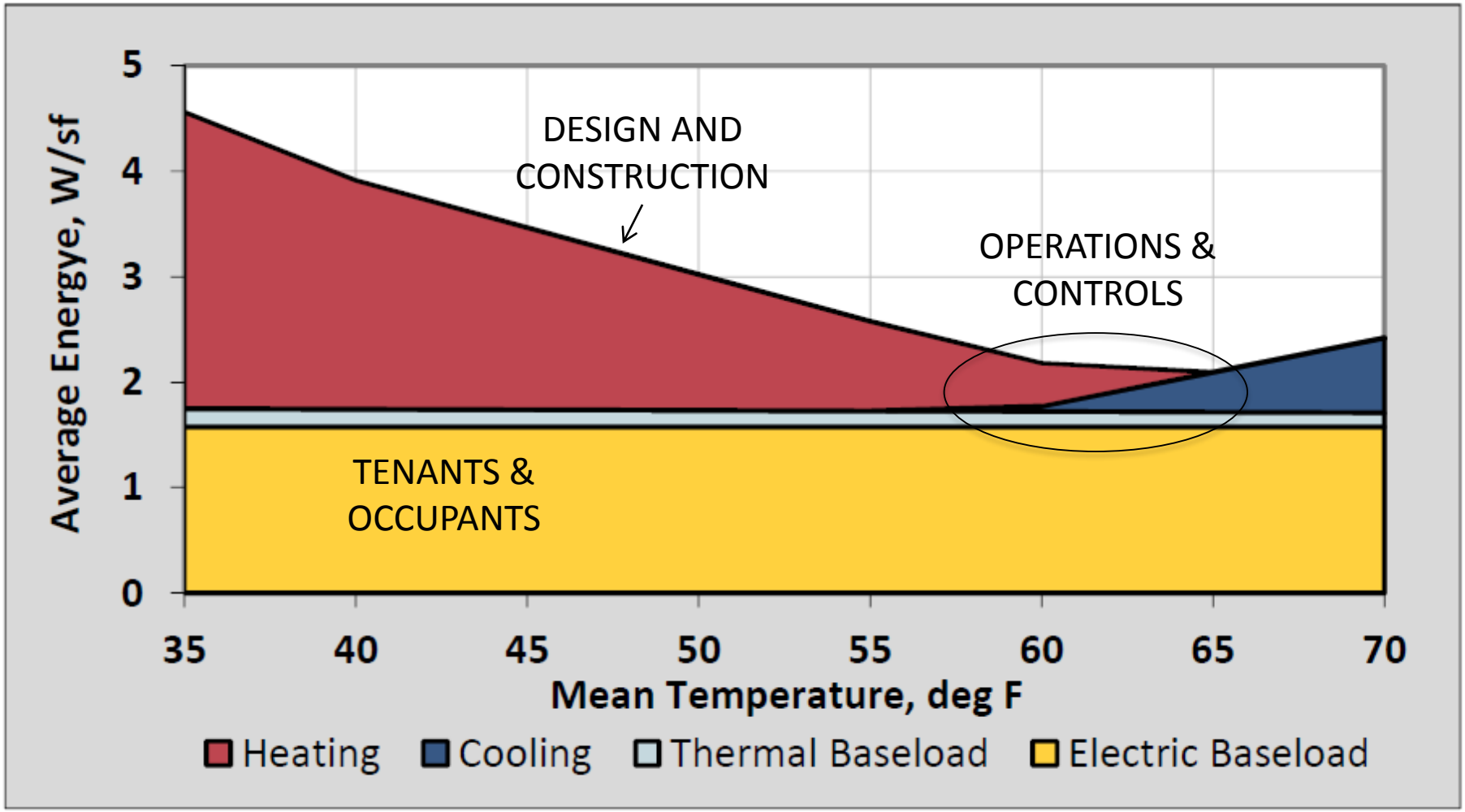
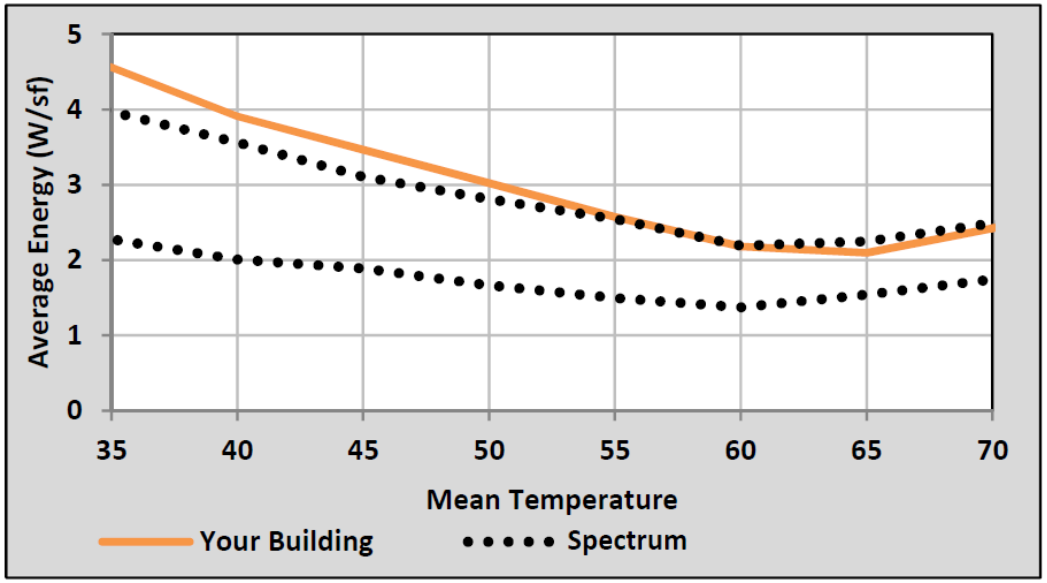
Energy Signature: Cambridge City Hall Annex



Peer Building Spectrum

- A Spectrum can be generated from buildings within the portfolio:
  - All buildings
  - Specific Building types

- OR use Existing Spectrums:
  - Offices
  - K-12 schools
  - Libraries
  - Fire stations
  - Community Centers
  - Market-Rate Multifamily
  - Affordable Multifamily



A Peer Building Comparison uses a graphical energy signature spectrum to show how a building compares to other similar buildings. The spectrum typically shows a median comparison peer set but may be configured to show high performance comparison buildings.

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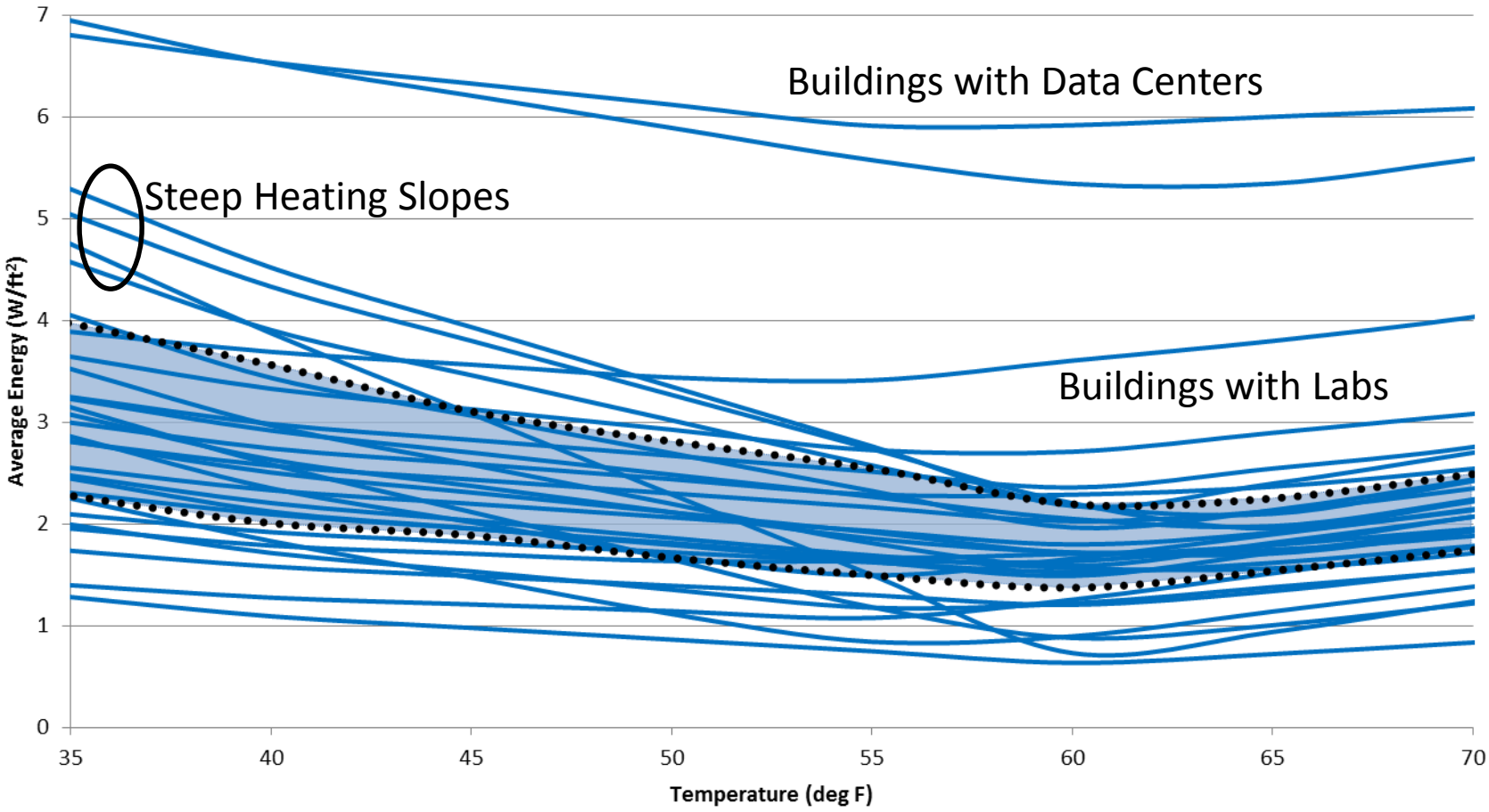
Spectrum Example: Offices



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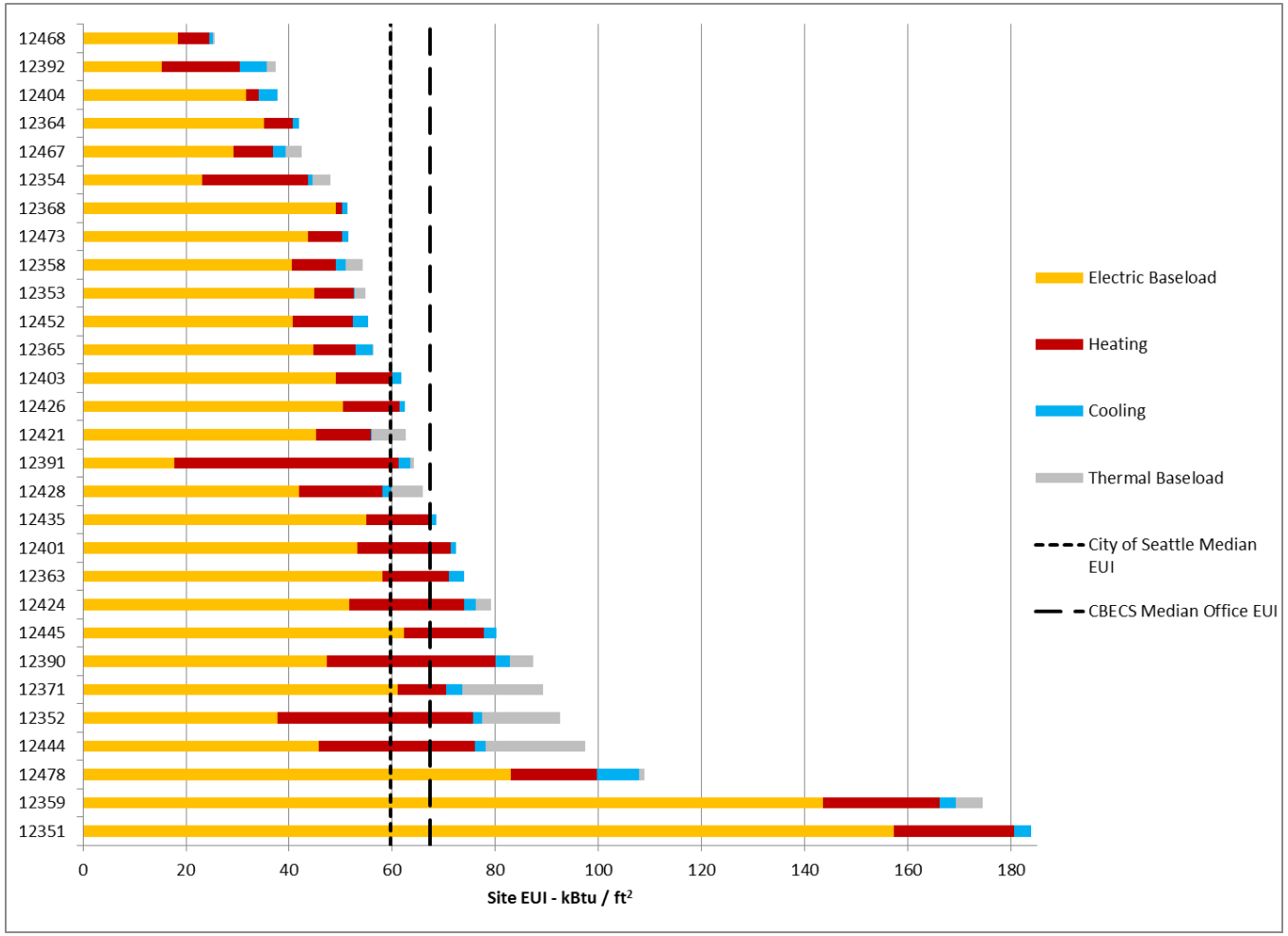
Portfolio Analysis



Disaggregated end loads can be compared across the portfolio. This enables us to prioritize and focus building retrofit efforts.

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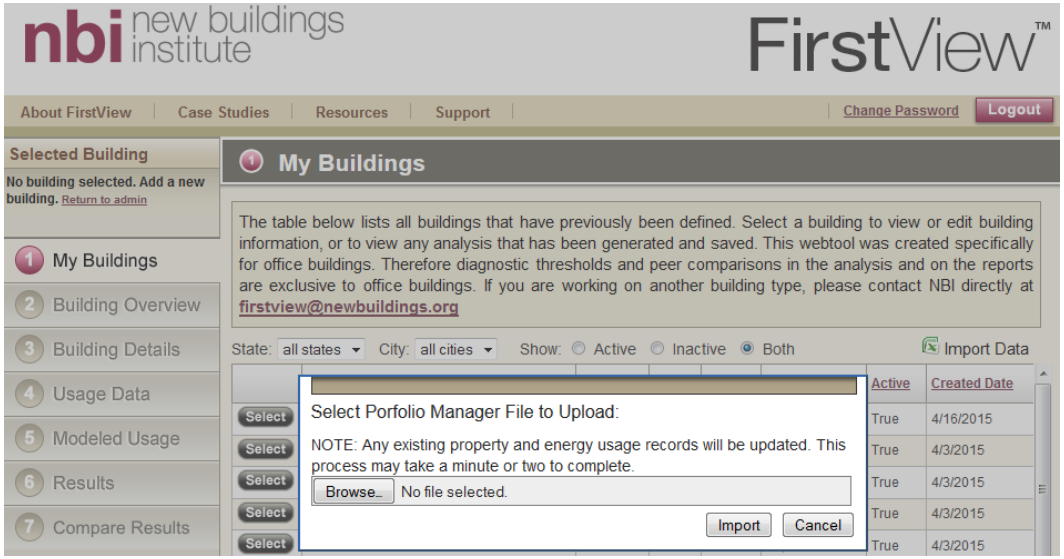
FirstView: *New* Bulk Upload Feature

- Can now upload a Portfolio Manager export spreadsheet directly to FirstView
- Automatic imports
  - Unlimited # buildings at once
  - Loads Building Characteristics
  - Loads Energy Usage Data



Summary

- Existing and Small Commercial Buildings are a Key to Unlocking Savings
- Deploy Analytical Tools and Design Guidance to Understand Where to Focus
- Engage Operators and Occupants in Design
- Engage Designers and Occupants in Operations

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A Phased Asset Management Framework for Incorporating Energy Efficient Planning & Operation in Small Commercial Buildings

March, 2016
ACEEE Market Transformation Symposium
Commercial Sector Track Session B2
Unlocking the Savings Potential in Small Commercial Buildings

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PennState

PennState College of Engineering

CBEI CONSORTIUM for BUILDING ENERGY INNOVATION

CONSORTIUM for BUILDING ENERGY INNOVATION

Vision:

By 2030, deep energy retrofits that reduce energy use by 50% in existing SMSCB, which are less than 250,000 sq ft

Mission:

Develop, demonstrate and deploy technology systems and market pathways that permit early progress (20-30% energy use reductions) in Small and Medium Sized Commercial Buildings

Our Goals:

- **Enable deep energy retrofits** in small to medium sized commercial buildings
- **Demonstrate energy efficient systems** tailored for SMSCBs in occupied buildings – living labs
- **Develop effective market pathways** for energy efficiency with utilities and other commercial stakeholders: brokers, finance, service providers.
- **Provide analytical tools** to link state and local policies with utility efficiency programs

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The CBEI Approach

- Develop cost-effective packages of technology solutions that have demonstrated energy savings
- Adapt solutions to the technical level of SMSCB owners and service providers
- Engage with key stakeholders (retrofit industry, building owners, tenants, cities, regulators) in 'real-world' settings
- Integrate workforce considerations: skills and training models
- Build on DOE innovations

Framework

- Asset Plans
- Challenges and Constraints
- Future State
- Systems Approach
- Asset Definition and Analytics
- CBEI Tools & Retrofit Solutions
- Example – Building 101

Asset Management Plan

The International Infrastructure Management Manual defines an asset management plan as:

> "a plan developed for the management of one or more infrastructure assets that combines multi-disciplinary management techniques (including technical & financial) over the life cycle of the asset in the most cost effective manner to provide a specific level of service."

Source: Wikipedia, accessed on 14 January 2016

Challenges and Constraints
in Small-to-Medium Sized Buildings (SMSCBs)

- Most opportunities in existing, occupied buildings
- Owners inexperienced about energy efficiency
- Split Incentive Problem
- Limited / No budget for professional assistance
- Limited pool of experienced service providers
- Difficulty obtaining building data
- Best practices not tailored to this sector
- Uncertainty of economic return
- Lowest bidder mentality and/or requirement
- Financing constraints and timing

Vision of SMSCB Practice: Future State

- Owners and Contractors Take the Lead
- Building Codes Encourage Efficient Retrofits
- Owners Take a Systems Approach to Asset Management
- Workforce Trained to Achieve Energy Efficiency
- Start with Building Re-Tuning
- Easy-to-Use Tools for Analytics → EEM evaluation & selection

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Vision of Practice in Future State - II

- Building Energy Data is Accessible, Up-to-Date
- Building Information Models (BIM) Widely Utilized
- Packages of Technology Solutions that have Verified, Demonstrated Energy Savings
- Experienced Contractors
  - *Leverage Prior Successes*
  - *Offer Performance Guarantees*
  - *Utilize Available Rebates*
- Multiple Options for Financing

CBEI Tools and Solutions

- Retrofit Roadmap
- Asset Score Training & Certificate
- Building Re-Tuning
- Integrated Hardware Solutions
- RTU Coordination
- Fault Detection & Diagnostics
- Integrated Wall Solutions
- BIM Planning Guide
- OpenStudio
  - Lighting Analysis
  - Evaluation of Technology Packages
- Benchmarking Training, Certificate, Data Analytics Guides
- Career Map / Competency Model
- Proposed changes to IECC

Systems Approach to Buildings

- Integrated Design: ~10% adoption
  - *Skilled Practitioners*
- 'Retrofit Roadmap'
  - *'Cookbook / Prescriptive Approach' to Integrated Design Principles*
  - *For Projects Without Professional Assistance or Facilitation*
  - *Four Scales of Retrofit Opportunities*

Integrated Design Advanced Energy Retrofit Roadmap

CONSORTIUM for BUILDING ENERGY INNOVATION

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PennDesign

Integrated Design Retrofit Roadmap Project Introduction

The market lacks process based products which can offer the architecture, engineering, and construction (AEC) industry a comprehensive action plan for completing Integrated Design (ID) advanced energy retrofits (AERs) in small to medium-sized buildings. This project is aimed at producing a set of step by step guidelines and protocols that organizes the actual design and construction process needed during an ID AER project. The Roadmap addresses integrated strategies for coordinating the full range of AEC services required. The ID AER Roadmap offers a three-tiered document suite.

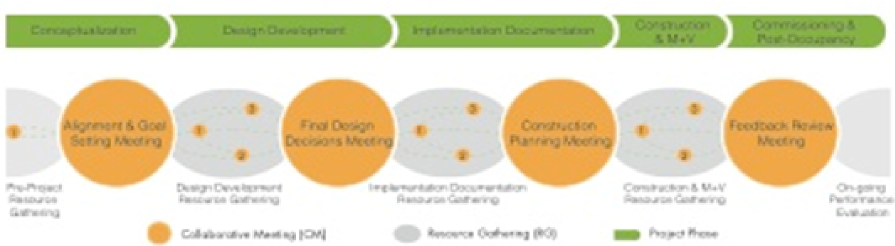
http://cbei.psu.edu/integrated-design-roadmaps-for-aer/

ID AER Roadmap Overview

The Overview is an introduction brochure to the document suite that outlines the basic concepts of Integrated Design (ID) and Advanced Energy Retrofits (AERs). A short quiz helps identify what scale of retrofit may be appropriate for the project.

ID AER Roadmap Reference Manual

The Reference Manual focuses on all info related to the execution of an ID AER project. This document is geared towards building owners, AEC professionals, and tenants with limited knowledge of ID, AERs, and/or buildings.



Integrated Design Process Diagram – Partial Retrofits

PROJECT TEAM GUIDE: LITE

Details the implementation of an ID process for a project scope that includes the Purchase, Installation and Commissioning of a minimum of one new building system and the existing building commissioning of at least one existing system.

PROJECT TEAM GUIDE: PARTIAL

Details the implementation of an ID process for a project scope that includes the Purchase, Installation and Commissioning of a minimum of two building systems and one building envelope component.

PROJECT TEAM GUIDE: SUBSTANTIAL

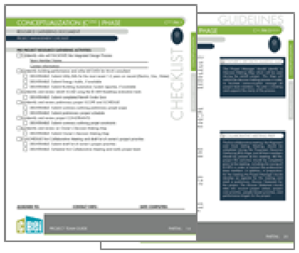
Details the implementation of an ID process for a project scope that includes the Purchase, Installation and Commissioning of of most building systems and building envelope components.

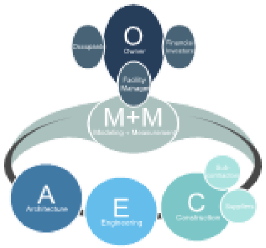
PROJECT TEAM GUIDE: COMPREHENSIVE

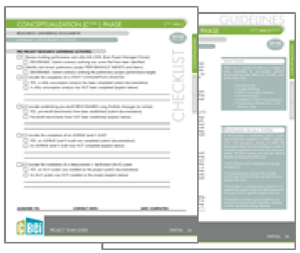
Details the implementation of an ID process for a project scope that includes the Purchase, Installation and Commissioning of all building systems and building envelope components through the use of customized process protocols and benchmarks.

ID AER Roadmap Project Team Guides

Critically important to the implementation of an ID process, the Project Team Guide outlines the activities involved in each scale of retrofit using phased Checklist and Guidelines. The Project Team Guide includes four separate documents developed for use by professionals that make up the team.







Asset Definition, Operations & Analytics

- Walk-Through – Building Re-Tuning (BRT)
- Physical Assets
  - *Drawings*
  - *Systems Inventory, Projected 'Ends-Of-Life'*
  - *Identify Applicable Retrofit 'Triggers'*
  - *Asset Scoring Tool → Building Model → EEMs*
- Analyze Energy Data
  - *Benchmark*
  - *Monthly Utility Data – parse heating, cooling, base loads*
  - *Interval Utility Data – loads and profiles, occupancy, scheduling → EEMs*

Building Re-Tuning Training

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The Pennsylvania State University

- Comprehensive program created by Pacific Northwest National Labs (PNNL) and enhanced by CBEI for widespread distribution
- Goal: Identifying and correcting operational issues to improve commercial building energy efficiency
  - *Two paths:*
    - *Observation-Driven*
    - *Data-Driven*
  - *In-person and On-line training options*

- CBEI has partnered with BOMA & APPA to deliver training around the country
- additional national distribution partners expected

http://cbei.psu.edu/finding-re-tuning-training/
http://retuningtraining.labworks.org/training/lms

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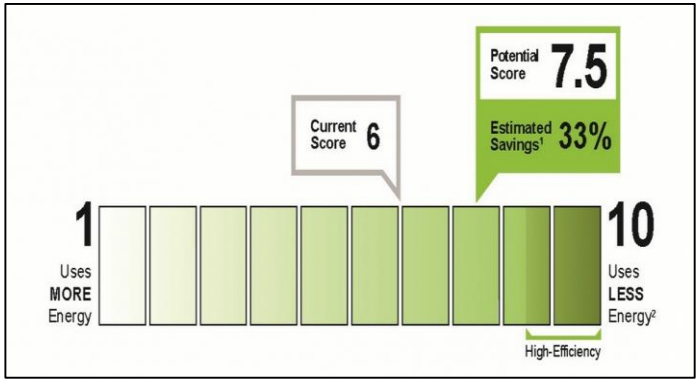
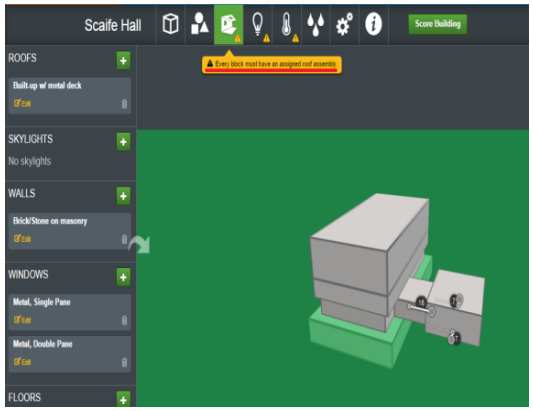
Asset Score Training & Certificate

- Free **web-based tool developed by PNNL**
- Users build a 3-D EnergyPlus (E+) model of a building's physical assets, and simulate energy use.
  - *3 levels: preview (minimal data, scored as range), short-form, long-form*
  - *Based on the building's **physical assets** and **weather**-normalized EUI*
  - ***Makes EEM recommendations***





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- 19 building use types
- CBEI's role
  - *Market Roll-Out & Technical Assistance; Feedback to Developers; Online Training Modules & Certificate*

http://energy.gov/eere/buildings/building-energy-asset-score
http://cbei.psu.edu/commercial-building-energy-asset-score/

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Integrated Hardware Packages for Existing Building Retrofits

- Identify high-impact retrofit packages with low $$ hurdles:
  - *HVAC, HW, lighting, refrigeration, cooking, plug loads*
  - **≥50% HVAC energy savings — simple payback of ≤4 years**
- 12 Baseline building types in 6 climate zones:
  - ***Small & Medium Offices*** — ***Primary Schools***
  - ***Stand-Alone Retail*** — ***Strip Malls***
  - ***Quick & Full Service Restaurants*** — ***Small & Medium Hotels***
  - ***Chain Convenience & Corner Stores*** — ***Supermarkets***
- **"Virtual Retrofits"** using EnergyPlus models
  - energy and economics vs. ASHRAE 90.1-1989 reference building
- Down-selected **Packages** can be **applied prescriptively** with a high degree of confidence in energy savings and cost-effectiveness.

Potential HVAC Energy Savings and Payback of Packaged Retrofit Solutions

U. S. Census Regions and Divisions		Northeast	South	South	Midwest	West	Midwest
U. S. Climate Zones for 2003 CBECS		Zone 2	Zone 4	Zone 5	Zone 2	Zone 4	Zone 1
Representative City (ASHRAE Climate Zone)		Boston, MA (5A)	Charlotte, NC (3A)	Houston, TX (2A)	Indianapolis, IN (5A)	Los Angeles, CA (3B)	Minneapolis, MN (6A)
Office	Small Office	62% / 71	51% / 19	50% / 29.2	34% / 6.5	52% / 2.9	31% / 17.1
	Medium Office	61% / 6.1	40% / 34.7	58% / 0	58% / 2.3	49% / 0	64% / 125
Mercantile	Stand-Alone Retail	53% / 0	48% / 0	50% / 0.2	51% / 0	50% / 0	48% / 1
	Strip Mall	30% / 1.5	40% / 0	48% / 0	30% / 0.3	52% / 8	25% / 0.3
Education	Primary School	51% / 2.4	31% / 0	54% / 2.6	47% / 2.9	40% / 2	47% / 3.1

HVAC energy savings

Simple payback (year) with incentives

Legend

	Meet both energy savings and payback target
	Meet only one of the energy savings or payback target
	Neither targets are met

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Distributed RTU Controls

James Braun, Ph.D.
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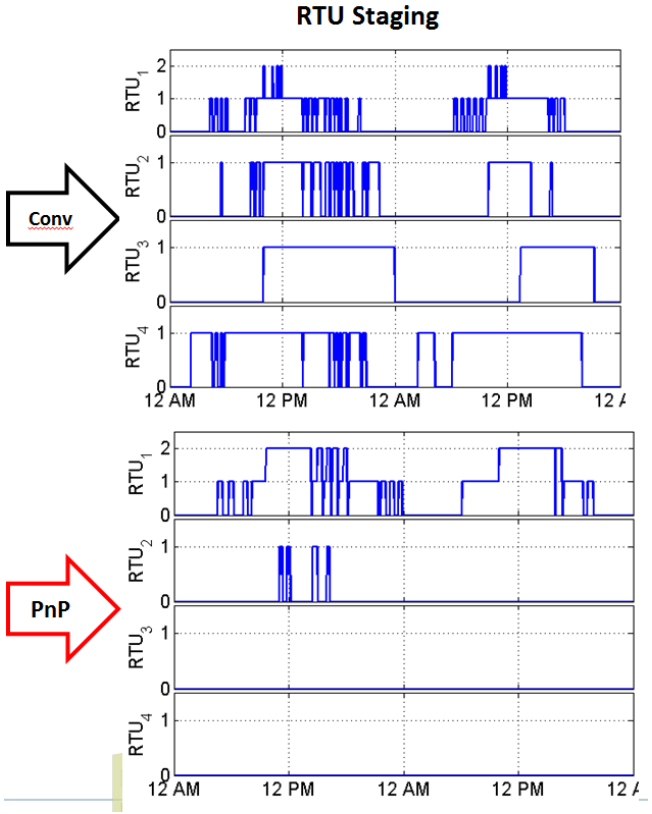
Motivation

- Multiple RTUs commonly used in open commercial spaces
- RTUs conventionally controlled independently with separate thermostats
  → *high demand, short cycling, simultaneous heating & cooling, poor comfort*
- Energy and demand savings opportunity from optimal RTU coordination
- Need for low-cost, simple solutions in buildings w/o BMS

CBEI Demonstrations

- Wireless thermostats networked together
- Learns relationship between thermostat temperatures and RTU on/off staging (no other measurements required)
- Determines RTU staging to minimize energy (based on RTU rated power or measurements if available)
- Virtual PnP testbeds at several 'real world' sites



Status

- ~20% energy and ~30% peak demand savings
- Currently being commercialized

http://cbei.psu.edu/testing-predictive-hvac-control-for-rooftop-units-at-harvest-grill/

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Building 101 Example

- 1999 renovated building
  - 65,000 sq. ft. occupied
  - single → multi-tenant
  - CBEI: M&V and E+ model used to evaluated impact of EEMs
- Phase 1 retrofit 'Trigger': BAS End-of-Life (EOL)
- CBEI integrated approach:
  - Unneeded exhaust fans off
  - BAS: refined Seq. Operations
  - VFDs on 3 AHU fans
  - Sensors on AHUs and 27 VAV boxes
  - RCx & TAB all 3 AHUs, repair perimeter heat
  - Exterior and some interior lighting; controls
  - 3 condensers at EOL; 1 replaced
    - Evaluated alternative cooling systems
- Phase 1a: 'Trigger': other two condensers spec'd in advance and replaced proactively
- Energy Star® scores: **45 → 45 → 76 → 65**
- Phase 2: lighting – as leases turn over
  - Bid spec drafted; no budget
- Persistence Issues

Phase I Retrofit Results

The annual electric savings was found to be $42,824 and annual gas savings were $12,559. The simple payback period for this retrofit was 2.7 years.

End Use	Pre-Retrofit Consumption (KWh)	Annual Savings (KWh)	Annual Cost Savings
Exterior Lighting	16,316	3,600	$529
Interior Lighting	266,603	56,422	$8,294
Exhaust Fans	13,884	9,880	$1,452
AHU supply fans	184,697	112,756	$16,575
Cooling	250,001	108,660	$15,973
Total	731,501	291,318	$42,824

Item	Capital Investment
Exterior Lighting	$2,700
Interior Lighting	$17,300
Building Automation System	$81,300
VFDs	$17,500
T, RH, CO_2 sensors	$9,500
Software Light Switches	$11,760
TAB	$16,300
Controls Retrofit	$146,860

http://cbei.psu.edu/building-101-at-the-navy-yard-in-philadelphia/

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Summary

- Owners and Contractors Must Take the Lead
- Systems Approach
- Start with Building Re-Tuning
- Analytics & Asset Score → EEM Evaluation & Selection
- Plan Timing of Retrofits to ‘Triggers’
- Validated Packages of Technology Solutions
- Contractors: Leverage Rebates & Successes
- Provide Multiple Options for Financing

Acknowledgement & Disclaimer

"This material is based upon work supported by the Consortium for Building Energy Innovation (CBEI) sponsored by the U.S. Department of Energy under Award Number DE-EE0004261."

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Supplemental Slides

Commonly Applicable Solutions

- Lighting / Daylighting Retrofits
- Retro- and Continuous Commissioning
  - *Proper Sequence of Operations, Scheduling, FDD*
  - *Periodically Repeat!*
- HVAC Controls & Retrofits
  - *Supply Air Temp Reset, VFDs, Filters, Static Pressure Reset*
- Advanced RTUs: Economizers, Energy Recovery, VFDs
- Envelope Upgrades

Capital & Financing

- Framing of EEM opportunities / value
  - At End-Of-Life: High vs. Standard Efficiency Systems are Incremental Costs
  - Simple Payback does not Capture 'Cost of Doing Nothing'
  - Decision-Makers' Pet Financial Criteria
  - Total Cost of Ownership: *LCCAid, Energy PathFinder®, B-RIM*
  - Capture Avoided Capital Costs
- Options for Financing
  - Buydowns: Utility Rebates, Incentives, Direct Install
  - Subsidized Loans
  - 'On-Bill' – Assessed on Monthly Utility Bill
  - PACE – Assessed on Property Tax Bill
  - ESC/PC & guaranteed savings

Chris Baker - The Weidt Group

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