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Achieving a More Meaningful Assessment of Commercial Building Code Compliance

Michael Rosenberg - Pacific Northwest National Laboratory
Poppy Storm - Ecotope

U.S. Department of Energy Building Energy Codes Program
Energy Codes Commentator Webinar Series
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PNNL-SA-121643

Course Description

This webinar describes two recent studies that have attempted to develop a deeper and more meaningful assessment of commercial building code compliance. The first study conducted by PNNL tries to answer the question: "How much energy cost savings can be achieved through better compliance?" The second study conducted by Ecotope argues that evaluating codes should be directed at the perennial need to understand and improve the construction of new buildings.

Learning Objectives

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At the end of this course, participants should be able to understand:

- Why are commercial energy code compliance assessments more challenging than residential assessments?
- What are more meaningful assessments of energy code compliance than simple pass fail metrics?
- How code evaluations can support interdependent efforts such as code design, enforcement training, and utility programs?
- What is the relationship between code compliance and post occupancy energy use?

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Study 1 - Assessing Potential Energy Cost Savings from Increased Energy Code Compliance in Commercial Buildings

Michael Rosenberg - PNNL

http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24979.pdf

Background

Why are Commercial Compliance Studies so Difficult Compared to Residential ?

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	Residential	Commercial
# of Pages of Model Code (2015 IECC)	13 (Residential EE Chapter)	62 (Commercial EE Chapter)
# of Measures to Verify in Compliance Studies	11	~100
# New Code Changes Since 2004 (3 Code Cycles)	191	263
# New Code Changes Affecting Building Controls	4	70
Distinct Building Types	Single Family, Low Rise Multifamily	High Rise Multifamily, Warehouse, Office, School, Laboratory, Assembly, Sports Arena, Hospital, Medical Office Building, Retail, Hotel, Industrial, Gymnasium, Supermarket, Restaurant,..
HVAC Equipment	Furnace, Heat Pump, Air Conditioning Unit, Wall Cadets, Radiant Floor	Furnace, Heat Pump, Air Conditioning Unit, Wall Cadets, Radiant Floor, VAV, MZ, WSHP, GSHP, FCU, Cooling Towers, Pumps, Chillers (8 types), PTHP, SPVHP, Boilers, Condensing Units, Chilled Beams, ….

Why are Commercial Compliance Studies so Difficult Compared to Residential ?

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Commercial Compliance – Previous Work

- Previous DOE efforts focused on checklists and % compliance
- Binary decision for each requirement
- Impact of partial compliance not well understood or quantified
- Relative importance of requirements either ignored or assigned importance based on judgment

Commercial Compliance – Previous Work – Check List Approach

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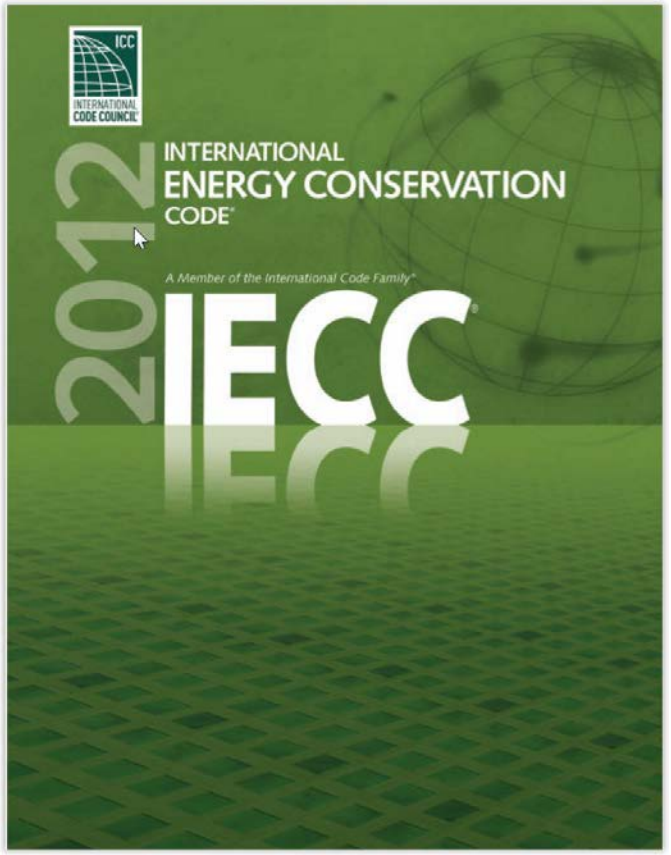
90.1-2010 Section #	Plan Review	Complies?	Comments/Assumptions
4.2.2, 5.4.3.1.1, 5.7 [PR1][1]	Plans, specifications, and/or calculations provide all information with which compliance can be determined for the building envelope and document where exceptions are claimed. Envelope tradeoff option (5.6) or energy cost budget (11) submitted for buildings with vertical fenestration area >40% or skylight area >5%.	☐ Complies ☐ Does Not Comply ☐ Not Observable ☐ Not Applicable	
4.2.2, 6.4.4.2.1, 6.7.2 [PR2][1]	Plans, specifications, and/or calculations provide all information with which compliance can be determined for the mechanical systems and equipment and document where exceptions are claimed.	☐ Complies ☐ Does Not Comply ☐ Not Observable ☐ Not Applicable	
4.2.2, 6.7.2.3, 6.7.2.4 [PR5][1]	Plans document that systems are balanced in accordance with generally accepted engineering standards. Detailed instructions for HVAC systems commissioning included on the plans or specifications for >=50,000 ft^2.	☐ Complies ☐ Does Not Comply ☐ Not Observable ☐ Not Applicable	
4.2.2, 7.7.1, 10.4.2 [PR3][1]	Plans, specifications, and/or calculations provide all information with which compliance can be determined for the service water heating systems and equipment and document where exceptions are claimed. Service water pressure booster systems designed with pressure sensors, pressure reducers, and flow controls.	☐ Complies ☐ Does Not Comply ☐ Not Observable ☐ Not Applicable	
4.2.2, 8.4.1.1, 8.4.1.2, 8.7 [PR6][2]	Plans, specifications, and/or calculations provide all information with which compliance can be determined for the electrical systems and equipment and document where exceptions are claimed. Feeder connectors sized in accordance with approved plans and branch circuits sized for maximum drop of 3%.	☐ Complies ☐ Does Not Comply ☐ Not Observable ☐ Not Applicable	
4.2.2, 9.4.4, 9.7 [PR4][1]	Plans, specifications, and/or calculations provide all information with which compliance can be determined for the interior lighting systems and equipment and document where exceptions are claimed.	☐ Complies ☐ Does Not Comply ☐ Not Observable ☐ Not Applicable	
4.2.2, 9.7 [PR8][2]	Plans, specifications, and/or calculations provide all information with which compliance can be determined for the exterior lighting systems and equipment and document where exceptions are claimed.	☐ Complies ☐ Does Not Comply ☐ Not Observable ☐ Not Applicable	

Current Research Project Approach

- Forget the question; “does it comply?”
- Instead; how much energy cost savings could potentially be gained through better compliance with the code?
- How can that savings be captured effectively?

Current Research Project Approach

- Simplified process to test the approach
  - One building type
    - Office buildings with simple HVAC systems
  - One climate zone
    - Climate zone 4C
  - One code
    - 2012 IECC



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Preliminary Analysis

1. Identify Applicable Requirements (2.3.1)

- Identify all requirements in the 2012 IECC = **396**
- Eliminate those not applicable to building type and CZ or not directly responsible for energy savings = **149** remaining
- Group into related measures = **63 relevant groups**
  - Example:

occupancy sensors must be present

+

occupancy sensors must be manual on

+

occupancy sensors must shut off within 30 minutes

=

1 occupancy sensor measure

2. Develop a Range of Conditions for Each Measure

- Develop a range of conditions expected to be encountered in the field. Code → Below → Worst

Measure Name	Code-Condition	Below-Code Condition	Worst Condition
Roofs shall be insulated to meet CZ requirements	100% required U-value	150% required U-value	No insulation
Thermostat deadband requirement	Deadband 5^0F as required	2^0F	No Deadband
Interior lighting power allowance	Meets whole building LPD	Exceeds whole building LPD by 50%	Exceeds whole building LPD by 100%

3. Simulate Measure Conditions to Assign Energy Cost Value

- Using prototype office building model simulate each condition to estimate lost energy cost savings
  - Used national average utility costs
  - Normalized cost impact to appropriate metric (i.e., ft^2, cfm, tons)

Measure Name	Metric	Code-Condition	Below-Code-Condition	Worst-Condition
Roofs shall be insulated to meet CZ requirements		100% req'd U-value	150% req'd U-value	No insul
Lost $ savings	per ft2 net roof area	$0.000	$0.015	$0.537
Interior lighting power allowance		Meets whole building LPD	Exceeds whole building LPD by 50%	Exceeds whole building LPD by 100%
Lost $ savings	per ft2 building floor area	$0.000	$0.152	$0.304

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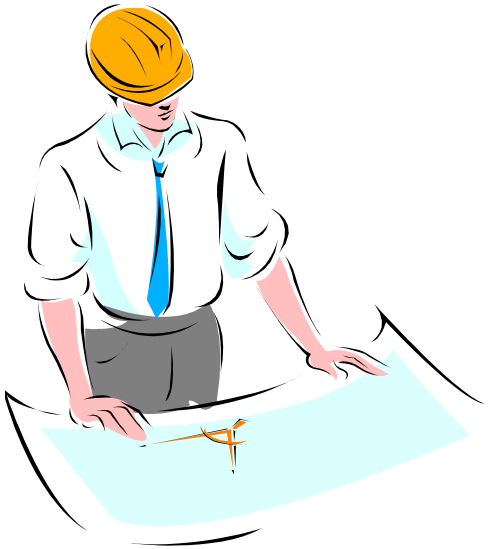
Field Work

4. Identify and Recruit Buildings

- Current research did not develop recruiting strategy or sampling metrics
- Contractor (Ecotope) used Dodge Database and cold calls
- Nine building sample
  - Recruiting success rate was 7.4% (9 out of 121 candidates).
  - On average, 10 phone contacts were necessary to screen, recruit, and schedule each successful site.
  - Recruiters spent about 135 person-hours to secure the nine buildings.

5. Field Audits

- Construction Document Review
- Field Audit
  - Determine Condition for Each Measure
  - 1 visit per site
  - Not all measures observable during single visit



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Calculation of Lost Savings

6. Calculation of Lost Energy Cost Savings from Field Data

- Based on found condition and metric quantity, lost $ savings is assigned to each measure and summed for total building impact

$$\boldsymbol{Measure\ lost\ savings} = \frac{Condition\ lost\ \text{savings}}{\text{metric unit}} * found\ metric\ units$$

Example Roof Insulation lost savings :
Found condition: Roof insulation U-value = 150% code
Roof area = 900 ft^2

$$Roof\ Insulation\ lost\ savings = \frac{\$0.015}{ft2} * 900\ \text{ft}^2 = \$13.50$$

$$\boldsymbol{Building\ lost\ savings} = \sum measure\ lost\ savings$$

$$\boldsymbol{Sample\ lost\ savings} = \sum building\ lost\ savings$$

Lost Energy Cost Savings Results – Nine Building Sample

- Summary
  - Of 63 measures, 19 not applicable in any building
  - 95% of all applicable measures were verifiable (plan or inspection)
  - 75% of all measures applicable complied

	Building Identifier									Total
	A	B	C	D	E	F	G	H	I	Sample
Building floor area, ft^2	1,056	1,540	2,897	4,554	2,940	7,075	2,595	900	3,600	27,157
Annual Lost Energy Cost Savings	$223	$515	$550	$573	$218	$101	$638	$204	$351	$3,372
Present Value of Lost Life-Cycle Cost Savings	$3,044	$6,711	$7,071	$8,494	$3,749	$1,272	$8,164	$2,730	$5,196	$46,430

- If all 9 buildings complied fully the total savings would **$3,372** annually or **$46,430** over the building life

Impact of Interactions

- Method does not consider interactive impacts

  below windows + below HVAC ≠ below windows + code HVAC

- How important are interactions? - Test
  - Develop average conditions for each measure in the sample
  - Simulate using prototype
  - Compare normalized lost savings between sum of individual measures and interactive simulation

Comparison of Savings Potential: Sum of Individual Measures vs. Interactive Impact

Applied to Nine Building Sample	Annual Lost Energy Cost Savings
Lost savings from interactive simulation ($/yr)	$3,603
Lost savings from sum of the individual measures ($/yr)	$3,372
Lost savings difference	$231
Interactive effect	6.8%

Cost of Compliance Verification

- Auditor tracked time to verify compliance
  - Both measure specific and indirect (travel, security, accessing plans)
- Prorated indirect to each measure

Cost of Compliance Verification

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Measures with Lost Savings	Verification hours
Mechanical systems commissioning requirement	0.24
Equipment sizing requirement	3.41
Building entrances shall be protected with an enclosed vestibule.	0.87
Thermostat setback and start/stop controls	2.55
Thermostat deadband requirement	2.56
Economizers have appropriate high-limit shutoff control and be integrated	3.00
Roofs shall be insulated to meet CZ requirements	2.47
Lighting commissioning requirement	2.90
Interior lighting power allowance	4.44
Window-to-wall ratio meets maximum limits.	4.25
Automatic time switch control	0.55
Economizer supplies 100% design supply air	2.89
Manual lighting control	2.74
Occupancy sensor control	3.36
Heat pump supplementary heat control	1.38
Slab-on-grade floors meet insulation requirements and are protected	2.66
Above grade frame walls shall be insulated to meet CZ requirements	3.34
Recessed lighting shall be sealed, rated and labeled.	0.98
Exit sign maximum power	2.78
SWH pipe insulation - non-recirculated	1.08
Daylight zone control	2.73
Duct insulation requirement	2.39
SWH heat trap	2.11
Water heater efficiency, electric	2.93
Damper control when space is unoccupied	2.17
Total for measures with below-code potential savings	60.8
Total for measures with no potential savings identified (met code)	40.9
Total for all applicable measures	102

Cost of Compliance Verification

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Measures with Lost Savings	Sample Lost Savings Life-Cycle	Verification hours
Mechanical systems commissioning requirement	$1,647	0.24
Equipment sizing requirement	$13,054	3.41
Building entrances shall be protected with an enclosed vestibule.	$1,758	0.87
Thermostat setback and start/stop controls	$4,990	2.55
Thermostat deadband requirement	$4,426	2.56
Economizers have appropriate high-limit shutoff control and be integrated	$3,353	3.00
Roofs shall be insulated to meet CZ requirements	$2,288	2.47
Lighting commissioning requirement	$2,525	2.90
Interior lighting power allowance	$3,705	4.44
Window-to-wall ratio meets maximum limits.	$3,163	4.25
Automatic time switch control	$280	0.55
Economizer supplies 100% design supply air	$1,444	2.89
Manual lighting control	$1,015	2.74
Occupancy sensor control	$918	3.36
Heat pump supplementary heat control	$356	1.38
Slab-on-grade floors meet insulation requirements and are protected	$446	2.66
Above grade frame walls shall be insulated to meet CZ requirements	$468	3.34
Recessed lighting shall be sealed, rated and labeled.	$85	0.98
Exit sign maximum power	$216	2.78
SWH pipe insulation - non-recirculated	$64	1.08
Daylight zone control	$121	2.73
Duct insulation requirement	$76	2.39
SWH heat trap	$25	2.11
Water heater efficiency, electric	$5	2.93
Damper control when space is unoccupied	$2	2.17
Total for measures with below-code potential savings	$46,430	61
Total for measures with no potential savings identified (met code)	$0	41
Total for all applicable measures	$46,430	102

Cost of Compliance Verification

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Measures with Lost Savings	Sample Lost Savings Life-Cycle	Verification hours	Lost Saving $ / Hour
Mechanical systems commissioning requirement	$1,647	0.24	$6,741
Equipment sizing requirement	$13,054	3.41	$3,829
Building entrances shall be protected with an enclosed vestibule.	$1,758	0.87	$2,014
Thermostat setback and start/stop controls	$4,990	2.55	$1,953
Thermostat deadband requirement	$4,426	2.56	$1,726
Economizers have appropriate high-limit shutoff control and be integrated	$3,353	3.00	$1,118
Roofs shall be insulated to meet CZ requirements	$2,288	2.47	$926
Lighting commissioning requirement	$2,525	2.90	$871
Interior lighting power allowance	$3,705	4.44	$835
Window-to-wall ratio meets maximum limits.	$3,163	4.25	$744
Automatic time switch control	$280	0.55	$510
Economizer supplies 100% design supply air	$1,444	2.89	$499
Manual lighting control	$1,015	2.74	$370
Occupancy sensor control	$918	3.36	$273
Heat pump supplementary heat control	$356	1.38	$259
Slab-on-grade floors meet insulation requirements and are protected	$446	2.66	$167
Above grade frame walls shall be insulated to meet CZ requirements	$468	3.34	$140
Recessed lighting shall be sealed, rated and labeled.	$85	0.98	$87
Exit sign maximum power	$216	2.78	$78
SWH pipe insulation - non-recirculated	$64	1.08	$59
Daylight zone control	$121	2.73	$44
Duct insulation requirement	$76	2.39	$32
SWH heat trap	$25	2.11	$12
Water heater efficiency, electric	$5	2.93	$2
Damper control when space is unoccupied	$2	2.17	$1
Total for measures with below-code potential savings	$46,430	60.8	$764
Total for measures with no potential savings identified (met code)	$0	40.9	$0
Total for all applicable measures	$46,430	102	$455

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Ranking Measures

Going Forward – Do We Need to Look at all Measures?

- Probably not realistic to verify all measures
- 63 for a simple building, could easily double for a complex building
- How to simplify in the future? **Prioritize**
  - Focus on measures with the biggest bang for the buck
  - Rank in 2 ways:
    - From Study → $ savings identified / hour spent on verification
    - From simulation sensitivity analysis →Highest potential lost savings

Ranking Based on Field Studies

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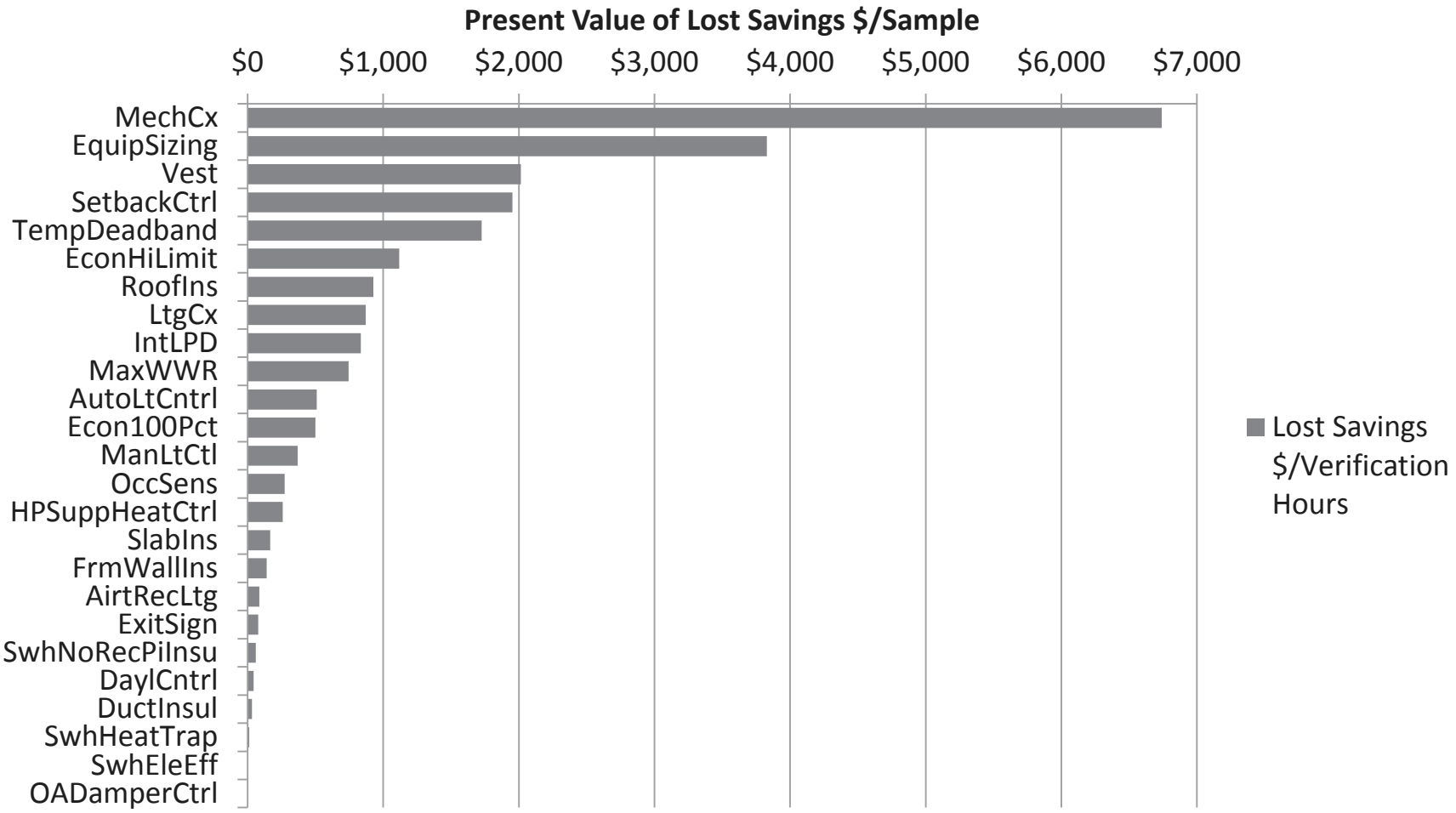
Lost Life-Cycle Savings From Code Non-Compliance/Verification Hours*



**** Results based on 9 buildings only. Will need additional data to draw conclusions***

Ranking Based on Field Studies

- In this sample, 9 measures (14%) responsible for 81% for the savings

Summary of Measures and Instances in this Sample

Grouping by Lost Savings per Hour and Applicability	Measures #	Measures %	Applicable Instances #	Applicable Instances %	Life-Cycle Lost Savings	% Lost Life-Cycle Savings
High lost $/verification hour (>$750/hour)	9	14%	61	21%	$37,747	81%
Med lost $/verification hour ($750-$400 /hour)	3	5%	18	6%	$4,886	11%
Low lost $/verification hour (<$400/hour)	13	21%	90	31%	$3,797	8%
Compliant with code	19	30%	120	42%	$0	0%
Not applicable this sample	19	30%	0	0%	$0	0%
Total	63		289		$46,430	

Ranking Based on Sensitivity Analysis Simulation

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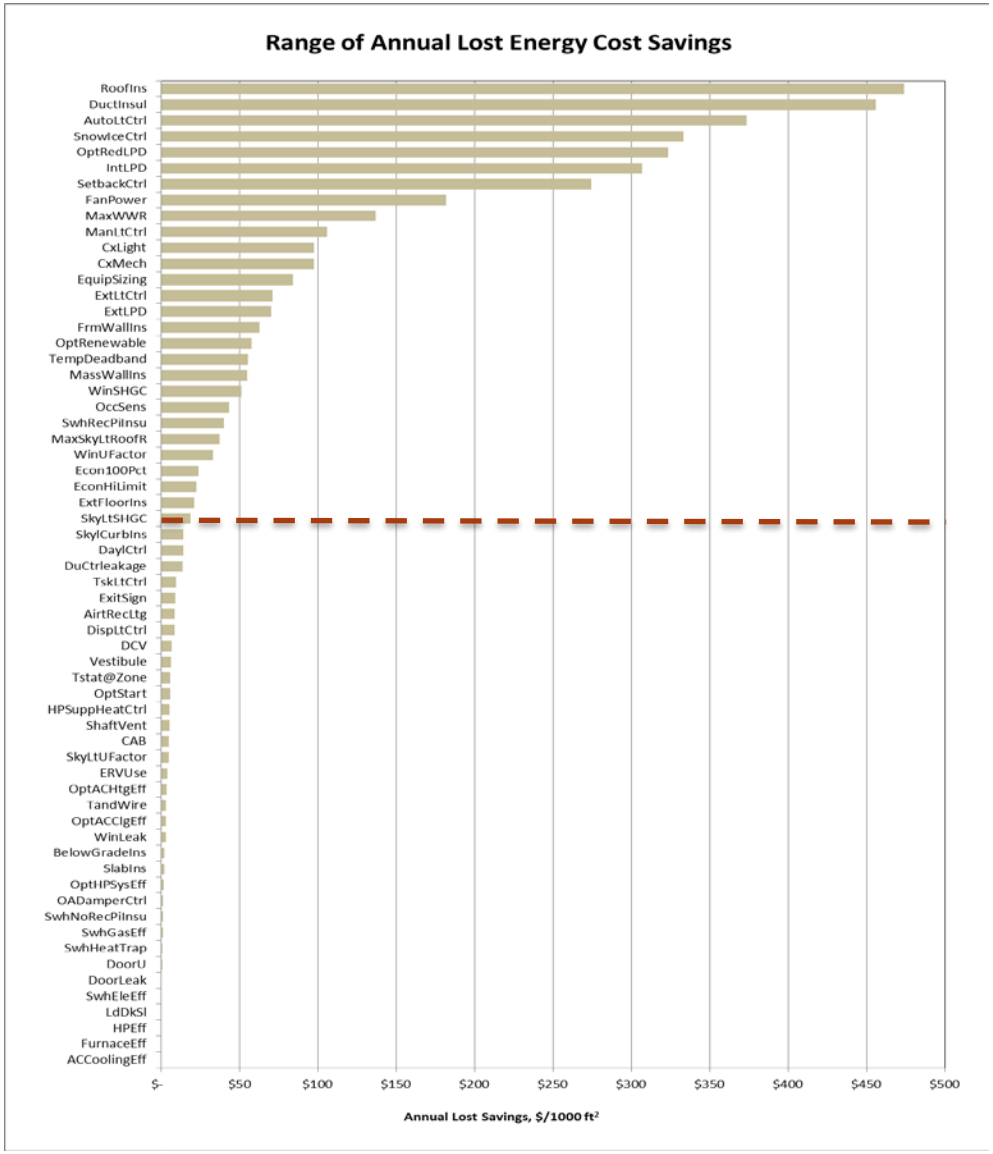

- Worst case lost savings
- Simulation can lead to initial screening
- No need to look at measures that have no chance of being impactful

Future Implications

Lessons Learned and Recommendations for Future Compliance Studies

- Prioritize measures to reduce study costs
  - Eliminate measures with low worst case potential lost savings based on simulation sensitivity analysis
  - Eliminate measures with low lost savings potential / verification hour based on data from future studies
- "Piggy back" assessment with jurisdiction compliance inspections
  - Too time consuming and low incidence rate with cold calls
- 1 visit is not enough to asses all measures
  - Follow residential approach for site visits
  - 1 visit per site at different phases of construction

DOE has awarded $1.7 Million to the Institute of Market Transformation (IMT) to roll out this approach on up to 250 buildings in 3 states

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Study 2 - Measuring What Matters: A Methodology for Moving from Code Compliance to Code Evaluation

Poppy Storm - Ecotope

Measuring what Matters: A Methodology for Moving From Code Compliance Assessment to Code Evaluation

Presented by Poppy Storm, Ecotope, Inc.

October 13, 2016

NORTHWEST ENERGY EFFICIENCY ALLIANCE

Codes Seek to Influence Current Practice…

…in order to reduce energy use overtime.

Evaluation approach moves away from narrow compliance determination for individual components toward building systems and impacts on actual energy use.

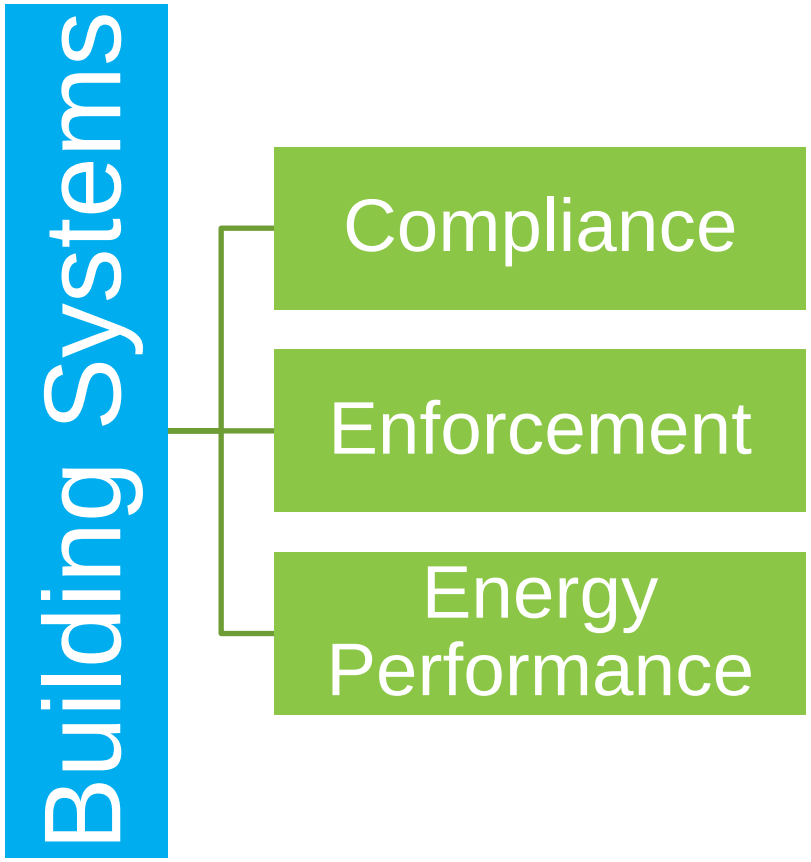
Current Practice & Actual Energy Use at the Heart of the Methodology

- Codes influence building characteristics
- Characteristics and design define energy use
- Energy use can be a gage of code progress over time
- Benchmarking and code compliance need the same core data:
  - Characteristics
  - Energy use

Approach Delivers Wide Spectrum of Value

- ✓ Benchmark characteristics and new construction practices
- ✓ Identify major compliance gaps
- ✓ Benchmark new construction EUIs
- ✓ Analyze relationship between characteristics, compliance and energy use
- ✓ Inform commercial code and program development
- ✓ Inform enforcement efforts
- ✓ Update commercial new construction baseline data
- ✓ Modeling inputs for *ex ante* savings estimates

Methodology Linked by Buildings Systems

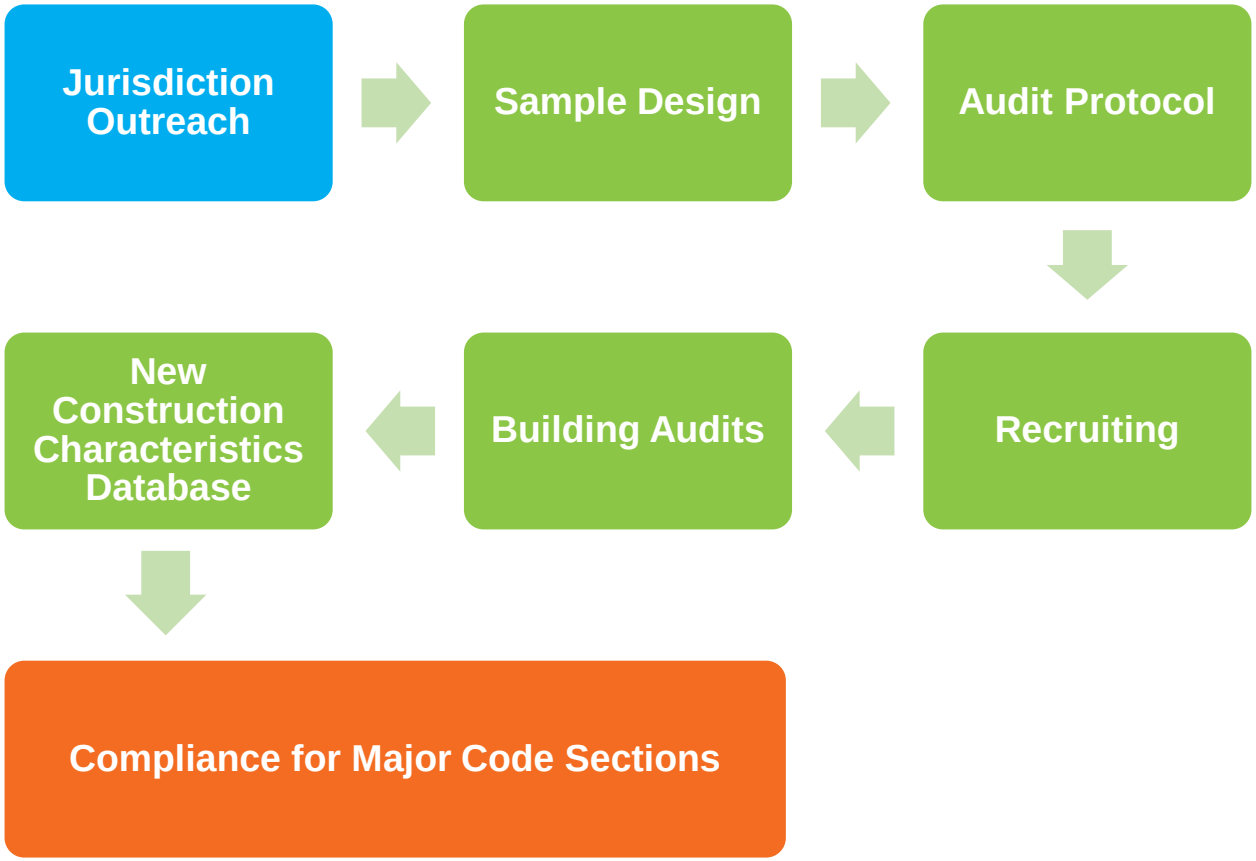


Focus on “High Value” Aspects of Each Major System

- Envelope: overall UA based on individual component UAs
- Mechanical: equipment efficiency, economizer, heat recovery, controls
- Service water: equipment efficiency, pump scheduling, pipe insulation
- Lighting: interior LPD, exterior lighting power, controls

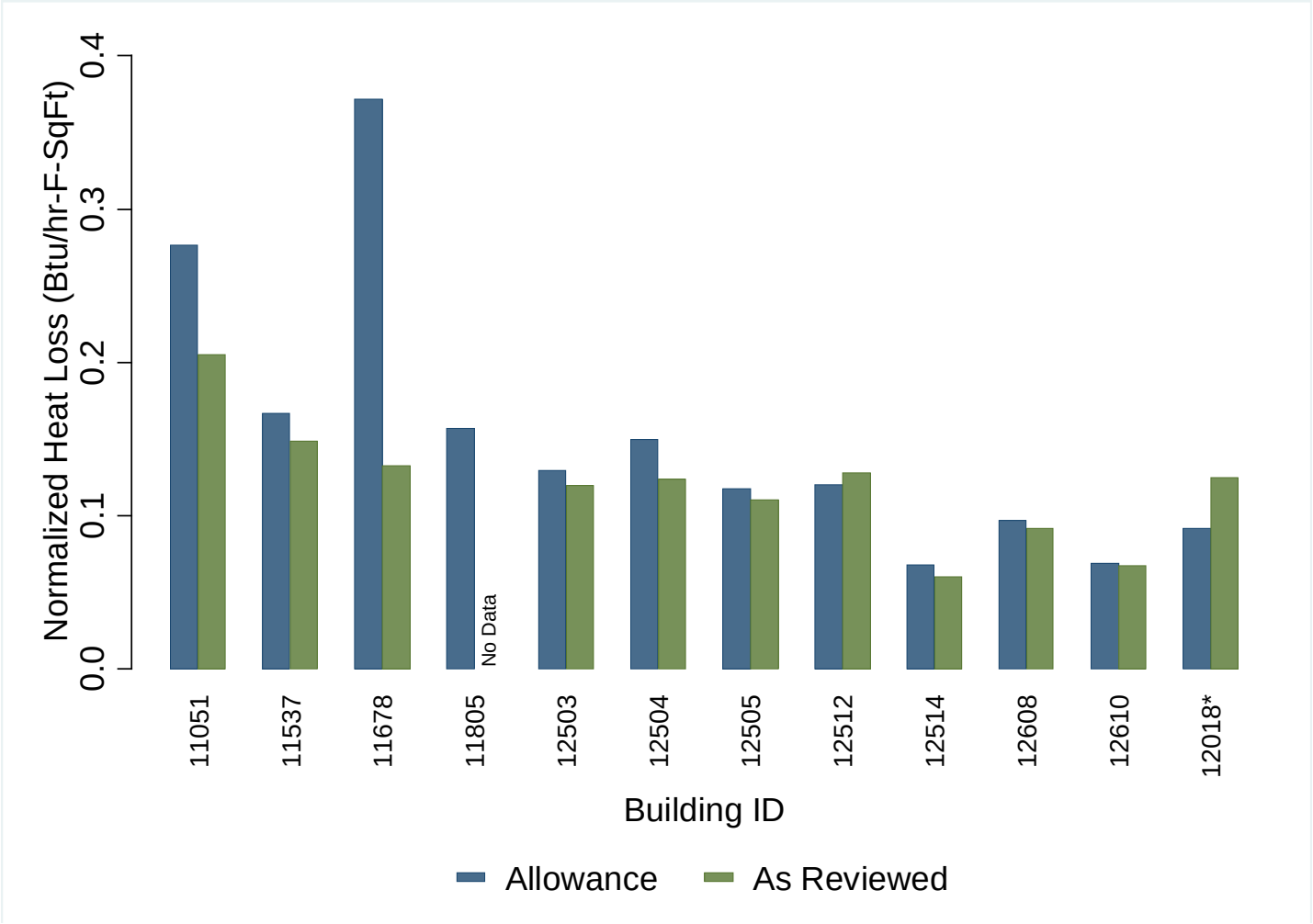
40

Compliance Assessment Steps



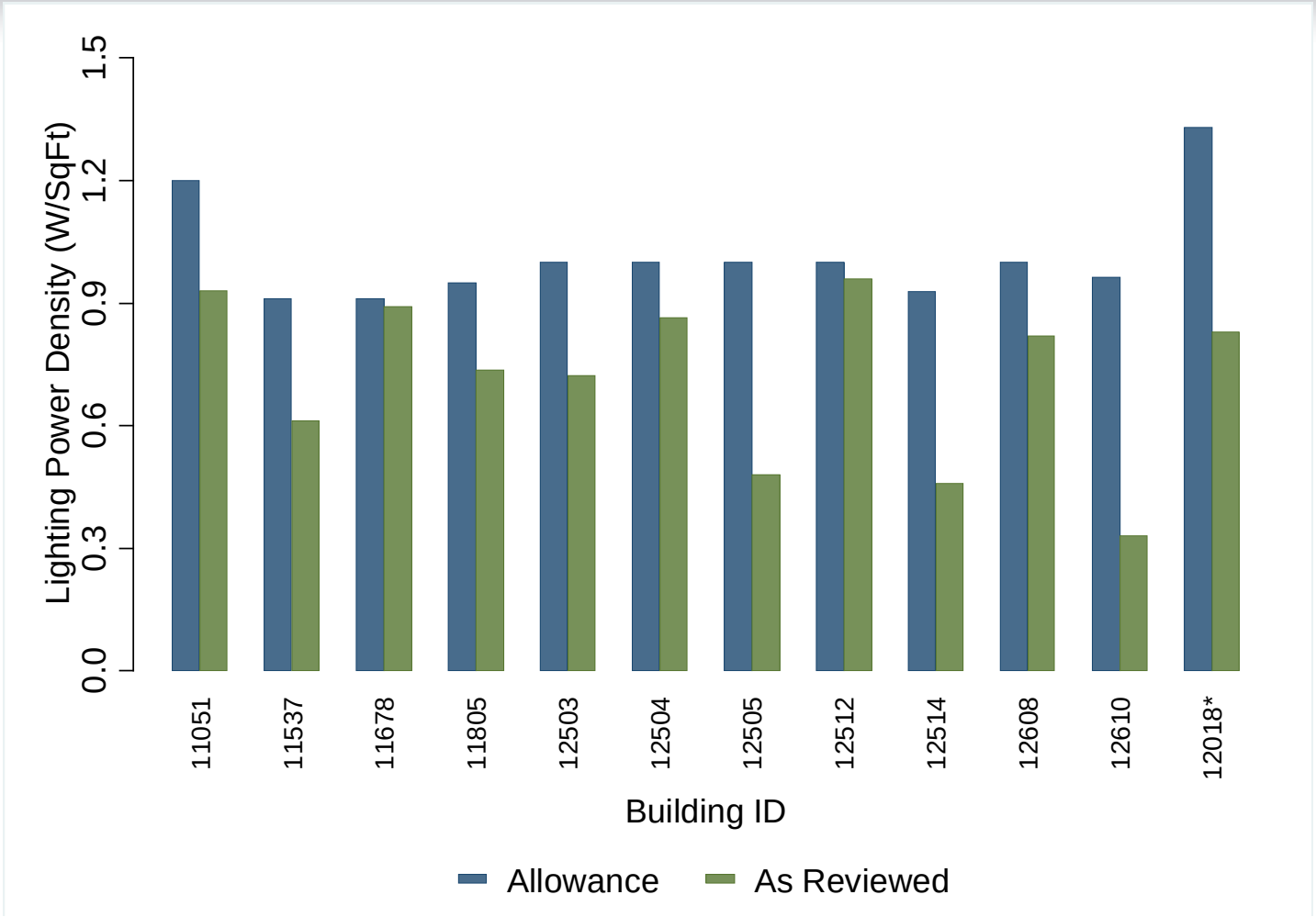
Overall Compliance by Major Code Components

Building Heat Loss Estimate Normalized by Floor Area

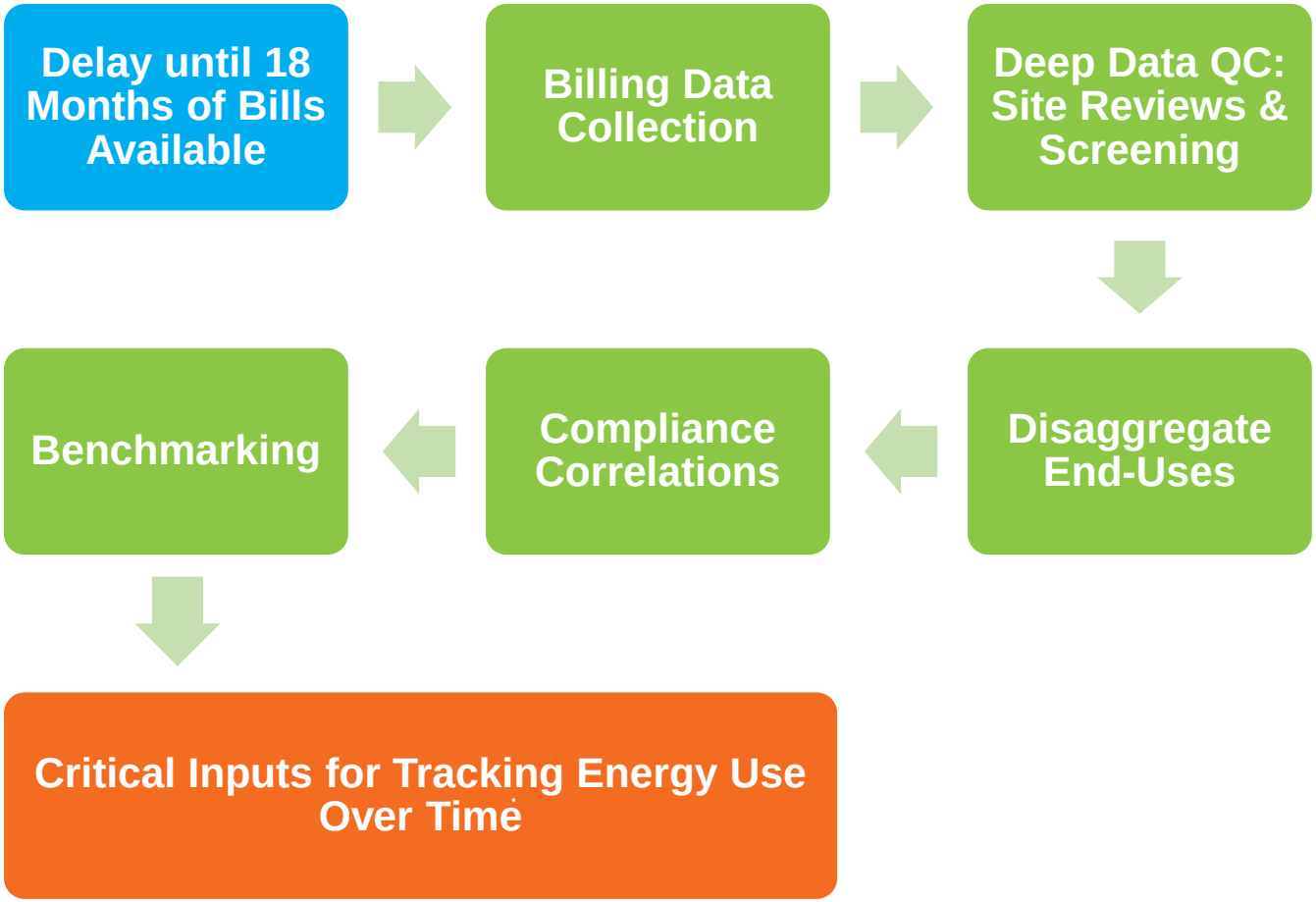


Mechanical Subcomponent Compliance

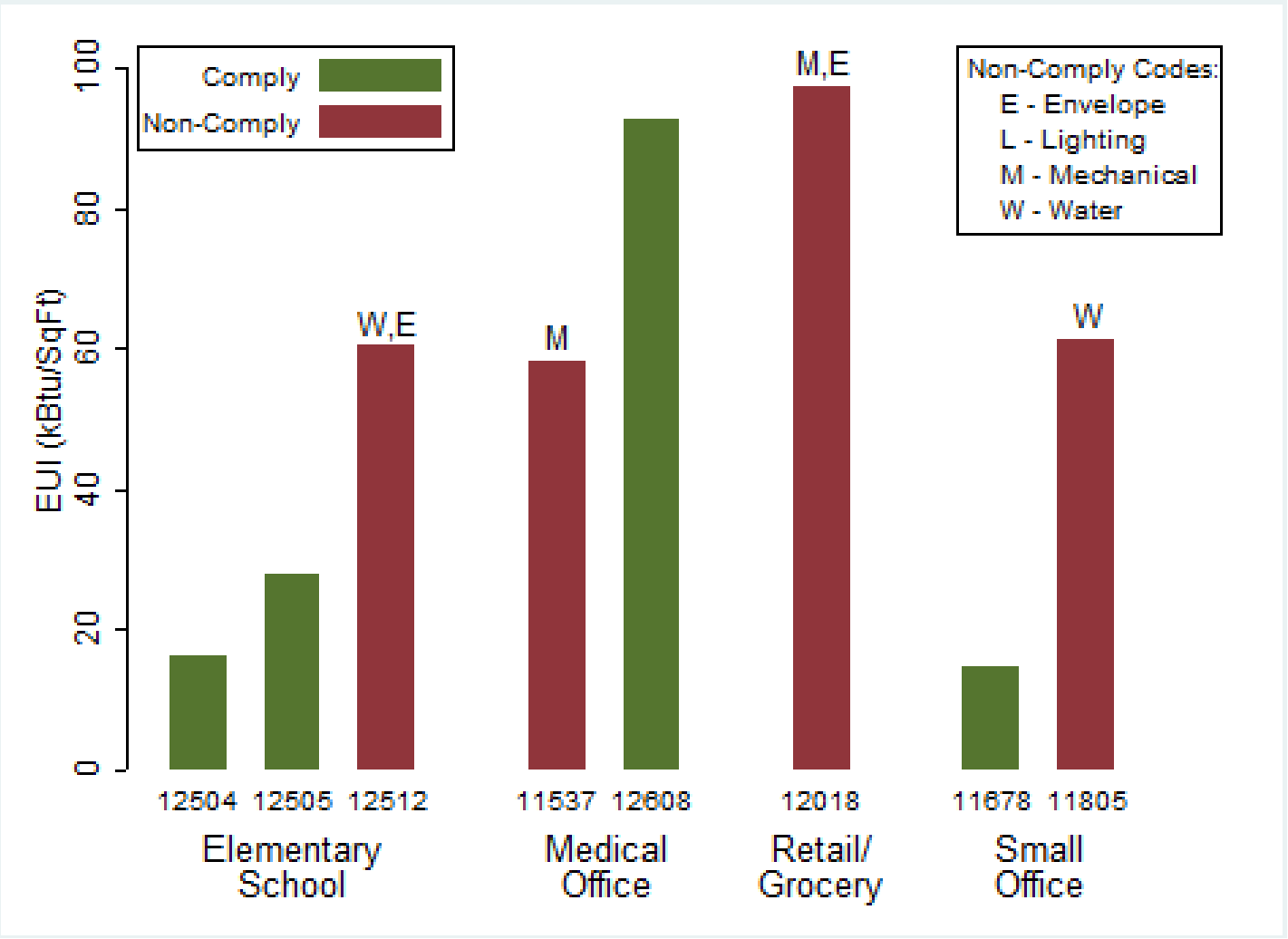
Interior Lighting Power Density by Building



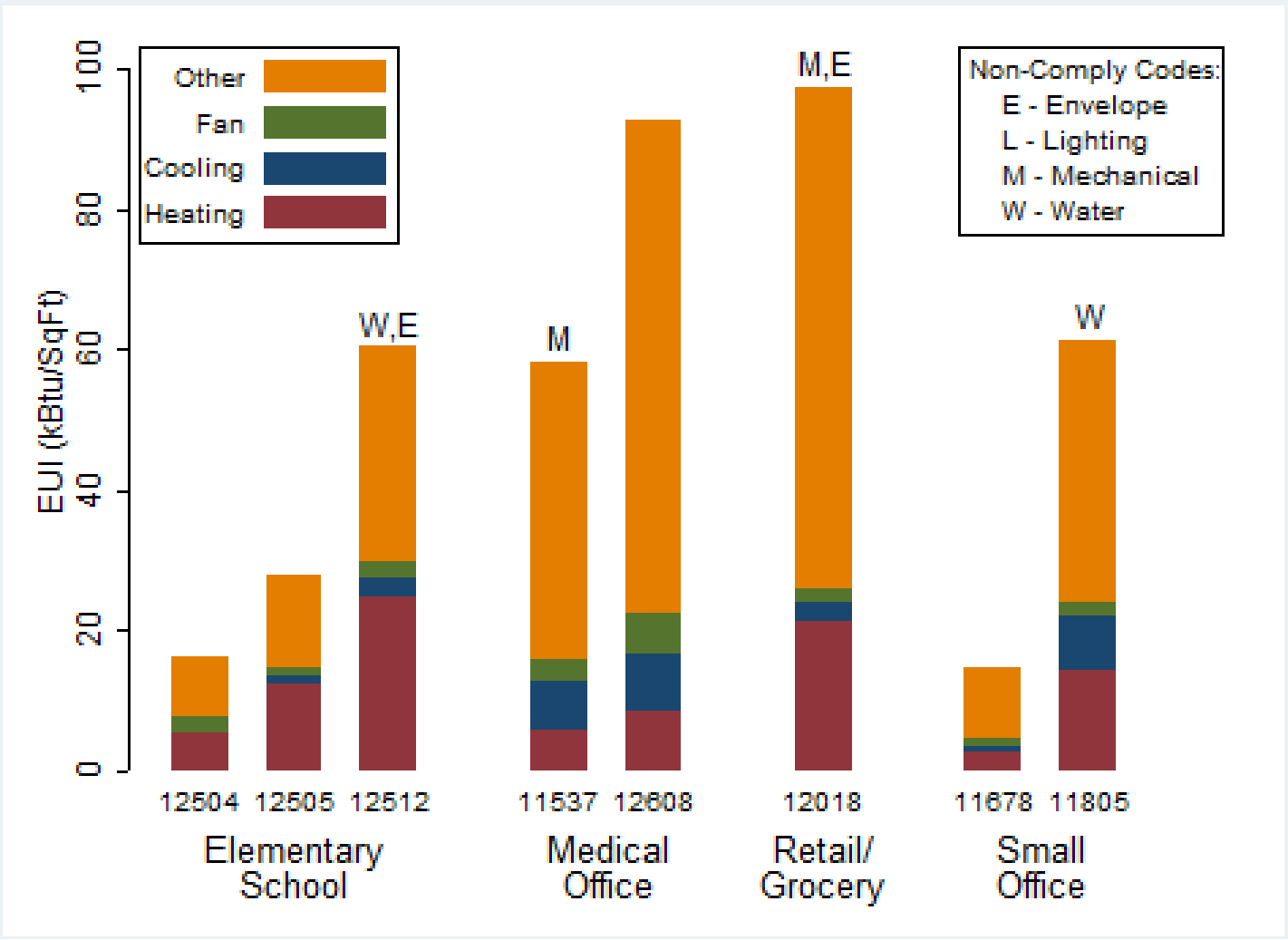
Energy Performance Assessment Steps



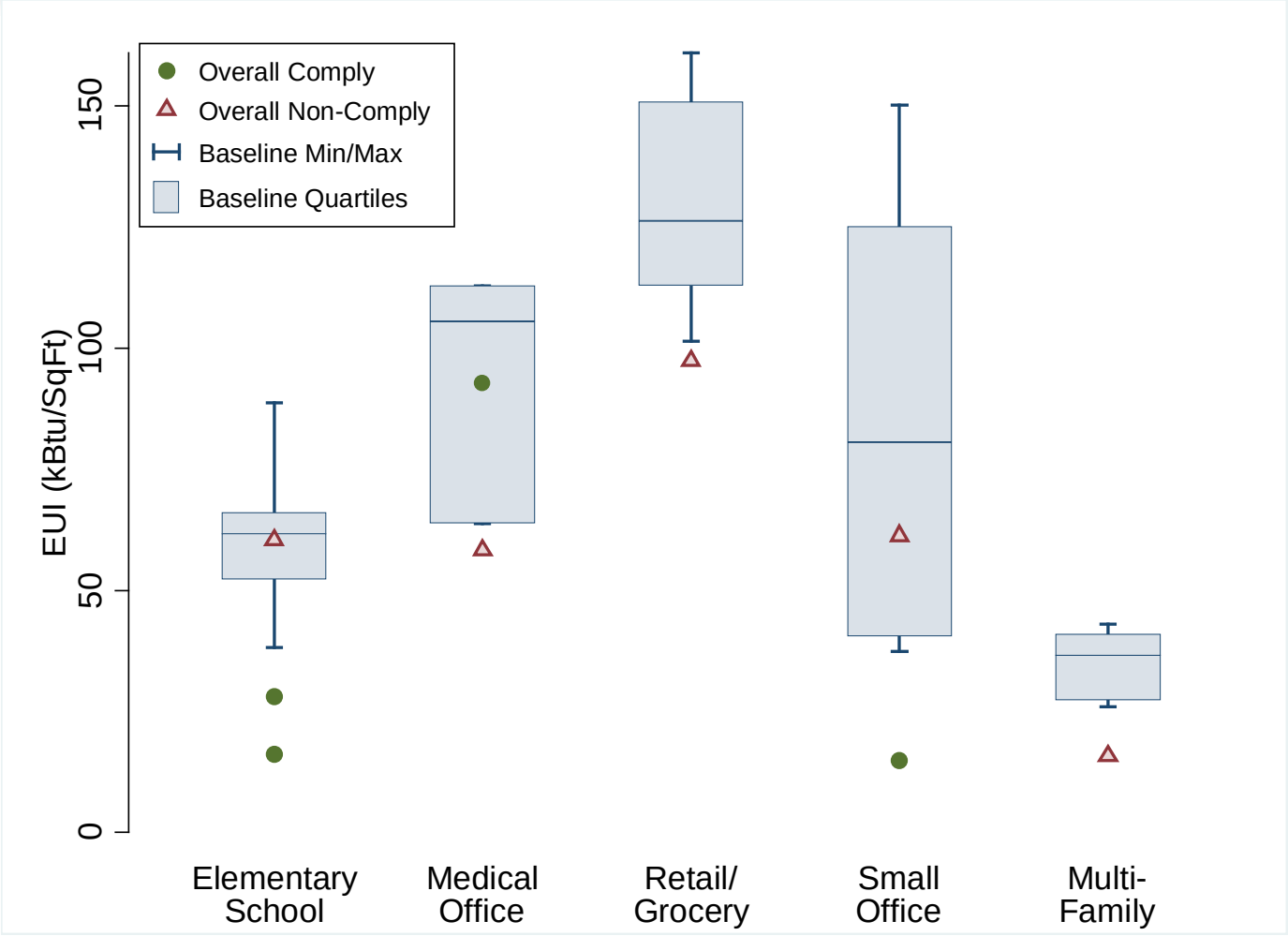
EUI by Compliance (from Small Pilot)



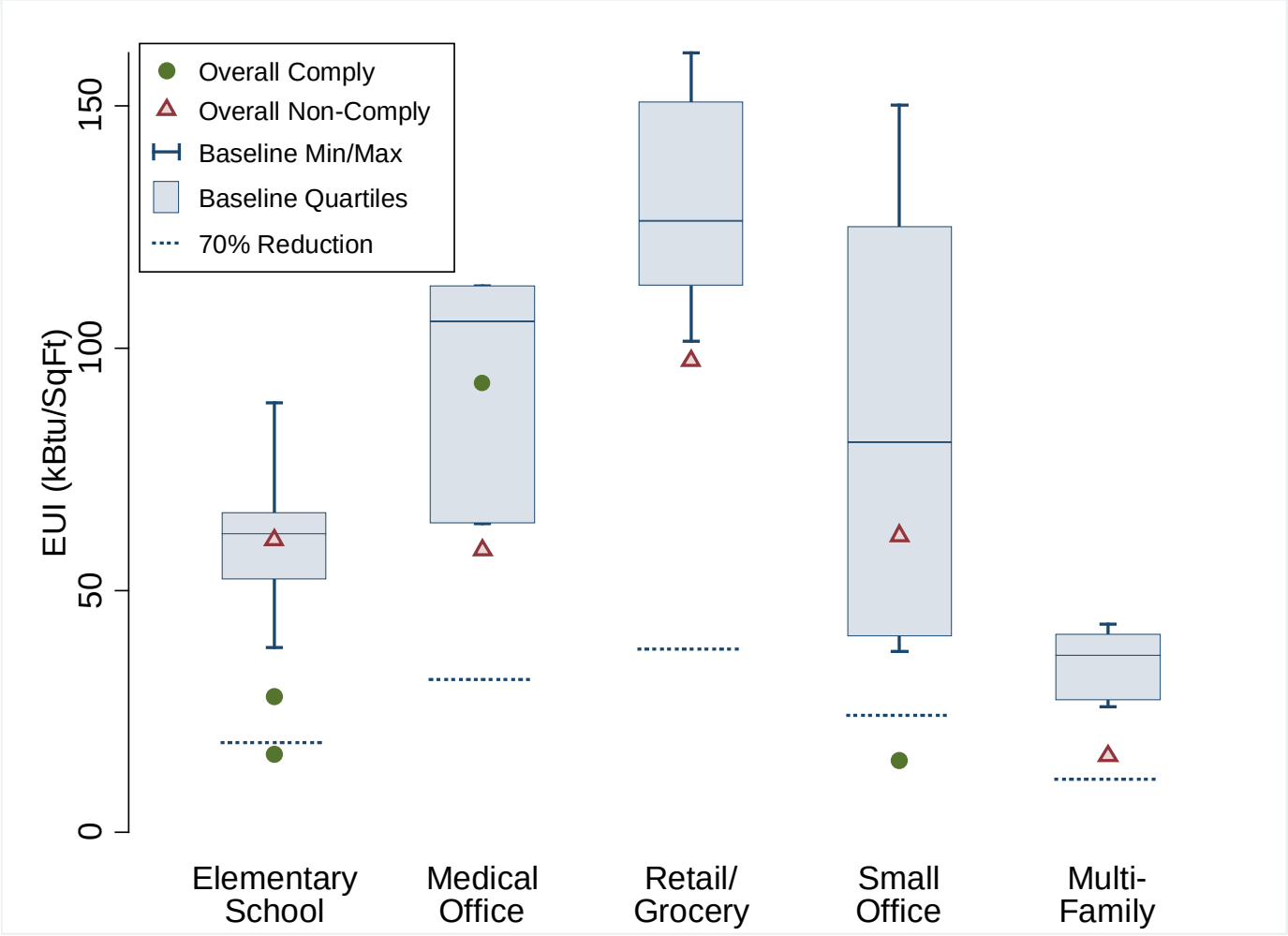
Total EUI by End Use (from Small Pilot)



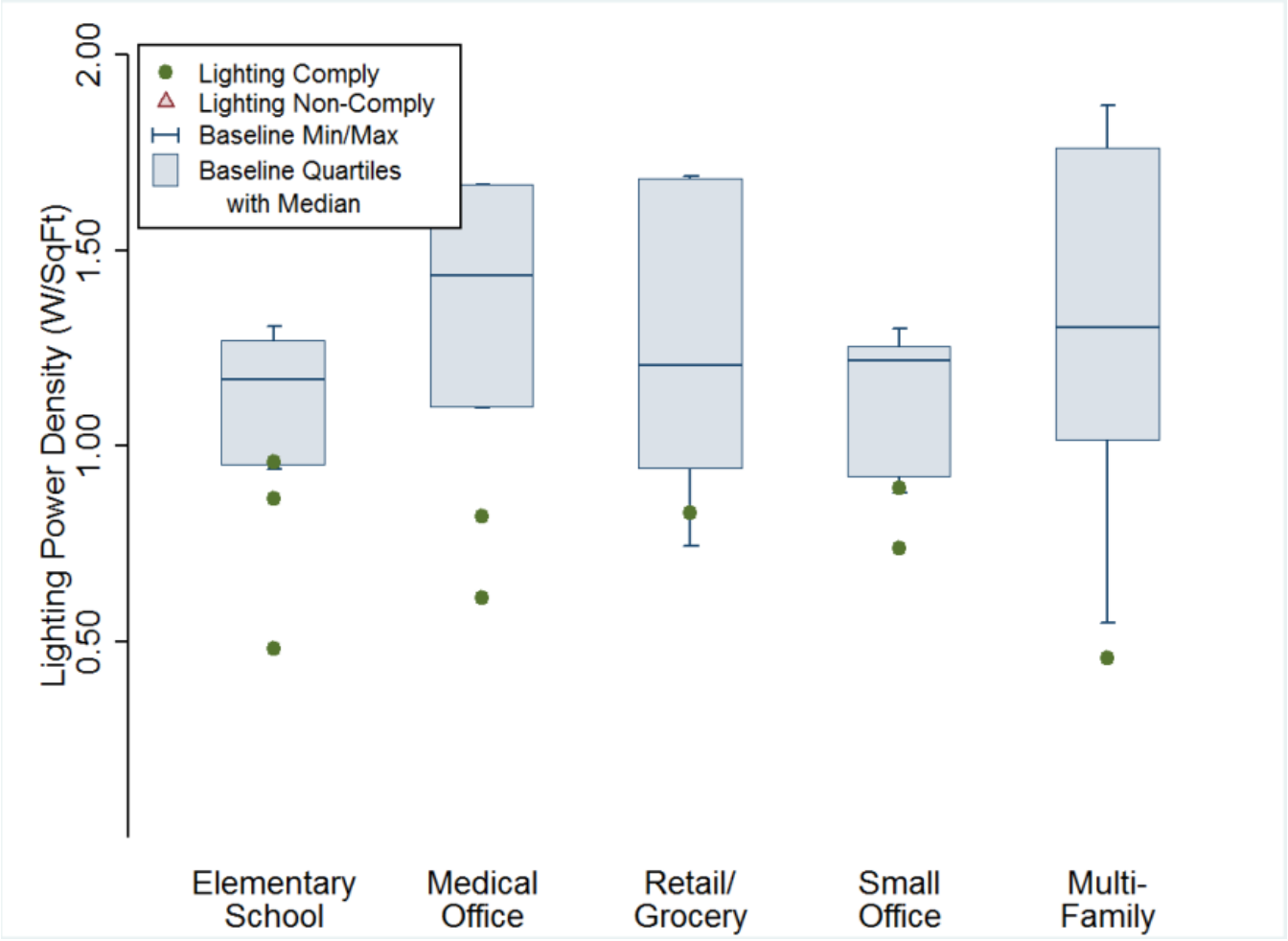
Comparing Building EUIs to the 2006 New Construction Baseline (from Small Pilot)



Tracking Progress Against State Energy Reduction Goals



LPD Benchmark (from Small Pilot)



Putting the Methodology into Practice

- Oregon Code Evaluation
- Washington Code Evaluation
- Idaho/Montana Code Evaluation

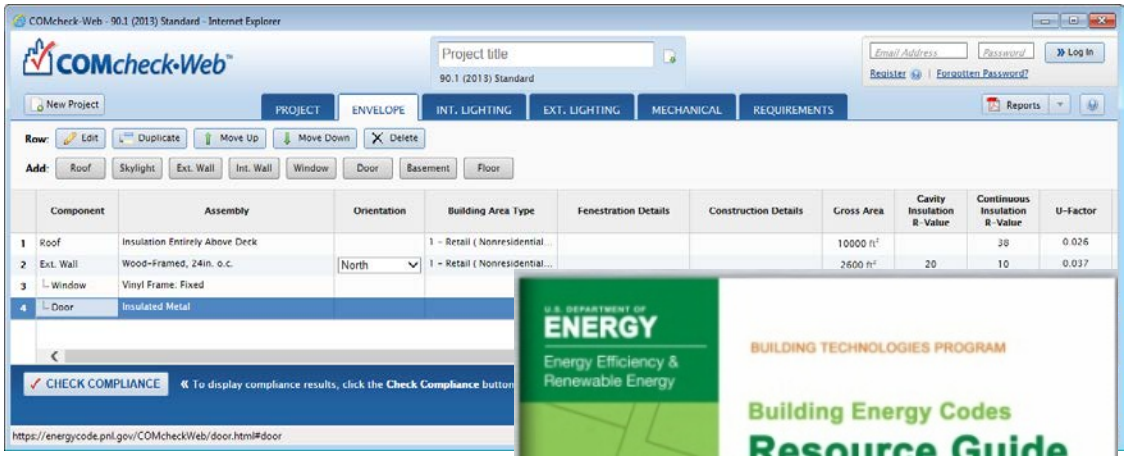
Contact Info

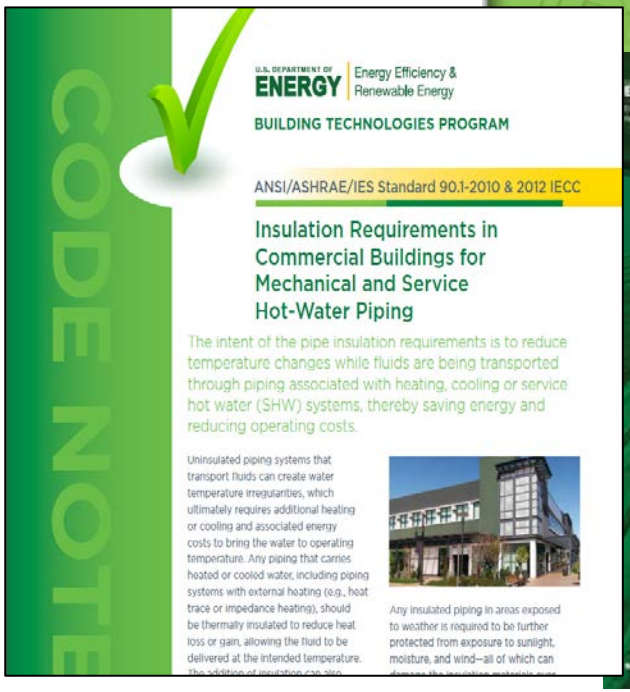
Poppy Storm
Director of Policy and Planning
Ecotope, Inc.
poppy@ecotope.com
206.596.4705

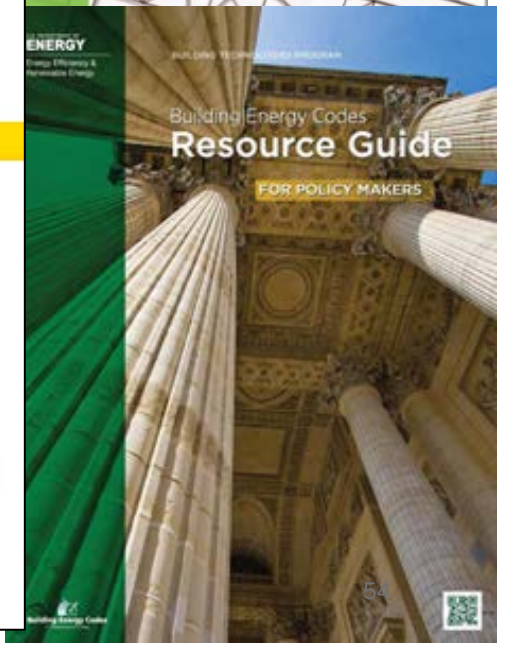
Building Energy Codes Program - Resources

- Compliance software
- Technical support
- Code notes
- Publications
- Resource guides
- Training materials

www.energycodes.gov







Training Topic Ideas?

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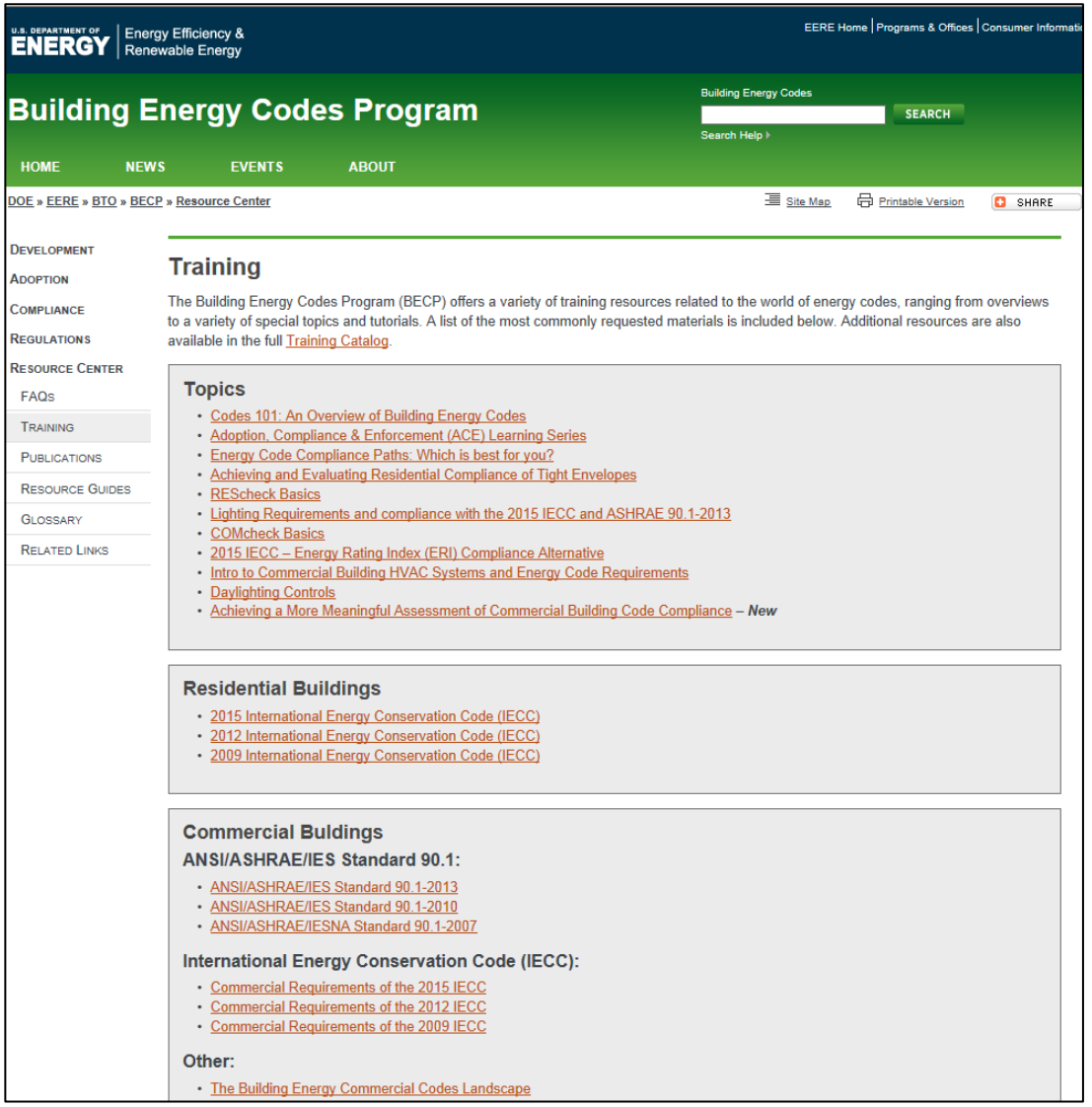
- Give us your topic ideas



https://www.energycodes.gov/training

THANK YOU!

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Building Energy Codes Program
www.energycodes.gov/training

BECP help desk
https://www.energycodes.gov/HelpDesk

Backup Slides

1. Identify Applicable Requirements Measure List (2.3.1)

- Roofs shall be insulated to meet CZ requirements
- Skylight curbs shall be insulated
- Above grade frame walls shall be insulated to meet CZ requirements
- Above grade mass walls shall be insulated to meet CZ and density requirements
- Below grade walls shall meet insulation requirements and be protected
- Exterior floors shall meet the minimum R-value or U-value by assembly type
- Slab-on-grade floors shall meet insulation requirements and be protected
- Opaque doors shall meet U-factor requirements
- Window-to-wall ratio shall meet maximum limits
- Skylight to roof ratio shall meet maximum limits
- Windows shall meet U-factor requirements
- Windows shall meet U-factor requirements In entry doors
- Windows shall meet SHGC requirements
- Skylights shall meet U-factor requirements
- Skylights shall meet SHGC requirements
- Building shall meet continuous air barrier requirements
- Recessed lighting shall be sealed, rated and labeled
- Fenestration assemblies shall meet air leakage requirements
- Bld openings to shafts, stairways, and elevator lobbies meet air leakage reqmts
- Stairway and shaft vents shall be provided with Class I motorized dampers
- Loading dock doors shall be equipped with weather seals
- Building entrances shall be protected with an enclosed vestibule
- Equipment sizing requirement
- Packaged air conditioner efficiency
- Packaged heat pump efficiency
- Gas furnace efficiency
- Thermostatic control is used for individual zones
- Heat pump supplementary heat control
- Thermostat deadband requirement
- Thermostat setback and start/stop controls
- Optimal start controls
- Demand control ventilation
- Energy recovery requirement
- Duct insulation requirement
- Duct leakage requirement
- Lighting Commissioning requirement
- Mechanical systems Commissioning requirement
- Fan power limit requirement
- Economizer supplies 100% design supply air
- Economizers have appropriate high-limit shutoff control and be integrated
- Water heater efficiency, Gas
- Water heater efficiency, Electric
- SWH Heat Trap
- SWH Pipe Insulation - Recirculated
- SWH Pipe Insulation - Non-recirculated
- Manual lighting control
- Automatic time switch control
- Occupancy sensor control
- Daylight zone control
- Display lighting control
- Task lighting control
- Exterior lighting control
- Tandem wiring
- Exit sign maximum power
- Interior lighting power allowance
- Exterior lighting power allowance
- Optional Additional packaged air conditioner cooling Efficiency
- Optional Additional packaged heat pump efficiency
- Optional Additional packaged air conditioner furnace efficiency
- Optional Additional Reduced whole building LPD
- Optional onsite renewable

5. Field Audits

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Building Code Verification Record

Building Information		
Building Identifier	104953	
City/St	Vancouver/WA	
Conditioned Floor Area (sqft)	7,075	
Number of Floors	1	
Occupancy 1	Office	100%
Occupancy 2		0%
Occupancy 3		0%
Building comments:	New office adjacent to production/storage/repair facility for natural resource business. Total ft2 about 25000. Split system heat pump systems serve individual zones. Because of stage of constrcution, had to use permit set vs as-builts.	

Date			
Plan Revu	10/5/2015		**See timing inputs to right >>**
Site Visit 1	10/1/2015		Note record total plan and
Site Visit 2			field time by area at right
ASHRAE Climate Zone	4C		For each measure record
			time estimate below
Actual code	2012 IECC with		View reconciliation in
Which option path?			column S and adjust
Total Tons Cooling	11		estimates to match
Total MBH Heating	209		
Complied via whole building performance?	N		

Verification Time Record for this building

Area	Plan	Field	Plan Est	Field Est	
Travel & Indirect	1.50	1.00	1.50	1.00	
General	3.50	0.00	3.50	0.00	
Envelope	0.60	0.60	0.61	0.60	E
Lighting LPD	0.15	0.30	0.20	0.33	L
Lighting Controls	0.20	0.25	0.25	0.31	LC
Mechanical & SHW Equip	0.50	0.60	0.30	0.60	M
Mechanical & SHW Controls	0.10	0.25	0.08	0.25	MC
Total this building	**5.05**	**2.00**	**4.94**	**2.09**	

Measure (see requirements tab for items included)	Apply to Bldg	Excep-tion used?	Plan	Field	Select Closest to Identified Condition (if not exact condition, describe and apply rating to right)	Default Energy Rating +10/0/-10	Final Overide Energy Rating	Found Factor	Required Factor	Factor Units	Plan Review Comments and Description	Field Inspection Condition Comments and Description	Applicable quantity, affected	Applicabile units	Est Plan Time, hr	Est Field Time, hr	Area for Time Check	Comments about barriers to checking or special tools or expertise required	Cx Req'd ?	Cx done
Roofs shall be insulated to meet CZ requirments	Y	N	Rvu	Insp	0.0: 100%-U; GoodInstallation; ; Code	0.0	0.0	0.039	0.039	U-factor	metal stud building; continuous insulation layer added outboard of girts. R-30 between girts with contin R-11 outboard. Probably equiv to code req		6,997	ft2 net roof area	0.05	0.05	E		No	
Skylight curbs shall be insulated.	N	N							5.000	R-value			58	ft2 of skylight curb			E		No	
Above grade frame walls shall be insulated to meet CZ requirments	Y	N	Rvu	Insp	4.2: 75%-U; Installed PerMfg; ; Above	4.2	4.2	0.040	0.050	U-Factor	see notes for ceiling, above. For walls, same detail used (including R-30 batts as first layer) and then 1 in rigid over everything. Found factor is an estimate; has some derating due to metal studs.		2,660	ft2 net opaque wall area	0.08		E		No	
Above grade mass walls shall be insulated to meet CZ and density requirments	N	N							0.078	U-factor			2,660	ft2 net opaque wall area			E		No	
Below grade walls shall meet insulation requirements and be protected.	N	N							0.119	C-factor			0	ft2 net opaque wall area			E		No	
Exterior floors shall meet the minimum R-value or U-value by assembly type	N	N							0.074/0.033	factor mass/joist			6,997	ft2 exterior/ crawl floor			E		No	
Slab-on-grade floors shall meet insulation requirements and be protected.	Y	N	Rvu	Inacs	0.0: 100%-R; Full depth; Protected; Code	0.0	0.0	0.540	0.540	F-factor	R-10 perimter insulation (vertical) spec'd		380	LF-Perimeter	0.06		E		No	
Opaque doors shall meet U-factor requirements.	Y	N	Rvu	Insp	10.0: 50%-U; ; ; Best	10.0	10.0	0.19	0.370	U-Factor		foam core metal flush	189	ft2 doors, net of windows in doors	0.05	0.08	E		No	
Window-to-wall ratio shall meet maximum limits.	Y	N	Rvu	Insp	10.0: 20% WWR; DL Controls; ; Above	10.0	8.3	25.0%	0.300	% window area			3,800	ft2 Gross Ext Wall	0.08	0.1	E		No	
Skylight to roof ratio shall meet maximum limits	N	N						0.011	0.030	% skylight area			7,075	ft2 Gross Roof Area			E		No	
Windows shall meet U-factor requirements.	Y	N	Rvu	Insp	0.0: 100%-U; ; ; Code	0.0	0.0	0.41	0.38/ 0.45	U-Factor fixed/ operable	U-value in cell J is wtd avg of all window types		886	ft2 window affected	0.05	0.15	E		No	
Windows shall meet U-factor requirements. In entry doors	Y	N	Rvu	Insp	0.0: 100%-U; ; ; Code	0.0	0.0	0.75	0.77	U-Factor entry			65	ft2 window affected	0.03	0.05	E		No	
Windows shall meet SHGC requirements.	Y	N	Rvu	Insp	7.3: 75%-SHGC; ; ; Above	7.3	6.2	0.34	0.40	SHGC			886	ft2 window affected	0.03	0.05	E		No	
Skylights shall meet U-factor requirements.	N	N							0.500	U-Factor			78	ft2 skylight affected			E		No	
Skylights shall meet SHGC requirements.	N	N							0.400	SHGC			78	ft2 skylight affected			E		No	
Building shall meet continuous air	Y	N	Rvu	Phase	0.0: Not tested; CAB sealed and intact; Mtls or assemb	0.0	0.0		NA	NA	language on plans suggests air		17,872	ft2 thermal	0.06		E		No	