

C19 -Commercial & Industrial New Construction Baseline And Code Compliance Study

**Connecticut Energy Efficiency Board Evaluation
Committee**

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Introduction

- Principal Investigators
 - Tom Ledyard, Project Sponsor
 - Tom Franks, Project Manager

- Study investigated C&I new construction practices during 2010 to 2013

- Authority to begin project granted in March 2014
 - Data collection initiated in December 2014
 - Data collection phase extended to maximize sample
 - Draft report submitted July 24, 2015
 - Comments received August 24, 2015

- Final Report and Response to Comments completed and filed on 11/14/15

Presentation Overview

- Study Goals & Objectives
- Methodology
 - Population Development
 - Sample Design
 - Data Collection
 - Analysis
- Findings
- Recommendations

Goals and Objectives

- **Goal** – To inform impact evaluations and the decision making processes of Energy Efficiency Board and Program Administrators with regard to C&I new construction.
- **Objectives**
 - To estimate the difference between observed construction practice and those used in the PSD
 - To estimate the level of energy code compliance in new C&I buildings
- **Need**
 - Baseline assumptions identified as the “greatest source of uncertainty” effecting program savings estimates and cost effectiveness
 - Preliminary look at code compliance (Full study for CT obligation to estimate code compliance under terms of ARRA grant will have a much higher cost.)

Methodology



Population and Sample

- Population of new C&I construction derived from purchased data
 - 3,359 Connecticut building permits issued 2010-2013
 - Included new construction, renovation, and additions
 - 722 out 1,014 new construction entries contained building area (sq.ft.)
- Sample based on USDOE's stratification and sample size recommendations for code compliance study

| Stratum | Size | Population (N=722) | Sample (45) |
|----------|-----------------------|--------------------|-------------|
| Small | <=25,000 sq. ft. | 474 | 24 |
| Medium | Up to 60,000 sq. ft. | 109 | 7 |
| Large | Up to 250,000 sq. ft. | 118 | 11 |
| X-Large | Up to 400,000 sq. ft. | 11 | 2 |
| XX-Large | Over 400,000 sq. ft. | 10 | 1 |

Set Up

- Recruiting tool – populated with sample, quotas, and recruiting script
- Data collection tool – populated with requirements derived from review of COMcheck™ code compliance software and Connecticut Program Savings Documentation (PSD)
- Training – Two days for field and recruiting staff covering
 - Project objectives, roles and responsibilities
 - Protection of health, safety, and the environment
 - Software and hardware tools
 - Protocols for recruiting, field work, incentive processing, data quality control and analysis
 - Document management including construction document review and site visit

Data Collection

- Recruiting script
 - Confirmed, or corrected, data acquired from purchased data
 - Confirmed availability of construction documents
- Site visit
 - Walk through inventory of energy using systems
 - Brief survey to collect supplemental information, e.g. participation in EnergizeCT program
 - Review of construction documents if not portable
 - Photograph energy using equipment, exterior, and interior
- Document acquisition and review
 - If not acquired during site visit
 - Construction documents reviewed to fill gaps in observed data (e.g. details not observable without intrusive investigation) and to quality check recorded data

Data Processing

- Data collected from multiple sources consolidated into comprehensive site-level data file (i.e., site data, construction documents, survey responses, additional research such as manufacturer data)
- Site data file review
 - Completeness
 - Spot check for accuracy
- Site data input into COMcheck™
 - Stringent COMcheck™ data requirements served as a second level of quality control
 - COMcheck™ inputs and outputs reviewed by second analyst

Analysis

- Code Compliance Estimate
 - COMcheck™ analysis of each site against code in effect at time of permitting
 - Site level results aggregated to estimate overall code compliance levels
- Baseline Estimate
 - Site-level data was aggregated by system type (e.g. Lighting)
 - The average efficiency by system type was calculated for the overall sample, the portion identified as potential program participants, and the portion identified as non-participants
 - These efficiencies were compared to the baseline requirements of the PSD and to the requirements of ASHRAE 90.1 – 2013, an example of a more rigorous energy efficiency standard.

Measure Level Efficiency Analysis

- The reference for efficiency requirements was the Connecticut PSD – 2012
- The PSD references ASHRAE 90.1 – 2007 for lighting and other measures
- ASHRAE 90.1 – 2007 is in many respects equivalent to IECC – 2009, the basis for the 2011 amendments to the State Building Code.
- Later version of ASHRAE 90.1 have more rigorous energy efficiency requirements

| Measure | PSD Efficiency Parameter |
|---|--------------------------|
| Standard lighting by building type | Lighting Power Density |
| Chillers | EER or kW/ton |
| Unitary Air Conditioning and Heat Pumps | SEER/EER & HSPF |
| Water and Ground Source Heat pumps | EER & COP |
| Gas Boiler and Furnaces | AFUE/Thermal Efficiency |
| Gas Domestic Hot water heaters | EF/Thermal Efficiency |

Data Summary

Acquired Sample

- Captured 6% of the population count and 10% of the floor area in 45 sites included in analysis

| Stratum | | % Count | | % Area | |
|-----------------|---|---------|-----|--------|-----|
| | | 722 | 45 | N | n |
| Small | 1 | 66% | 53% | 13% | 7% |
| Medium | 2 | 15% | 16% | 13% | 10% |
| Large | 3 | 16% | 24% | 43% | 42% |
| X-Large | 4 | 2% | 4% | 11% | 21% |
| XX-Large | 5 | 1% | 2% | 21% | 20% |
| Sample Share | | | 6% | | 10% |

Note: N = Population, n = Sample

Building Type Distribution

| Building Type | Population (N=722) | Sample (n=45) |
|--------------------|-----------------------|------------------|
| Education | 9.0% | 20.0% |
| Food Service | 11.8% | 2.2% |
| Health Care | 5.3% | 2.2% |
| Lodging | 19.8% | 17.8% |
| Office | 13.2% | 17.8% |
| Public Assembly | 10.5% | 17.8% |
| Retail | 16.5% | 11.1% |
| C&I | 11.2% | 11.1% |

Data Sources for Energy Efficiency Code Analysis

| Building Component | Data Source (# of Sites) | | | |
|--------------------|--------------------------|------------------------|--------------------|------------------------|
| | NA* | Construction documents | Direct observation | Engineering assumption |
| Below grade wall | 33 | 10 | 0 | 2 |
| Floor | 0 | 38 | 0 | 7 |
| Exterior wall | 0 | 39 | 0 | 6 |
| Roof | 0 | 39 | 0 | 6 |
| Fenestration | 0 | 7 | 1 | 37 |
| Cooling system | 2 | 6 | 33 | 4 |
| Heating system | 0 | 3 | 37 | 5 |
| Lighting interior | 0 | 19 | 22 | 4 |
| Lighting exterior | 1 | 23 | 17 | 4 |
| Hot water heater | 6 | 5 | 30 | 4 |

Note: NA = Not applicable or Not acquired

Findings

Code Compliance by Strata and System

- Site level compliance comparing default COMcheck™ values (“no EA”) to average discovered input values (“w/ EA”) in cases where data was not available.
- Total column incorporates average discovered input values.

| Strata | n | Envelope no EA | Envelope w/ EA | Lighting | DHW | Cooling | Heating | Total |
|--------|----|----------------|----------------|----------|------|---------|---------|-------|
| 1 | 24 | 54% | 92% | 96% | 83% | 100% | 100% | 79% |
| 2 | 7 | 57% | 100% | 86% | 86% | 86% | 100% | 71% |
| 3 | 11 | 27% | 100% | 100% | 82% | 91% | 91% | 64% |
| 4 | 2 | 0% | 100% | 50% | 100% | 100% | 100% | 50% |
| 5 | 1 | 0% | 100% | 100% | 100% | 100% | 100% | 100% |

Note: EA = engineering assumption, e.g. average discovered sample values used

Estimate of State-Wide Code Compliance

| Sample (n=45) | Envelope no EA | Envelope w/ EA | Lighting | DHW | Cooling | Heating | Total |
|--------------------------|----------------|----------------|----------|-----|---------|---------|-------|
| Unweighted | 44% | 96% | 93% | 84% | 96% | 98% | 73% |
| Weighted by Count | 49% | 95% | 94% | 84% | 96% | 99% | 75% |
| Weighted by Area | 26% | 99% | 92% | 88% | 94% | 96% | 73% |

- For context, a recent Massachusetts study with very different data collection and analysis methodologies estimated 80% overall compliance for the 2009- 2011 time frame
 - 81% compliance in envelope (Three visits during construction)
 - 79% compliance in HVAC systems
 - 74% compliance in lighting systems

End Use - Lighting

LPD by Building Type Compared to PSD and ASHRAE 2013

- Lighting efficiency in the sample was better than the baseline in the PSD for 13 out of 16 of building types.

| Building Type (N=45) | Compared to PSD | Compared to ASHRAE 2013 |
|----------------------------------|-----------------|-------------------------|
| Automotive Facility (n=1) | 6% | 19% |
| Dining: Bar Lounge/Leisure (n=1) | -43% | -27% |
| Dormitory (n=2) | -52% | -15% |
| Gymnasium (n=2) | -17% | -3% |
| Healthcare-Clinic (n=1) | -66% | -74% |
| Hotel (n=1) | -86% | -84% |
| Manufacturing Facility (n=2) | -30% | -22% |
| Multifamily (n=6) | -9% | 26% |
| Office (n=8) | -32% | -17% |
| Parking Garage (n=1) | -47% | -24% |
| Religious Building (n=2) | -36% | -17% |
| Retail (n=6) | -70% | -64% |
| School/University (n=6) | -54% | -37% |
| Sports Arena (n=2) | -17% | 0% |
| Transportation (n=1) | -14% | 23% |
| Warehouse (n=3) | -25% | -9% |

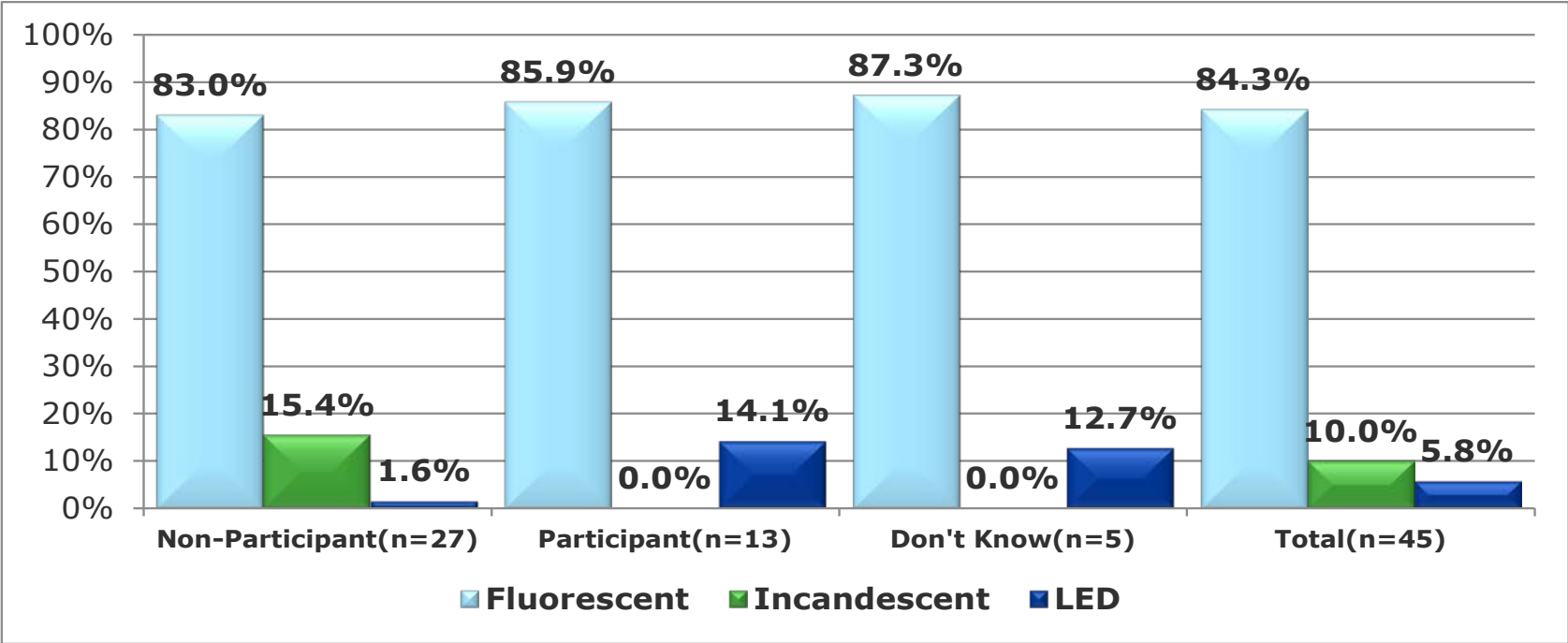
LPD by PSD Bin

- Average lighting efficiency in the sample was better than the baseline for 8 out of 9 LPD bins

| PSD LPD | Sample LPD | % Difference |
|----------------------------|------------|--------------|
| 0.3 | 0.2 | -47% |
| 0.7 | 0.6 | -9% |
| 0.8 | 0.6 | -44% |
| 0.9 | 1.0 | 6% |
| 1 | 0.6 | -40% |
| 1.1 | 0.9 | -20% |
| 1.2 | 0.5 | -48% |
| 1.3 | 0.8 | -34% |
| 1.5 | 0.5 | -75% |
| Total for All Areas | | -30% |

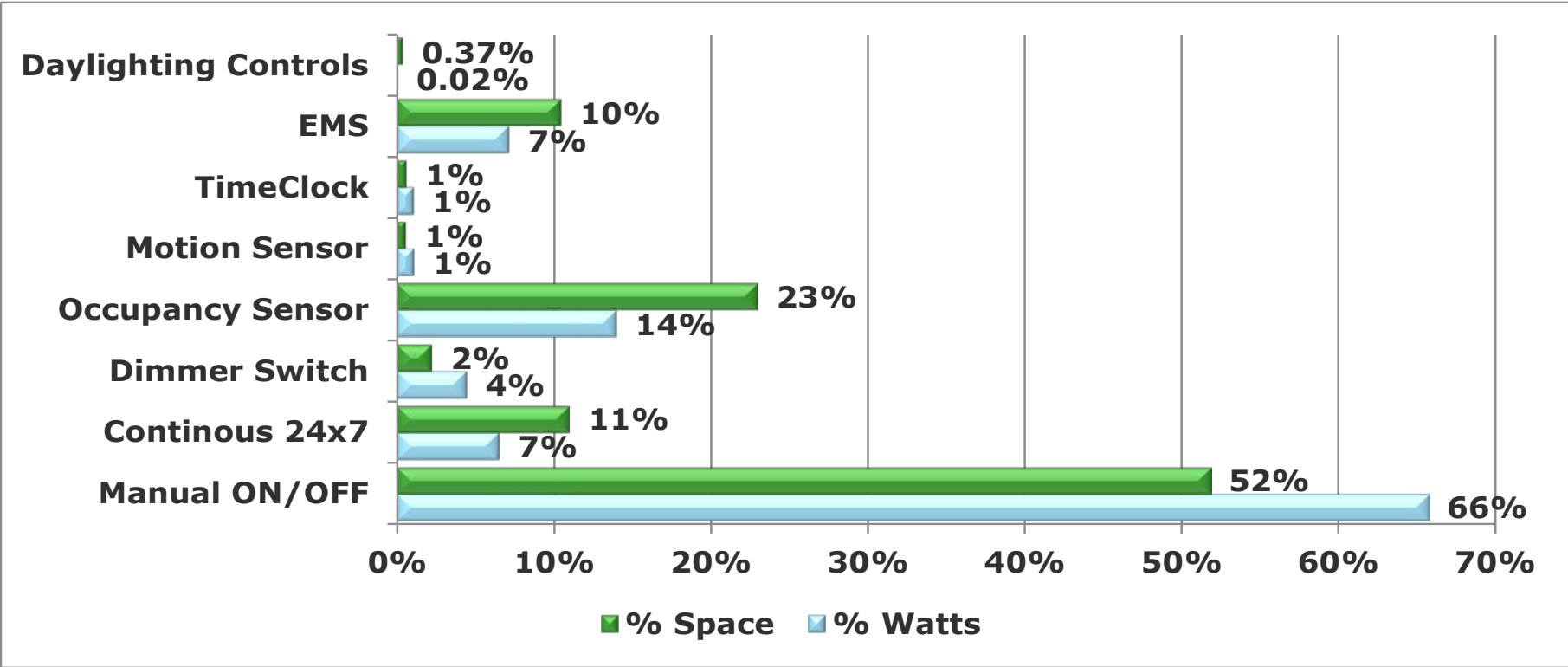
End Use – Lighting Technology

- LED lamps accounted for 2.9% of interior floor area and 16.7% of exterior area surveyed.
- It is worth noting that these facilities were designed and mostly commissioned prior to the recent decline in LED lamp cost.



Measure – Lighting Controls

- The majority, in both terms of space served and energy consumed, of lighting was controlled manually.



End Use – Cooling Technology Penetration

- 53% of cooling capacity found was direct expansion, 33% chiller, and the balance heat pump.

| Technology | System Type | % of Installed Capacity |
|------------------|------------------------------------|-------------------------|
| Chiller | Water Cooled Centrifugal | 1.7% |
| | Water Cooled Positive Displacement | 22.9% |
| | Air Cooled Chiller | 8.7% |
| Direct Expansion | Packaged DX Unit | 14.8% |
| | Split System | 37.9% |
| Heat Pump | Ground Source Heat Pump | 0.1% |
| | Water Source Heat Pump | 0.6% |
| | Air Source Heat Pump | 13.3% |
| Total | | 100% |

Measure –Cooling Efficiency - DX

- Average efficiency in each direct expansion size bin exceeded PSD standards

| Size | Units | PSD | ASHRAE 2013 | n | Average |
|-----------------------|----------|------|-------------|-------|---------|
| <65,000 | SEER | 13.0 | 14.0 | 1,147 | 13.8 |
| ≥65,000 and <135,000 | EER/IEER | 11.0 | 12.7 | 24 | 12.3 |
| ≥135,000 and <240,000 | EER/IEER | 10.8 | 12.2 | 16 | 11.3 |
| ≥240,000 and <375,000 | EER/IEER | 9.8 | 11.4 | 31 | 12.1 |
| ≥375,000 and <760,000 | EER/IEER | 9.8 | 11.1 | 3 | 10.0 |

Measure – Heat Pump Efficiency

- Average efficiency of heat pumps surveyed exceeded PSD standards

| Size | Use | PSD | Average |
|---|---------|-----------|-----------|
| <65,000 (n=110) | Cooling | 13.0 SEER | 14.7 SEER |
| | Heating | 7.7 HSPF | 8.92 HSPF |
| ≥135,000 and <240,000 (n=2) | Cooling | 11.0 SEER | 12.6 EER |
| | Heating | 3.3 COP | 3.73 COP |

End Use – Space Heating Technology Distribution

- Natural gas accounted for 89% of the space heating capacity, electric 7%, and propane 4%

| Technology | # Units | % kBtuh | Energy Source | | |
|-------------------------------|---------|---------|---------------|----------|---------|
| | | | Nat Gas | Electric | Propane |
| Central Furnace | 93 | 43.9% | 93.4% | 0.0% | 6.6% |
| Condensing Boiler | 11 | 36.6% | 100.0% | 0.0% | 0.0% |
| Duct Furnace | 43 | 9.2% | 89.3% | 0.0% | 10.7% |
| Unit Heater | 92 | 4.4% | 68.8% | 25.8% | 5.4% |
| Air Source Heat Pump | 112 | 5.0% | 0.0% | 100.0% | 0.0% |
| Water Source Heat Pump | 6 | 0.4% | 0.0% | 100.0% | 0.0% |
| Ground Water Source Heat Pump | 2 | 0.3% | 0.0% | 100.0% | 0.0% |
| Radiant Heater | 2 | 0.1% | 0.0% | 100.0% | 0.0% |
| Ground Loop Source Heat Pump | 6 | 0.1% | 0.0% | 100.0% | 0.0% |

Measure – Heating Efficiency

- The average furnace and boiler efficiency observed on-site exceeded the PSD

| Type | n | Size | PSD Efficiency | Average |
|-----------------------|----|-------------------------|-------------------------|---------|
| Warm Air, Gas-Fired | 53 | <225,000 | 78% AFUE or 80% Thermal | 82.9% |
| Warm Air, Gas-Fired | 40 | ≥225,000 | 80% Thermal | 81.8% |
| Gas duct furnaces | 43 | All capacities | 80% Thermal | 88.6% |
| Warm air unit heaters | 20 | All capacities | 80% Thermal | 89.4% |
| Condensing Boiler | 11 | ≥300,000 and ≤2,500,000 | 80% Thermal | 91.0% |

Measure – Domestic Hot Water

- Natural gas was the energy source for 95% of DHW capacity in sample
- Instantaneous DHW equipment provided 84% of capacity, storage equipment 9%, and central plants 7%

| Fuel | Technology | Size | Sample | PSD (EF) | ASHRAE 2013 (EF) | Average (EF) |
|----------|---------------|-----------------------------|--------|----------|------------------|--------------|
| Electric | Storage | ≤12 kW, ≥20 gal | 506 | 0.85 | 0.95 | 0.91 |
| Gas | Storage | ≤75 kBtuh, ≥20 gal | 96 | 0.53 | 0.65 | 0.64 |
| Gas | Instantaneous | >50 kBtuh and <200 kBtuh | 946 | 0.62 | 0.62 | 0.93 |

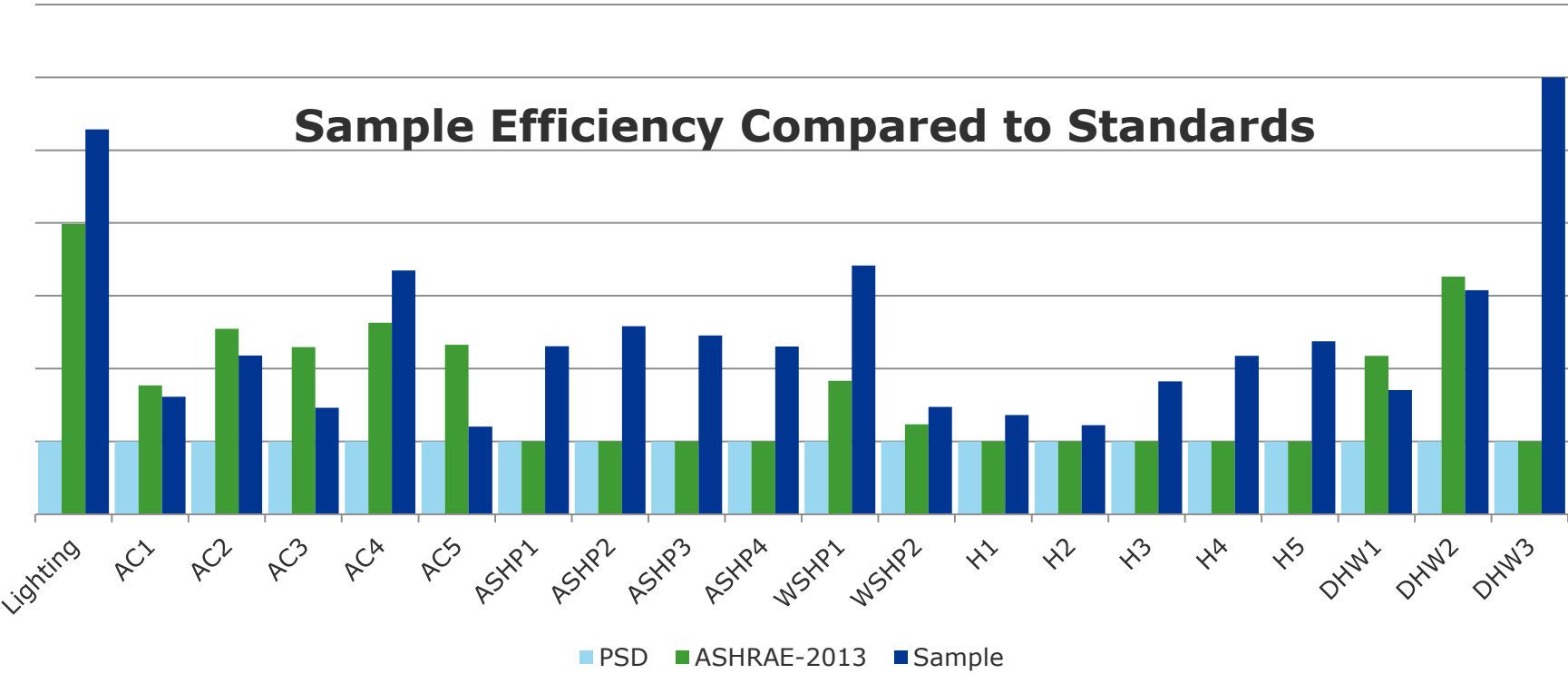
Conclusions & Recommendations

Code Compliance

- Estimated code compliance $\sim 73\%$ is reasonable within the constraints of the study methodology and of comparable magnitude to that discovered in an adjacent state
- Accuracy and precision of subsequent studies can be increased by:
 - Acquisition of complete and accurate new construction population data
 - Revised methodology to identify qualified site contacts
 - Enhanced recruitment incentives
 - Adoption of the USDOE multiple-visit study methodology

Baseline Conclusion

- The average efficiency of the sample exceeded the efficiency requirements of the PSD and in many cases exceeded the requirements of the more efficient ASHRAE 90.1 – 2013



Note: Higher is more efficient, not comparable across measure categories

Participation Influence

- The average efficiency for both participant and non-participant respondents exceeded the PSD requirements

| | PSD | ASHRAE 2013 | Participant Average | Non-Participant Average |
|-----------------------|-------|-------------|---------------------|-------------------------|
| Lighting* | Unity | -23% | -37% | -24% |
| AC1 (SEER) | 13.00 | 14.00 | 14.4 | 13.6 |
| AC2 (EER) | 11.00 | 12.70 | 12.7 | 12.1 |
| AC3 (EER) | 10.80 | 12.20 | 10.9 | 11.5 |
| AC4 (EER) | 9.80 | 11.40 | 14.3 | 10.6 |
| ASHP1 (SEER) | 13.00 | 13.00 | 15 | 14.6 |
| ASHP2 (HSPF) | 7.70 | 7.70 | 8.5 | 8.99 |
| H1 - E _t | 80% | 80% | 83% | 83% |
| H2 - E _t | 80% | 80% | 82% | 81% |
| H3 - E _t | 80% | 80% | 94% | 87% |
| H4 - E _t | 80% | 80% | 93% | 89% |
| H5 - E _t | 80% | 80% | 92% | 92% |
| DHW1 - E _f | 85% | 95% | 92% | 92% |
| DHW3 - E _f | 62% | 62% | 93% | 94% |

Note – Lighting basis is allowed watts per square foot.

Recommendations

- Consider increasing efficiency of baseline assumptions in PSD. This can be a measure by measure process that is accompanied by other additional research and analysis available to the PAs and EEB.
- Continue, and consider enhancing, program support of LED and advanced lighting control technologies. These are two technologies where we observed opportunities in the sample.
- Consider additional research into the use of instantaneous hot water heaters as an energy source for both domestic hot water and space heat.

Thank you for your time

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