Commercial Energy Code Compliance – Just the Facts, Ma'am

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ABSTRACT

What percent of newly constructed commercial buildings comply with the energy code? How much energy and cost could be saved if the compliance increased? Which code requirements have low compliance rates and high savings potential? These are the questions U.S. Department of Energy (DOE) is trying to answer through its Commercial Energy Code Field Study. Previous commercial studies were very limited and have not resulted in a widely accepted and tested methodology. DOE's goal is to create a standardized methodology that can produce actionable results at a reasonable study cost, which state and local governments and utilities can use and that also provides valuable information to policy makers. This paper builds on the methodology presented at the 2016 Summer Study and provides a first glimpse of the results as seen in the field.

The field study team implemented the pilot methodology, compiling a data set of 230 office and retail buildings in climate zones 2A[1] and 5A.[2] The approach is based on identifying lost savings on a total energy cost basis rather than simply counting the quantity of measures that do not meet code. This paper reviews the findings of that analysis, discusses critical aspects of the methodology, including sampling and recruitment strategies, and identifies areas where the greatest return—bang for the buck—exists in improving compliance with codes in commercial buildings. In addition, the team makes specific recommendations for jurisdictions looking to use the methodology to maximize energy code savings achieved in the field.

Introduction

The U.S. Department of Energy (DOE) moved from a binary assessment of commercial building code compliance to a compliance methodology that focuses on estimating lost savings due to non-compliance. Following on the development of the new method and a pilot field test, DOE released a Funding Opportunity Announcement (DOE, 2016) to scale the field test to two additional climate zones and a larger sample of commercial buildings.

Background and DOE's Previous Commercial Compliance Work

DOE developed a commercial compliance methodology and associated tools focused on determining a percent compliance rating for states (DOE 2010) to support the American Recovery and Reinvestment Act of 2009 (ARRA 2009). Section 410 of ARRA requires states to

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[1] Climate zone 2A includes portions of southeast Texas, southern Louisiana, Mississippi, Alabama, Georgia, and the majority of Florida.

[2] Climate zone 5A includes Nebraska, southern South Dakota, northwest Kansas, southern Iowa, northern Missouri, Illinois, Indiana and Ohio, southern Michigan, eastern West Virginia, most of Pennsylvania, western and eastern portions of New York, northern New Jersey, Connecticut, Rhode Island, Massachusetts and southern New Hampshire.

develop "a plan for the jurisdiction achieving compliance with the building energy code … in at least 90% of new and renovated residential and commercial building space." The approach developed by DOE calculates an average compliance score for the sample set. For each code requirement that is applicable and observable, a binary decision determined whether or not the building complied. The percentage of requirements where the building complied established the score for each individual building. This approach does not explicitly distinguish between varying levels of non-compliance nor does it evaluate the energy impact of individual requirements (DOE 2013A).

A Value Based Compliance Methodology

The binary approach of the previous compliance determination methodology failed to answer a critical question: What is the dollar value of increasing compliance with the energy code? Ultimately, this is the question that policy makers, funders, and program implementers care about. With this in mind, Pacific Northwest National Laboratory (PNNL) developed a new methodology capable of determining, for a sample of buildings, how much energy cost savings[3] could potentially be gained through better compliance with the code (Rosenberg et al. 2016).

PNNL previously tested the new approach in a pilot study of nine office buildings in climate zone 4C. To begin, PNNL inventoried all the requirements in the non-residential provisions of the 2012 International Energy Conservation Code (IECC) (ICC 2012) applicable to office buildings in climate zone 4C. PNNL then grouped the requirements into measures consisting of related requirements and developed prototype building simulations to estimate the energy cost impact of varying levels of non-compliance for each measure. Next, we compared the pilot study data collected from the nine buildings to the simulation results. By comparing the specific conditions relative to code requirements, PNNL found the potential lost energy savings for each building and for the sample of buildings. The result is the amount of energy cost savings they could have achieved had they complied fully with the 2012 IECC. In addition, this approach allowed the team to rank measures based on actual and worst-case lost cost savings. For each building in the pilot study, the annual lost energy cost savings ranged from a minimum of $101 to a maximum of $638 and 2% to 29% of total annual energy cost. For the entire nine-building sample, the annual lost cost savings was $3,372 or 13% of total annual energy cost.

During data collection, the compliance reviewer tracked total hours spent verifying individual measures. We were then able to calculate the lost savings cost in dollars per verification hour. In other words, what possible savings could occur through better compliance per hour spent on the verification process based on this pilot study? The potential recovered annual savings per verification hour ranged by measure from less than one dollar to $533/hr.

Field Study Approach

The project team executed the field study by developing a sample, recruiting buildings, collecting and completing quality assurance reviews (QA) on data, and analysis by PNNL. The following describes the processes in further detail.

[3] Energy cost savings is the expected reduction in building occupant utility bills.

Sample

The project targeted new construction (defined as permitted within the study period) office and retail construction. Office and retail comprise about 29% of new construction floor space each year (Jarnagin and Bandyopadyay, 2010). Constraints on the sample are presented in Table 1.

Table 1. Applicable Building Activities and Categories[4]

Principal Activity	Subcategory	Description/Examples
Retail other than mall	Vehicle dealership	Dealership or showroom for vehicles or boats
	Retail store[5]	Department store, furniture, clothing, sporting goods, office supplies, drugstore, bookstore, auto parts, home improvement, farm equipment, floral, crafts, gifts, antiques, pawn shop, wholesale club.
	Other retail	Beer, wine, or liquor store;[6] rental center; studio or gallery; showroom; wholesale supply.
Strip shopping mall	Strip shopping mall[7]	Strip shopping center buildings with establishments that are operated independently of each other.
Office	Administrative/ professional office	Consulting, insurance, law, utilities, publishing, college administration; nonprofit or social services; religious; research and development; sales or leasing.
	Bank/other financial	Bank, credit union, home finance
	Government office	Government office, city hall, city center
	Medical office (non-diagnostic)	Doctor's or dentist's office that did not report equipment for medical diagnosis or treatment.
	Mixed-use office	Mixed-use office
	Other office	Call center; contractor's office.

In consultation with DOE, the team defined target sample sizes as shown in Table 2.

Table 2. Building populations and target sample sizes for Climate Zones 2A and 5A

Size strata	Climate Zone 2A				Climate Zone 5A			
	2016 pop. (N)		Sample size (n)		2016 pop. (N)		Sample size (n)	
	Office	Retail	Office	Retail	Office	Retail	Office	Retail
Small-medium (< 75K ft^2)	91	186	56	40	72	188	44	46
Large (≥75K ft^2)	1	14	1	14	19	8	10	8

[4] Derived from PNNL guidance and Commercial Building Energy Consumption Survey building category descriptions https://www.eia.gov/consumption/commercial/building-type-definitions.php
[5] Chain retail stores were limited to 3 per chain, and further limited to no more than 2 per designer or contractor.
[6] Beer, wine or liquor stores were limited to those with small amounts of refrigeration.
[7] Assuming the strip and tenants fit into the constraints for recruitment, an individual center could be used three times: 1) for core and shell construction, 2) and 3) for tenant fit-out construction.

Building Recruitment

The project team tested two primary recruitment approaches: building department leads and owner/developer leads. All recruitment methods began with collecting permit lists within the study area to identify potential sites that would match the building types within the study parameters.

The team used building department leads in two ways: building department contacts put the data collection teams directly in contact with general contractors to visit sites alone, or a building inspector accompanied data collection teams to identified sites. The team accessed owner and developer leads by direct contact. This initial contact was completed either by calling the contact information on the permit application or through the local building owners' organizations. The successes and challenges of these approaches are discussed in depth later, but neither of these methods provided a high enough return rate to be pursued alone.

In addition to the initial methods of recruitment, the team added two additional methods: walk-up recruitment and high-level networking. For walk-up recruitment, or "cold-calling", the project team showed up on site (with full personal protective equipment, data collection forms, etc.), asking to speak with the general contractor or superintendent, introducing the project, and asking to be allowed on site. High-level networking built off the owner outreach. In these cases, the project team presented the project to local chapters of building industry groups to develop familiarity with the project and ask for attendees to volunteer buildings.

Data Collection

Two primary data collection contractors, Mozingo Code Group[8] and FSEC Energy Research Center,[9] conducted most of the field work. The project team added a third data collection contractor, Three Points Planning,[10] later in the project to resolve the lag in timing and budget constraints.

Prior to the field project, the project team identified potential measures by building type and climate zone, and selected high impact measures (Zhang, Hart, and Rosenberg 2016; Hart et al. 2019). With the measures of interest determined, the project team developed a data collection form to capture all pertinent information needed for each code measure. The form had five main sections: General Information, Envelope, Mechanical, Lighting, and Renewables. The form captured minimum code requirements, plan review, "as found" values, and measure verification time for each of the 78 measures of interest.

Training and Consistency. The project team developed a training module and trained the two primary teams at the start of the data collection period to provide consistency in collection. In addition to the initial training, over the first few months of active data collection, the project team held regular calls with each data collection teams to discuss common issues and questions and problem solve. The project team called a short pause to review the initial set of five building data collection sheets and to get feedback from PNNL. Quality assurance reviews throughout the data collection period continued to ensure consistent reporting between data collection teams.

[8] shaunnamozingo.com; began study under Colorado Code Consulting
[9] energyresearch.ucf.edu/; administered by the University of Central Florida.
[10] sites.google.com/view/threepointsplanning

Plan Review. To acclimate teams to what was expected in the field and to more fully depict the features affecting energy use in the subject building, all buildings required a plan review. Primarily, data collection teams conducted the plan review portion of the process prior to the field visit.[11] To obtain plans, the project team submitted public records requests of selected permits during outreach to each jurisdiction. Data collection teams reviewed building plans and other available compliance documentation.[12]

During plan review, data collection teams entered the minimum requirements based on code, code version, and compliance path indicated for each measure in the data collection form. The teams extracted the prescriptive requirements directly from the code version selected, they found trade-off information in COM*check*™ reports,[13] and performance requirements in energy model documentation. When the compliance path was unclear, teams defaulted to the prescriptive path. The data collection team documented the plan review findings for each measure including applicability, factor units, and measure verification time[14] for plan review activities on the data collection form. The plan review process supplemented direct observations, especially in situations where a particular measure could not be observed directly.

Field Site Visits. The data collection teams used the site visits to observe the as-found condition and to identify key information for each measure for the analysis. Data collection teams took photos of products and labels and observed conditions for each measure. The data collection forms included space to enter site visit findings for each measure including factor units and measure verification time for inspection, ensuring it was possible to discern discrepancies between plan review and observed field data.

The project team conducted a single site visit for each building. To get a diverse sample of all measures, this meant that the project team visited projects at a variety of stages, from framing to early occupancy. Because of the site visit timing, only about 68% of the applicable measures for each building could be field verified. The condition of some measures could be confirmed in either plan review or during site inspection, while the condition of other measures could not be confirmed in either.

The PNNL team only reported a measure as verified and used as a basis for estimated savings when the team directly observed the measure or verified the measure through other evidence[15] . The team recorded measures as inferred or unknown based on the level of information available through observation, plan review, and documentation on site. In all cases, the team sought verified field data before accepting alternative evidence.

Results of the Field Study

The project team visited 230 buildings, covering over 6 million square feet of commercial office and retail space. The final data set compared to the sampling plan is presented in Table 3.

Table 3. Target sample sizes and actual data sets for Climate Zones 2A and 5A

[11] When using the walk-up approach to recruitment, data collection teams conducted the field visit step first.
[12] E.g., COM*check*™, performance-based submissions, project specifications.
[13] COM*check*™ is a DOE commercial energy compliance tool, www.energycodes.gov/comcheck
[14] Time required to verify measure, reported in hours.
[15] E.g., photographs kept by construction team on-site, measurements of depth, verification on other exposed area to account for whole building, etc.

Size strata	Climate Zone 2A				Climate Zone 5A			
	Sample plan (n)		Data set		Sample plan (n)		Data Set	
	Office	Retail	Office	Retail	Office	Retail	Office	Retail
Small-medium (< 75K ft^2)	56	40	58	47	44	46	49	50
Large (≥75K ft^2)	1	14	4	8	10	8	12	2

This compilation of field study energy code compliance data includes 107 retail and 123 office buildings from both climate zones, for a total of 230 buildings. One building had no verified measures, so the sample for buildings with verified measures was 229.

Lost Savings Analysis

The project team transferred data from the field forms into the measure calculation worksheet to arrive at potential lost savings based on as-found vs. code prescriptive or performance required conditions. PNNL reviewed each building's worksheet for quality assurance and questionable entries were corrected by the field teams. The project team extracted collected building and measure data to a database for lost savings analysis.

In determining the impact of building construction that falls short of code, several factors must be considered:

- Is the code requirement applicable to the building or part of the building?
- What is the case, defined by measure, climate zone, and building type?
- What condition is **verified** to be installed relative to the code requirement?

The first two factors can be readily determined, but as previously discussed, a high confidence in the field information is only possible if the field inspection occurs when direct verification of the conditions is possible (third factor). The reliability of the verified information depends on the number of actual field observation for each case. When there is verified information for a case, an estimate of lost savings can be calculated (Jiang, Hart, and Rosenberg 2016; Hart et al. 2019) and it can be reasonably applied to other cases where the measure was applicable, but not directly observed. Once the statistical review of measure results is complete, a general measure result from all verified cases will be applied where measures are applicable but not verified. For some measures there are no verified cases, and no estimate can be made. **The authors emphasize that these results are preliminary, and the statistical significance of lost measure savings will be assessed once the field data are analyzed statistically.**

Overall Lost Savings. What is the total verified lost savings for all buildings surveyed? This roll-up includes the concept of applicability, as lost savings are not estimated where the measures are not applicable. Table 4 shows results by case and Figure 1 shows overall results by measure, with measure descriptions found in Table 5.

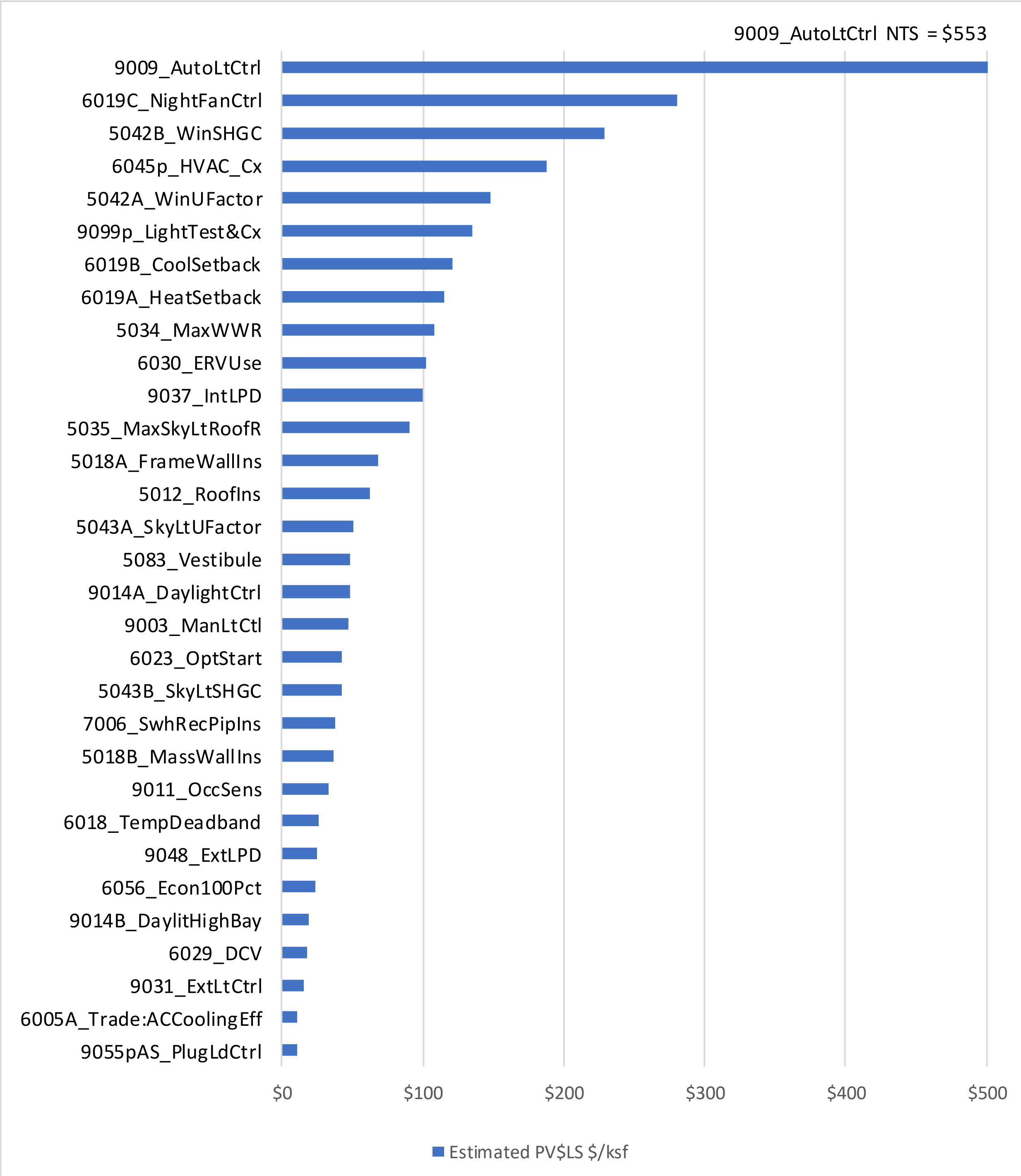

Figure 1. Overall estimated measure lost savings for all cases, Present Value lost savings per ksf, excluding those with no observations or estimated present value lost savings below $10/ksf.

To represent the true cost of lost savings over the life of the building, the annual lost savings from each measure is converted to a present value (PV) using National Institute of Standards and Technology discount rates based on the measure life (Lavappa, Kneifel, and O'Rear 2017). This represents the value today of all lost savings over the life of each measure.

Then the data are divided by thousand square feet (ksf) of building area to normalize the values, resulting in the present value dollar lost savings (PV$LS) per ksf. The Table 4 and Figure 1 values are calculated as follows:

$$Verified\,\frac{PV\$LS}{ksf} = \frac{\sum(PVfactor * \$/year\ lost\ savings)}{\sum ver\ surveyed\ floor\ area\,/1000}$$

These verified measure savings are extrapolated to the entire sample or building type and climate zone case as follows:

$$Estimated\,\frac{PV\$LS}{ksf} = Verified\,\frac{PV\$LS}{ksf} * \frac{\sum Applicable\ floor\ area}{\sum Verified\ floor\ area}$$

Table 4: Commercial Energy Code Field Survey Results Summary

Building type	Climate Zone	Buildings surveyed	Average floor area, ft^2	Lost savings from non-compliance		
				$/year	**$/year/ksf**	**PV$/ksf**
Office	2A	62	17,406	208,442	193	2,778
Office	5A	61	36,127	277,679	126	1,951
Retail	2A	55	33,487	446,646	243	3,468
Retail	5A	52	18,817	223,388	228	3,901
All Buildings		230	26,535	1,156,155	189	2,868

Building Lost Savings Distribution. Figure 2 shows the distribution of present value lost savings by building type and climate zone, and for the data set overall. Review of the distribution reveals several things:

- Only 4 out of 229 buildings had zero lost savings or were fully compliant with the energy code. In the old way of counting, that represents only a 1.7% compliance rate.
- Half of the buildings have lost savings (PV$LS) $1682 or less per 1000 square feet.
- One-quarter of buildings have lost savings (PV$LS) $724 or less per 1000 square feet.
- The upper quartile of lost savings (PV$LS) has a greater spread, ranging from $4,065 to $9,000 per 1000 square feet, excluding outliers.
- There are several outlier buildings with very large lost savings, between $9,000 and $22,000 present value lost savings (PV$LS) per 1000 square feet.

These results are **minimum** lost savings, as only 69% of applicable measure instances were able to be verified by the field crew. Envelope verification was higher at 80%, with lighting at 73% and mechanical (HVAC and water heating) at 48%. Actual lost savings are likely in the range of 1.3 to 1.6 times the lost savings reported here.

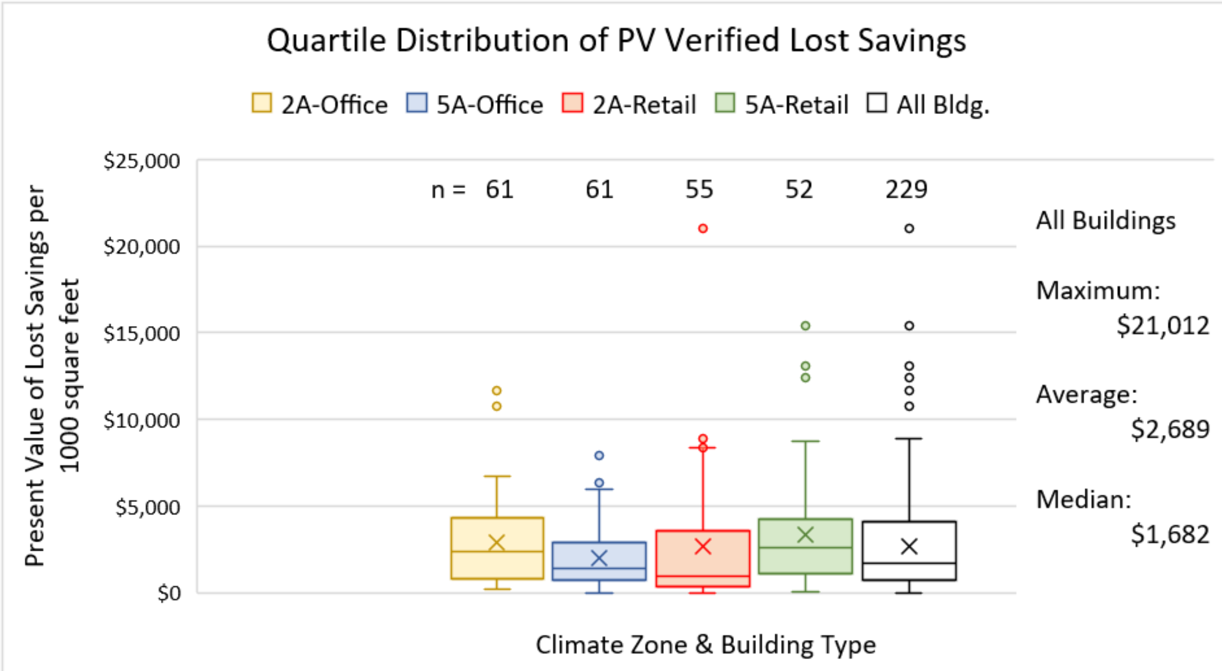

Figure 2: Distribution of Present Value Lost Savings by Climate Zone and Building Type.

Normalized Measure Lost Savings. What is the estimated lost savings found in the field by measure, on the basis of present value dollars normalized per thousand square feet (PV$/ksf)? Table 5 shows the savings for discrete measures, including the impact of applicability. The values are calculated as discussed above under overall savings, except on a per-measure basis. When there were no verified cases below code in the sample to date, the lost savings is shown as zero and grey in the table, even though a larger sample or more measure instances may reveal some lost savings. Table 5 also shows the number of buildings in which the measure was applicable and the number of buildings in which it was verified. Three lost savings from non-compliance values are shown:

- $/year is the estimated lost savings for all buildings
- $/yr/ksf is the $/year divided by the total building conditioned floor area
- PV$/ksf includes a present value factor: total savings over the life of the measure

Table 5: Commercial Energy Code Field Survey Measure Results

Measure		**# Buildings**		**Lost Energy Cost Savings**		
ID	**Description**	**Appl.**	**Ver.**	**$/year**	**$/yr/ksf**	**PV$/ksf**
5012	Roofs shall be insulated to meet CZ requirements	48	19	$16,861	$2.76	$63
5014	Low slope roofs in CZ 1-3 shall be cool roofs	18	6	$2,439	$0.40	$8
5018A	Above grade frame walls shall be insulated to meet CZ requirements	90	53	$17,079	$2.80	$68
5018B	Above grade mass walls shall be insulated to meet CZ and density requirements	27	13	$9,359	$1.53	$36

Table 5: Commercial Energy Code Field Survey Measure Results

Measure		# Buildings		Lost Energy Cost Savings		
ID	Description	Appl.	Ver.	$/year	$/yr/ksf	PV$/ksf
5023B	Exterior mass floors shall meet the minimum R-value or U-value by assembly type	2	1	$555	$0.09	$2
5029B	Opaque rollup doors shall meet U-factor requirements	8	6	$1,111	$0.18	$4
5034	Window-to-wall ratio shall meet maximum limits	40	40	$30,192	$4.95	$108
5035	Skylight to roof ratio shall meet maximum limits	1	1	$25,332	$4.15	$90
5042A	Windows shall meet U-factor requirements	143	138	$37,636	$6.17	$148
5042B	Windows shall meet SHGC requirements	154	147	$69,980	$11.47	$229
5043A	Skylights shall meet U-factor requirements	7	4	$12,470	$2.04	$50
5043B	Skylights shall meet SHGC requirements	7	6	$12,815	$2.10	$42
5056	Building shall meet continuous air barrier requirements	3	3	$354	$0.06	$1
5077	Stair and shaft vent leakage	2	1	$547	$0.09	$2
5083	Building entrances shall be protected with an enclosed vestibule	12	12	$12,763	$2.09	$48
5089	Fenestration orientation	12	11	$492	$0.08	$2
6005A	Packaged air conditioner efficiency	35	16	$5,244	$0.86	$11
6005B	Packaged heat pump efficiency	6	2	$2,189	$0.36	$5
6005C	Gas furnace efficiency	1	0	$0	$0.00	$0
6005D	Boiler efficiency	2	1	$45	$0.01	$0
6017	Heat pump supplementary heat control	3	1	$4	$0.00	$0
6018	Thermostat deadband requirement	30	12	$11,796	$1.93	$26
6019A	Thermostat heating setback	49	22	$48,221	$7.90	$115
6019B	Thermostat cooling setback	47	25	$57,511	$9.42	$121
6019C	Night fan control	48	30	$130,563	$21.39	$281
6023	Optimal start controls	17	13	$18,249	$2.99	$42
6026p	Snow and ice-melting system control	1	0	$0	$0.00	$0
6029	Demand control ventilation	22	10	$7,120	$1.17	$18
6030	Energy recovery requirement	3	1	$37,739	$6.18	$102
6035	Duct leakage requirement	1	1	$611	$0.10	$2
6042B	Hydronic Piping Insulation Requirement HW	10	9	$400	$0.07	$1
6045p	Commissioning requirement	64	18	$88,502	$14.50	$188
6046A	Fan power limit requirement for PkgAC	8	2	$832	$0.14	$2
6056	Economizer supplies 100% design supply air	38	25	$11,123	$1.82	$23
6070	Multi-zone systems shall be VAV and fans with motors ≥threshold hp shall have variable speed, variable pitch axial, or fan demand reduction	1	0	$0	$0.00	$0
6071	Static pressure sensors used to control VAV fans shall be properly placed	1	0	$0	$0.00	$0

Table 5: Commercial Energy Code Field Survey Measure Results

Measure		# Buildings		Lost Energy Cost Savings		
ID	**Description**	**Appl.**	**Ver.**	**$/year**	**$/yr/ksf**	**PV$/ksf**
6110pAS	Zone Isolation	1	0	$0	$0.00	$0
7006	SWH Pipe Insulation - Recirculated	3	1	$14,628	$2.40	$37
9003	Manual lighting control	40	38	$19,353	$3.17	$48
9009	Automatic time switch control	69	57	$265,212	$43.45	$553
9011	Occupancy sensor control	51	47	$15,875	$2.60	$33
9014A	Daylighting control	49	44	$23,006	$3.77	$48
9014B	For large, high-bay spaces total daylight zone under skylights at least 1/2 of floor area	12	11	$9,235	$1.51	$19
9031	Exterior lighting control	25	22	$7,081	$1.16	$15
9037	Interior lighting power allowance	20	17	$47,690	$7.81	$100
9047	Additional retail lighting power allowance	3	3	$2,500	$0.41	$5
9048	Exterior lighting power allowance	23	15	$11,629	$1.91	$24
9055pAS	Plug load controls	10	7	$4,898	$0.80	$10
9099p	Lighting Testing or Commissioning	101	34	$64,487	$10.57	$135
6005E	WSHP efficiency	2	0	$0	$0.00	$0
5023A	Exterior frame floors shall meet the insulation requirements	1	1	$6	$0.00	$0
6109pAS	Parking garage fan controls	1	0	$0	$0.00	$0
9054AS	Parking garage lighting controls	1	1	$296	$0.05	$1

Ratio of Measure Lost Savings to Inspection Hours. What is the overall PV lost savings for each measure per total hours invested in verifying the measures in the field? Figure 3 gives an indicator of where field time investigating measures is best spent. Actual dedicated field time data was collected for about 30% of the measure instances. The idea is to emphasize large savings measures with low field verification effort. The values are calculated as follows:

$$\frac{\sum PVfactor * \frac{\$}{year} verified\ measure\ lost\ savings}{\sum hours\ to\ survey\ measure}$$

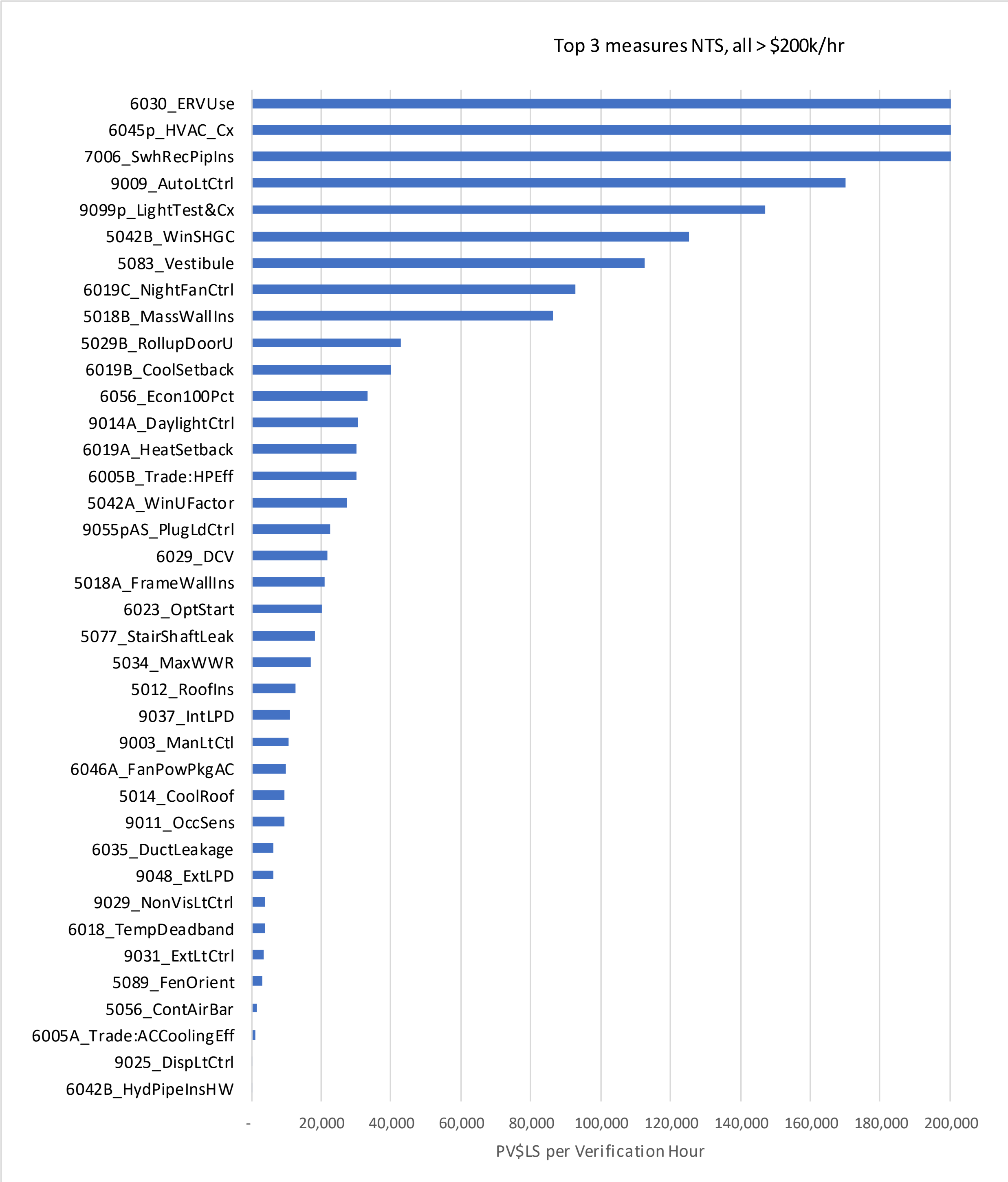

Figure 3: Measure verified savings per inspection time: [PV/ksf lost savings] / [total inspection hours by measure]. Unverified or zero lost savings measures excluded.

Observations and Lessons Learned

Setting the Sample

Geographic Sample Proportionality. The project teams' initial sampling plan sought reflect geographic proportionality. The field study departed from this approach, for the following reasons: (1) The study represented two climate zones, which include broad areas that were not participating; (2) The team anticipated that recruitment and site visits would be very time-consuming. Given resources, the project team concentrated in areas with the greatest construction volume; (3) sampling and data collection prioritized the coverage of specific measures more than geographic proportionality in itself.

For states, or other geographically bounded uses of the methodology, development of a sampling plan that is geographically representative may prove to be more valuable than a measure level significance focus. The goals of future national level studies on commercial construction should be prioritized over geographic proportionality.

Census Sample Approach. Large buildings were important for this study for two key reasons: 1) greater quantities of energy savings are at stake; 2) they commonly contain energy-efficiency measures such as complex HVAC equipment and lighting controls not present in smaller buildings. Therefore, to the extent that such measures would be included in this study, the project team must get into large buildings to find these measures.

Numbers of large buildings were relatively low across all of the study states, even in populous and economically vibrant areas, and even under the newly defined size strata. The study employed a census approach[16] for large buildings. This proved to be difficult if not impossible for final recruitment. The census approach required the data collection teams to find all large buildings, and to get 100% recruitment. This approach to defining sample size is not recommended for future studies.

Data sources for Determining Populations. In Florida and Illinois, estimated population sizes were based solely on 2016 data purchased from Dodge Data and Analytics[17]. In Nebraska and Iowa, the study team sought to determine population sizes based on direct requests to permitting jurisdictions, as well as from Dodge. Collecting data from jurisdictions was labor-intensive, with results hinging directly on the willingness of the jurisdictions to provide timely support. Despite some gaps, the data from jurisdictions appeared to be comparable to or more comprehensive than reflected in Dodge, yielding greater numbers and revealing considerably greater nuance about specific building types. While a formal cost comparison has not been conducted, it seems that for entities conducting similar efforts in the future, collection of population data from jurisdictions could be a more cost-effective option than purchasing Dodge data.

[16] Complete enumeration of the study objects, compared to sampling which is an enumeration of the subgroup of objects chosen for participation.
[17] https://www.construction.com/

Recruitment

Four primary recruitment methods were used with varying levels of success. This experience leads the project team to recommend building departments and walk-ups for future recruitment. An overview of success of each method is presented in Table 6.

Table 6. Success of Recruitment Methods

Method	Building Leads	Building Samples[18]	Conversion Rate (%)	Time spent (hrs)	Bldgs/Hr.
Bldg. Dept.	183	117	63.93	247	0.47
Owner/Dev.	36	8	22.22	80	0.10
Walk-up	119	94	78.99	20[19]	4.70
Networking	32	5	15.63	76	0.07

Building Department Leads. This method was most successful when directly accompanied by a building inspector, but produced some success with a direct introduction, eliminating a cold call. Obstacles to this method include a fair amount of coordination of schedules and was most fruitful when a group of five or more buildings could be visited with an inspector in a day. Unless the jurisdiction was very close, coordinating inspections one by one was unmanageable for travel. There is potential bias in this method, and the field team carefully drove the building selection to not allow the inspectors to select the buildings.

Owner/Developer Leads. This method developed a set of promising leads, but ultimately very few sample sites. This effort involved significant time conducting outreach and follow up, including many phone calls with unreturned messages. Calls were often redirected and when the right person was finally located, some refused participation for lack of interest or inability to devote any resources toward the effort. This method was abandoned by the project team halfway through data collection.

Walk-Ups. This effort had a relatively low time effort compared to others. This approach proved best in an area where there were multiple potential sites within short driving distance. A single building that is in a more remote location is not ideal because if turned down, the low time effort is negated by a long drive. This approach was most successful when a student data collector was present. The only drawback is that this approach restricts building plan review until after the site visit has been completed.[20]

High Level Networking. This approach developed a set of promising leads. In comparison to owner/developer cold-calling method of outreach, this method provides a direct introduction through a source that is familiar to the architect, owner, developer, or contractor and promotes broader awareness of the goals of the project. Connections through this method are easily strung

[18] Total does not represent full sample. 14 building samples were obtained from a concurrent study in Illinois.
[19] Does not include time traveling to sites.
[20] Review of plans can be time consuming and without a guarantee to get on site is not suggested before access is granted.

together to build a larger pipeline of potential samples. Like building owner outreach, this method still requires a fair amount of phone time.

Data Collection

Use of spreadsheet-based collection forms. The project team used a two-stage data collection approach, with field data reported on paper or electronic forms, and then measure conditions transferred by a senior staff member to the building lost savings workbook. The process might have been improved though development of a tablet app that received field data, interpreted it and delivered measure condition data; however, for more experienced field staff, such a system can actually slow field work. Data entry validation in the building lost savings workbook is one important addition for any further phase.

Use of Student Data Collectors. Partnership with the University of Nebraska at Lincoln initially provided five undergraduate students to assist with data collection and data recording. Undergraduate students required a fair amount of training to get to the level of understanding and consistency required for an accurate data set. After the first semester, three students remained interested in the study and completed work over the summer, dwindling to two in the fall, and one student remained with the study almost through completion.

The project team expected student data collectors to reduce the cost of the study. The students' primary challenge is their lack of familiarity with the energy code and building systems. Additional training time is needed for students on the energy code itself. For this reason, student data collectors are recommended for future studies only if they can continue for multiple semesters, so the amount of time spent training does not offset reduction in costs.

Conclusion and Acknowledgments

While there was a wide range of individual measure savings in buildings, the average annual building lost cost savings was at least $189 per thousand square feet or more than a present value of $2,868 per thousand square feet. Actual lost savings are higher, as only 68% of the applicable measures could be field verified due to site visit timing. It is also noted that some outlier buildings had very high present value lost savings, exceeding $20,000 per thousand square feet.

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References

Department of Energy Building Technologies Office. March 2010. *Measuring State Energy Code Compliance.* Prepared by Pacific Northwest National Laboratory.

Department of Energy Building Technologies Office. June 2013. *90% Compliance Studies Final Report.* DOE/EE-0929.

Department of Energy. February 2016. DE-FOA-0001532 Commercial Buildings and Energy Code Field Studies. https://eere-exchange.energy.gov/.

International Code Council. 2012. *2012 International Energy Conservation Code*. Washington, D.C. International Code Council.

Lavappa, P., J. Kneifel, and E. O'Rear. 2017. *Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis-2017: Annual Supplement to NIST Handbook 135*. https://www.nist.gov/publications/energy-price-indices-and-discount-factors-life-cycle-cost-analysis-150-2017.

Hart, R., M. Rosenberg, J. Zhang, and Y. Chen. February 2019. *Development of Lost Energy Cost Savings for Energy Code Compliance in Commercial Buildings.* PNNL-28503.

Jarnagin, R.E., and G.K. Bandyopadhyay. 2010. *Weighting Factors for the Commercial Building Prototypes Used in the Development of ANSI/ASHRAE/IESNA 90.1-2010*. PNNL-19116, Pacific Northwest National Laboratory, Richland, Washington.

Rosenberg, M., R. Hart, R. Athalye, J.Zhang, W. Wang, B. Liu. 2016. *An Approach to Assessing Potential Energy Cost Savings from Increased Energy Code Compliance in Commercial Buildings*. PNNL-24979. Richland, Washington: Pacific Northwest National Laboratory.

Zhang, J., R. Hart, and M. Rosenberg. 2016. "Energy Cost Impact of Non-Residential Energy Code Requirements." PNNL. http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24979.pdf.