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DOE Commercial Building Compliance FOA

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Background



- ▶ 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

PNNL Pilot Project Research Project Approach



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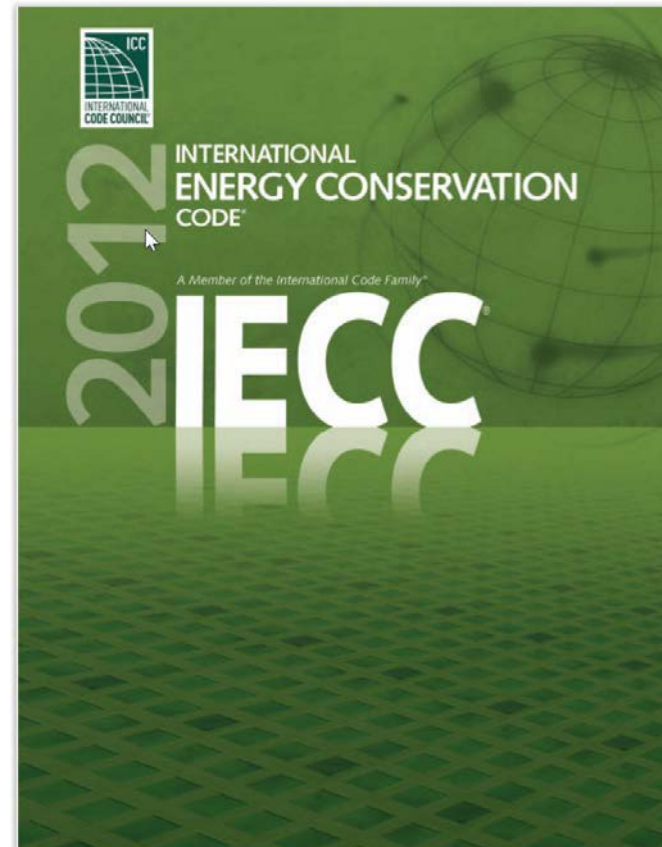
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- ▶ Forget the question; “does it comply?”
- ▶ Instead; how much energy cost savings could potentially be gained through better compliance with the code?
- ▶ How can that savings be captured effectively?





- ▶ 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



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- ▶ Identify all requirements in the 2012 IECC = **396 commercial**
- ▶ 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



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- ▶ 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 ⁰ F as required | 2 ⁰ F | 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., ft², 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 ft ² 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 ft ² building floor area | \$0.000 | \$0.152 | \$0.304 |



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Field Work

4. Field Work – Identify, Recruit, and Audit Buildings



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- ▶ Pilot project 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.
- ▶ Construction document review and field observation determined conditions for each measure
 - 1 visit per site. Not all measures observable



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Calculation of Lost Savings

5. Calculation of Lost Energy Cost Savings from Field Data



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

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

Example Roof Insulation lost savings :

Found condition: Roof insulation U-value = 150% code

Roof area = 900 ft²

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

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

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

Lost Energy Cost Savings Results – Nine Building Sample



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► 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 Sample |
|---|---------------------|---------|---------|---------|---------|---------|---------|---------|---------|--------------|
| | A | B | C | D | E | F | G | H | I | |
| 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 be **\$3,372** annually or **\$46,430** over the building life

Cost of Compliance Verification



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- ▶ 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 | Verification |
|---|---------------------|--------------|
| | Life-Cycle | 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 |

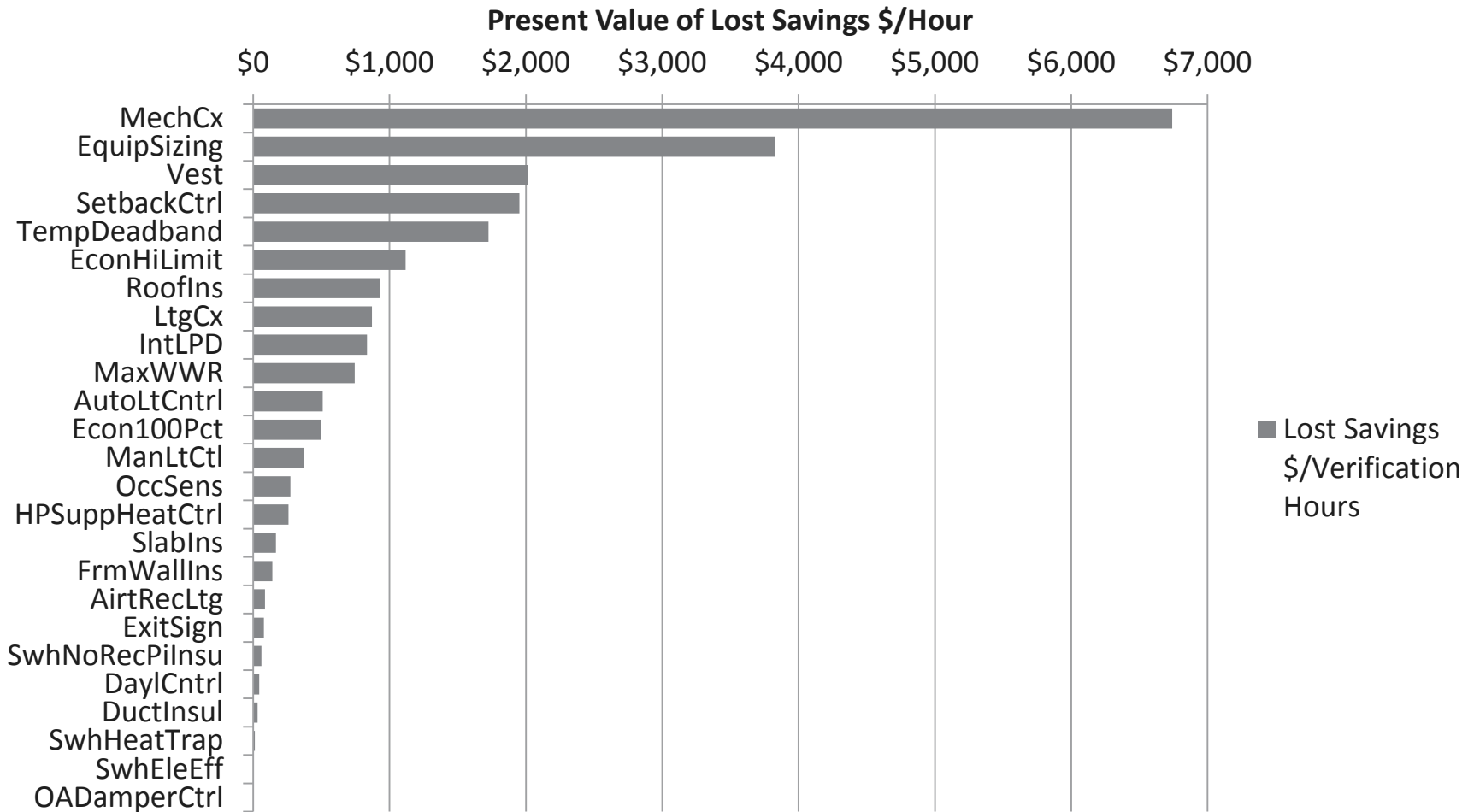
Ranking Based on Field Studies



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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



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Ranking Measures

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



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- ▶ 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**
 - Rank in 2 ways:
 - from study → \$ savings identified / hour spent on verification (bang for the buck)
 - from simulation sensitivity analysis → highest potential lost savings

Ranking Based on Field Studies



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- ▶ 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 | | 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 | |



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Future Implications

Lessons Learned and Recommendations for Future Compliance Studies



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- ▶ 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



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PNNL Activities for Current FOA Support

Expanded Scope and PNNL Analysis for Current Project



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- ▶ DOE awarded \$1.7 Million to the Institute of Market Transformation to roll out this approach on up to 250 buildings in 3 states
- ▶ Current project includes expanded scope from pilot
 - All offices and retail buildings
 - 3 climate zones: Florida, Nevada, Iowa/Nebraska
- ▶ Needs to accommodate expanded scope
 - Identify code requirements – **complete**
 - Identify expected worst case conditions - **complete**
 - Run simulations of worst case conditions – **in process**
 - Rank measures based on worst case – **not started**
 - Select measures based on worst case ranking (IMT, DOE) – **not started**
 - Simulation and lost cost savings analysis for selected measures – **not started**
 - Creation of compliance forms – **not started**
 - Field work! – **not started**



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