Minnesota Commercial Energy Baseline and Market Characterization Study

Characteristics, Energy Code Compliance, and Beyond-Code Opportunities

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Definition of Terms and Acronyms

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

Building envelope: The elements of a building that separate conditioned spaces from the exterior.

COG: Center-of-glass, typically in the context of U-value.

COP, heat pump heating: Coefficient of performance, the ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system, including the compressor and, if applicable, auxiliary heat, under designated operating conditions.

Continuous insulation (c.i.): Insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings.

Deadband: The range of values within which a sensed variable can vary without initiating a change in the controlled process.

DCV: Demand control ventilation.

EER: Energy efficiency ratio, the ratio of net cooling capacity in British thermal units/hours to total rate of electric input in watts under designated operating conditions.

High-rise multifamily: Multifamily buildings four stories and above.

HSPF: Heating seasonal performance factor, the total heating output of a heat pump during its normal annual usage period for heating (in Btu) divided by the total electric energy input during the same period.

IECC: International Energy Conservation Code

KSF: thousands of square feet

LPD: Lighting power density, the maximum lighting power per unit area of a building classification of space function.

MEP: Mechanical, electrical and plumbing.

MBH: 1000 Btu per hour in terms of HVAC capacity.

Photosensor: A device that detects the presence of visible light, infrared (IR) transmission, and/or ultraviolet (UV) energy.

SEER: Seasonal energy efficiency ratio, the total cooling output of an air conditioner during normal annual usage period for cooling (Btu) divided by total electric energy input during same period (Wh).

SHGC: Solar heat gain coefficient, the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation.

Executive Summary

This report examines the characteristics and energy savings opportunities associated with new and majorly renovated commercial properties in Minnesota. The objectives of this study were to: 1) Characterize energy efficiency in MN for new and renovated buildings using a methodology that provides statewide statistically significant results; 2) Identify specific opportunities for increased energy savings through existing commercial energy codes; and 3) Identify specific opportunities for increased energy saving measures that go beyond existing commercial energy code requirements including, but not limited to, existing or new utility conservation improvement programs.

The study gathered data for 78 building projects using the 2015 Minnesota Commercial Energy Code, which was in effect from June 2015 to March 2020. The projects spanned four major building segment groups which included 1) high-rise multifamily, 2) office, 3) food service and retail, and 4) education and other (which encompasses public assembly, public order and religious facilities). We divided all segments except food service/retail into two size categories: small (less than 100,000 square feet of conditioned space) and large (greater than or equal to 100,000 square feet). We collected data in two forms: through a detailed plan review and through on-site verification. We applied regression models to calculate the lost energy and cost savings relative to energy code non-compliance based on a tool originally developed by the Pacific Northwest National Laboratory and modified for this study. The compliance rate and lost savings results were presented as population-weighted estimates. We also conducted secondary research on successful initiatives that support code compliance and beyond-code efforts in other states. These research efforts to understand current and future national energy code trends helped inform how our recommendations could support long-term energy code efforts in the state of Minnesota.

It is important to recognize that this study is not a building code compliance study in the sense of a building code official formally deciding whether the commercial building projects in the study complied with the building code or not. Rather, it is a study of lost energy savings relative to prescriptive energy code. The methodology used in this study was compiled and developed by the U.S. Department of Energy to research energy code compliance and builds upon a legacy of work and understanding of energy code compliance within the energy industry.

Key results from the study are as follows:

- All building segments demonstrated population weighted average compliance rates ranging from 69% to 84%. Small high-rise multifamily and both education/other building segments showed a statistically significantly higher level of energy code compliance when compared to others.

- The statewide potential for energy savings from complying with energy code elements that are not currently complied with is estimated to be approximately $10,345,500, with an electrical savings of 78,892,600 kWh and a natural gas savings of 3,298,800 therms.

- The statewide potential for beyond code energy savings from exceeding the requirements of the baseline energy code in high-rise multifamily, office, food service and retail building types is estimated to be approximately $6,381,800, with an electrical savings of 48,050,600 kWh and a natural gas savings of 2,128,000 therms.

- Envelope energy code elements had higher levels of code compliance and lower lost energy savings than mechanical, plumbing, electrical or lighting code elements.

- Mechanical energy code elements generally yielded the lowest compliance rates. Much of the non-compliance in this category comes from control and configuration elements, as opposed to equipment or hardware. HVAC control elements were likely to be not complied with when mechanical commissioning did not meet code.

- We found several code elements that commonly go beyond prescriptive energy code requirements, suggesting that in these instances, code may be lagging industry standards and/or market capacity. These include: mass wall insulation, interior and exterior lighting power, HVAC equipment efficiency, energy recovery type and effectiveness, gas domestic water heater efficiency, and gas space-heating boiler efficiency.

- Plan documentation has the potential to affect whether a building meets energy code because it is the primary method to convey to the construction team what is to be built. If an element is poorly documented in the plans and specifications, there is risk for confusion in how the building actually gets built. Energy code elements that are often found to be poorly documented include: mechanical and lighting commission plan and a number of controls such as thermostat setback and deadband, optimal start control and receptacle control.

- Energy code compliance path was not always documented clearly in the drawing set. In about a third of the study sample, we were able to confirm that the 2015 Minnesota Energy Code was specified but there was no indication of selecting IECC 2012 or ASHRAE 90.1-2010. In cases where IECC 2012 was specified, the majority did not further indicate an additional efficiency package option path under C406.

We summarize key opportunities and recommendations below for both reaching the full potential of the energy code and going beyond current energy code.

Key opportunities and strategies for reaching the full potential of the current energy code

Opportunities

- **Support for code officials:** Support the plan review and inspection process to improve energy code compliance and enforcement.
- **Support for design teams:** Provide guidance for design teams to improve understanding of energy code elements and documentation practices.

- **Support for controls documentation and commissioning:** Support improved documentation of mechanical and lighting control energy-code elements and improve commissioning efforts.

Recommendations

- **Offer menu of support options for code officials.** We recommend considering two methods of support: the circuit rider model which delivers energy code resources and on-call project technical support to code officials and the third-party energy code reviewer model which provides a la carte energy code review and/or inspection services.
- **Develop a shared set of energy code resources.** To help ensure that all parties responsible for code compliance and enforcement have access to the information they need, provide a shared set of energy code resources. These resources could be developed and shared as part of a circuit rider program in consultation with the Department of Labor and Industry and the Department of Commerce, with code officials and/or third-party energy code reviewers disseminating to project teams as needed. Resources include sample agendas for early design kick-off meetings, phase-specific checklists, energy code interpretation guidance for HVAC commissioning, and protocols for code officials to request additional documentation from project teams.
- **Leverage existing new construction programs.** Existing new construction programs implemented by Minnesota utilities offer an already-established touchpoint with design and construction teams that could be leveraged to provide energy code support and resources.

Key Opportunities and recommendations for going beyond the current energy code

Opportunities

- **Promote high-impact prescriptive strategies** to attain higher energy savings than current prescriptive baselines.
- **Promote energy modeling** to address non-regulated design decisions and help projects identify the most cost-effective strategies.
- **Address operational performance** to ensure promised energy savings are delivered and to capture additional savings from operational and behavioral strategies.

Recommendations

- **Expand prescriptive new construction programs**. We recommend expanding already existing programs to take advantage of the market-ready beyond-code energy efficiency strategies identified in the Results section of this report.
- **Conduct a market analysis of commercial building energy modeling in Minnesota**. A market analysis of energy modeling practices would identify the barriers to using performance-based energy code pathways.
- **Expand reach and function of performance-based new construction programs.** High beyond-code energy savings can be achieved through simulation-based new construction programs that include early design analysis of non-regulated elements, such as building massing, orientation, window placement, and HVAC system type.

- **Implement a voluntary whole-building pay-for-performance program.** Pay-for-performance programs reward project savings on an ongoing basis as they occur versus providing up-front payments to fund energy-efficiency strategies. Directed at new commercial construction projects, such a program can incentivize savings derived from operational energy use and inform the development of a future outcome-based energy code pathway.
- **Evaluate options for new energy code pathways within the recommended Codes and Standards program.** The roadmap that is currently being developed with funding from the Department of Commerce will identify pathways for utility Conservation Improvement Programs (CIP) to create a statewide energy codes and standards program. While that roadmap is not yet published, we recommend several options be evaluated including adopting more aggressive prescriptive and performance-based pathways, developing a step code for adoption by local jurisdictions, and develop a pilot outcome-based energy code pathway.

Introduction and Background

Building energy codes are an effective tool to improve building energy performance. However, building energy codes are only as effective as the rate of compliance with them. Minnesota has policy mechanisms in place to create utility energy efficiency programs to capture some of the lost savings in the code process, but the potential for additional savings has not been quantified with current energy codes and industry activity. It is important for a wide variety of audiences to understand energy savings opportunities relative to energy code in their territory.

In 2015, Minnesota adopted a new commercial building code with the energy portion based on IECC 2012 and ASHRAE Standard 90.1-2010.[1] These versions had the largest increase in stringency (by level of energy performance) compared to previous versions in the history of the Standards. An advancement of that magnitude makes compliance more challenging, so it is possible that more energy savings are left on the table in such a transition.

Minnesota has now recently adopted IECC 2018 and ASHRAE 90.1-2016 as their newest energy code in March 2020. And there will not only be further increases going forward, but some government and policy stakeholders are discussing the possibility of a step code for municipalities. Both understanding and dealing with code compliance has therefore become a critical issue in the state of Minnesota.

Some states have employed their utility energy efficiency program mechanisms to capture some of the lost savings in the code process, through code compliance programs that provide training, review, or design support. Minnesota has many of the policy mechanisms in place to create such a program, but the potential for additional savings has not been quantified with current codes and industry activity.

This study seeks to inform these efforts to maximize the impact of energy codes by collecting data on design and construction practices from a representative sample of new construction and major renovation projects through the state.

Study Objectives

The study was funded by the State's Conservation Applied Research and Development (CARD) Grant Program, which is intended help improve the effectiveness of utility energy conservation programs.

The objectives of this study were to:

1) Characterize energy efficiency in MN for new and renovated buildings using a methodology that provides statewide statistically significant results.
2) Identify specific opportunities for increased energy savings through existing commercial energy codes.

[1] Digital Codes Library provides the 2015 Minnesota Commercial Energy Code at this website: https://codes.iccsafe.org/content/MEC2015/2015-minnesota-commercial-energy-code

3) Identify specific opportunities for increased energy saving measures that go beyond existing commercial energy code requirements including, but not limited to, existing or new utility conservation improvement programs.

It is important to recognize that this study is not a building code compliance study in the sense of a building code official formally deciding whether the commercial building projects in the study complied with the building code or not. Rather, it is a study of lost energy savings relative to prescriptive energy code. The methodology used in this study was compiled and developed by the U.S. Department of Energy to research energy code compliance and builds upon a legacy of work and understanding of energy code compliance within the energy industry.

Review of Related Work

This study builds on and proceeds alongside a substantial body of research into energy code compliance and baseline characterizations. The US Department of Energy (DOE) has been providing code compliance research and resources for many years, but a significant body of research by both the DOE and individual states occurred following funding from the American Recovery and Reinvestment Act in 2009. Guidance resulting from this work can be found in the DOE's Building Energy Codes Program Resource Center (DOE 2020), including guidance for those enforcing codes and those conducting field research (such as this study). The design of this study was based on the framework set forth by DOE.

During that same period many states received funding to study compliance with energy codes within their borders. This included a number of states in the Midwest, Minnesota included. The Minnesota study addressed compliance with the Minnesota code at the time, which was ASHRAE Standard 90.1-2007 (Hernick and Sivigny 2013). The study found that code compliance for commercial buildings in Minnesota was over 90% for new construction, additions, and renovations. Code elements that demonstrated high percentages of compliance include integration of lighting controls, temperature controls on service hot water heaters, and use of energy-efficient exit signs. Areas for improving energy efficiency include providing adequate documentation related to proper heating and cooling equipment sizing, fenestration products and their testing for U-value, solar heat gain coefficient (SHGC), air leakage, and HVAC commissioning. For all building types, the study found that insufficient documentation was provided with permit applications to demonstrate energy code compliance. The study recommended additional education on building energy codes for building officials, design professionals, contractors and other groups.

In the years following, the DOE and partners, especially Pacific Northwest National Laboratory, published significant guidance on what all of these compliance studies in different areas meant for professionals that design to, construct to, enforce, or consult on energy codes (e.g. Rosenberg 2016a). They also began to develop improved methods for continually evaluating energy code compliance (Rosenberg 2016b).

The Minnesota Center for Energy and Environment implemented a pilot in 2014 (funded by the Department of Commerce) to test methods of improving commercial energy code compliance and accounting for the resulting energy impact (Landry, 2018). The study tested two programmatic interventions: 1) direct intervention with design teams and their process and 2) support of code reviewers in cities. The interventions focused on coaching and supporting both design teams and code reviewers on just the most impactful elements of the energy code to be as cost-effective as possible. They tested this method for a number of real commercial building projects against a set of control buildings and found that 70-87% of energy that was lost by not complying with code could be recovered with this type of intervention.

In 2016, the Institute for Market Transformation (IMT) received DOE funding to complete a broad field study of commercial code compliance to build on the lessons learned from the earlier round of code compliance work and create an efficient, established method for evaluating commercial energy code compliance. They piloted the new method by conducting field data collection in Florida, Nebraska, Iowa, and Nevada. Our study followed closely after this national effort and used that study as the default foundation for our methodology. Results from the IMT study are expected in a similar timeframe to this report (IMT 2020).

In the past few years, a new round of energy code compliance studies has been undertaken in a number of states and regions. Most closely to Minnesota, MEEA conducted a study of commercial code compliance in Illinois that is just completing.

Finally, the Department of Commerce has funded a project currently underway in Minnesota which will create a roadmap for utility Conservation Improvement Programs (CIP) to create a statewide energy codes and standards program. Such a program would include supporting designers, contractors, and code officials in their work to keep up with the newest codes. These CIPs would look to claim energy savings as a result of utility-funded support efforts. The results from this study will inform recommendations developed for a statewide codes and standards program.

Approach

The study characterizes energy code elements in the new construction and renovation market through detailed data collection of commercial projects that are under construction or newly constructed. The scope of this project includes four major building groupings: 1) high-rise multifamily, 2) office, 3) food service and retail, and 4) education, public assembly, public order, worship. We collected data on each of these building segments through a detailed design and/or construction document review as well as a site visit. We collected data to inform recommendations for capturing energy savings through supporting better compliance with code or encouraging projects to build to beyond-code levels.

Sampling Methods

This study's sampling frame is the Dodge Data and Analytics commercial construction start dataset, which is a fee-based online platform developed to provide services for building constructions firms looking for new projects. While it is not specifically created for research purposes, other code compliance and baseline studies have used the Dodge dataset for sampling and recruitment. The Dodge dataset includes most commercial projects throughout the state that are in planning, pre-design, design, construction, or recently completed. The set provides contact information for the entire building design and construction team, as well as other useful data points such as a building use type, projected building size, and location (although the level of information is variable based by project).

At the outset of the project, our intention was to use Dodge data of construction starts to both set the sampling targets and provide a basis for random sampling of projects and outreach. The methods were originally presented at a stakeholder meeting at the outset of the project and we solicited feedback from the 35 attendees. A smaller group of stakeholders provided feedback throughout the project in regard to specific questions raised by the project team. We describe the sampling methods and modifications we made below.

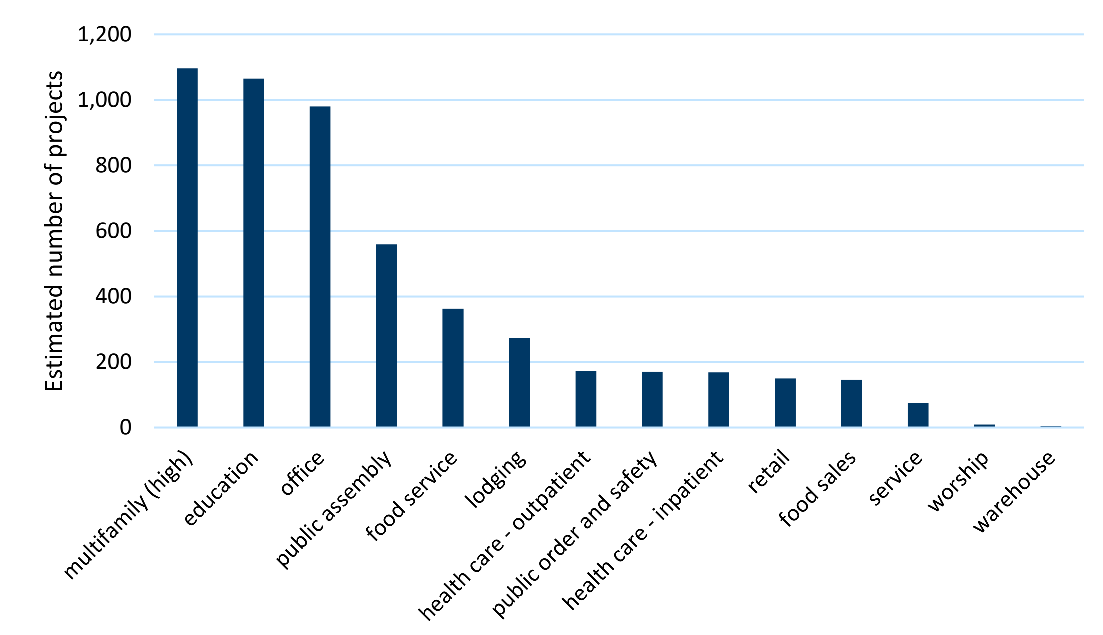
Development of Stratification Targets

To understand the recent construction trends in the commercial sector with the goals of defining subpopulation strata, we first downloaded four years of Dodge Data, including all commercial building types and all phases of construction and design. The dataset included all business types that would be included in the project; the first business segment listed is typically the predominant business activity in the building, although they do not list percentage breakdowns by activity. Linking the Dodge Data to the Commercial Building Energy Consumption Survey (CBECS[2]) average energy use intensities by principal building activity, we ranked business types in order of their overall frequencies in the data, weighted by energy use intensity. This allowed us to identify business types that have the most energy impact

[2] The Commercial Buildings Energy Consumption Survey (CBECS) is a national sample survey that collects information on the stock of U.S. commercial buildings, including their energy-related building characteristics and energy usage data (consumption and expenditures)

statewide. As shown in Figure 1, high-rise multifamily, education, and office buildings are most frequently represented in the data, when energy intensity is taken into consideration. While difficult to prove, we believe that retail projects are slightly underrepresented in the Dodge dataset because retail spaces may not comprise the predominant building activity of a building project (e.g. a large high-rise multifamily structure with retail on the first floor) and therefore would not appear as the first business segment listed in the data.

Figure 1: Estimated number of projects weighted by energy intensity (4 years of Dodge Data)



Using this information and also referencing a similar baseline study currently being conducted by the Department of Energy, we developed a list of four building segments upon which we stratified our sample:

- Office
- High-rise multifamily
- Food service and retail
- Education, public assembly, public order, worship (referred to as “Education/other”)

Office and high-rise multifamily stand alone as individual stratum. We grouped retail with food service because energy code elements tend to be designed and constructed very similarly in these two segments and are expected to be transferable in our analysis. We also included some other impact segments with education, primarily those that are institutional or involve dense gatherings of occupants, because of similarities in ways building codes are applied to these business types; this allowed us to capture additional buildings in our sample.

To ensure that building size is accurately represented in our sample, we also split some building segments into size stratifications. For office building projects, the Dodge data suggests that nearly 80%

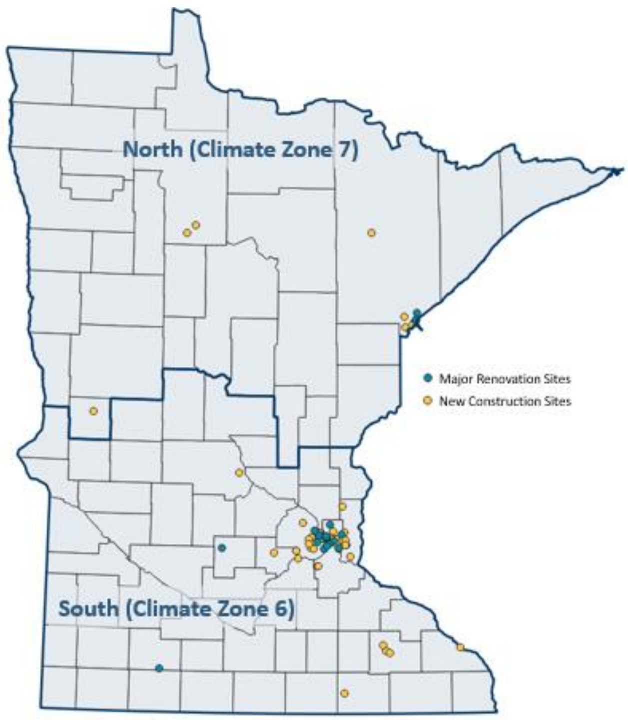
of buildings are less than 100,000 square feet. The situation is in reverse for high-rise multifamily, where nearly 70% of buildings are over 100,000 square feet. For these two building types, we set a sampling target for both small and larger buildings to ensure our results represent the two building size categories. Conversely, for food service/retail nearly all of the buildings in the Dodge dataset appeared to be less than 100,000 square feet; unless we oversampled the largest of buildings, the number of buildings in the largest size category would be so low that data integrity issues would arise. For education/other, we originally did not assign a sampling target based on size, but as described in further detail below, we divided the sampled buildings into small and large categories based on the number of buildings we ultimately sampled. Table 1 shows the resulting building segments with their original sampling target, final sampled counts and average building area.

Table 1: Original sampling target, final sampled counts and average building area by building segment

Building segments	Size category	Original sampling target	Final sampled projects	Mean building area (SF)
High-rise multifamily	Small (<100,000 SF)	7	7	68,675
	Large (≥100,000 SF)	15	12	138,345
Office	Small (<100,000 SF)	15	17	21,583
	Large (≥100,000 SF)	5	1	264,275
Food service and retail	n/a	22	6	11,936
Education, public assembly, public order, worship	Small (<100,000 SF)	26	27	38,536
	Large (≥100,000 SF)		8	155,373

The map in Figure 2 provides a geospatial illustration of the projects in our final sample. This map shows both the relationship of sampled projects to climate zone and distinguishes new construction from major renovation.

Figure 2: Map of projects in sample, by climate zone and construction scope



While we did not specifically ask about in which service territory a project is located, we were able to use available data on service territory to identify the breakdown of our sample into electric and natural gas service territories. The electric utilities are listed in alphabetical order and illustrates the large portion of our sample in the Xcel service territory (Table 2).

Table 2: Number of projects in Minnesota electric utility territory

Electric utility	Number of projects in sample
Austin	1
Beltrami Electric Cooperative	2
Connexus Energy	1
Dakota Electric Association	2
Elbow Lake	1
Hutchinson	1
Minnesota Power - Allete	7
Mountain Iron	1
North St. Paul	1
Proctor	1
Rochester	3
Shakopee	1
Windom	1
Xcel Energy	55

For natural gas utilities, the service territory boundaries are not as clear. Several projects could fall in one of two service territories and in those cases, both options are listed in Table 3. Additionally, there were two projects for which we could not identify a gas utility, one of which was an all-electric building.

Table 3: Number of projects in Minnesota natural gas utility territory

Natural gas utility	Number of projects in sample
Austin Utilities	1
CenterPoint Energy	30
City of Duluth/MERC	6
Hutchinson Utilities	1
MERC	8
Xcel Energy	24
Xcel/CenterPoint	6
Unknown	2

Additional Sampling Targets

While we could not add further stratification without adversely affecting the precision of our results, we took into consideration two other variables in developing our sampling plan: project scope (e.g. major renovation versus new construction) and climate zones. The study's original completion targets and final number of projects in sample are shown in Table 4, with more description below.

Table 4: Proposed quota groups for renovations and climate zones

	Completion targets	Final number of projects in sample
Major renovation	30	20
Climate Zone 7	10	12

Major Renovations

Buildings that undergo major renovations are required to meet the same building energy codes as new construction. For purposes of this study and applying feedback received after our initial kick-off meeting, we defined major renovation as building projects that modify two out of the three major systems: HVAC, envelope, and lighting and electrical. From our initial review of the Dodge dataset, we found that just under half of the buildings were renovation or alteration projects. However, without a clear description of Dodge Data's classifications, we suspected the dataset included renovation projects that would not meet our definition of major renovation. As such, we set our original sampling target at approximately a third of the total buildings in our sample. In our recruitment and outreach process, we included targeted questions to identify whether each building meets the criteria.

Climate Zones

The state of Minnesota is split between two climate zones as defined by the IECC and Association of Space Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). Certain energy code element requirements vary based on climate zone. To capture some of the differences between climate zones, we proposed a target completion of 10 buildings for climate zone 7, based on Dodge Data that showed approximately 11% of the buildings are located in that zone. Similar to the major renovation target, the climate zone target was not meant for stratification purposes, but rather to ensure we worked to attain projects in climate zone 7. Ultimately, we recruited 12 projects in climate zone 7 for our sample.

Enforcement Zones

While the energy code applies statewide in Minnesota, local jurisdictions of counties, cities, or townships must formally adopt and choose to enforce it. Even if a jurisdiction is in an enforcement zone, it does not necessarily mean that all aspects of the code are reviewed and enforced by code officials, but rather that there is a mechanism to do so. Currently, enforcements zones occur for approximately 80 percent of the population basis (DOE 2020), although as our research suggests, enforcement zones may be located where the commercial new construction market is strongest. During our initial analysis, we merged the Dodge data with the list of enforcement counties and cities. We found that only 5% of the Dodge projects were located in non-enforcement zones. Given that low estimate for potential buildings in non-enforcements zones, we chose not to set a target for recruiting buildings in those areas, but rather we tracked whether a building was in an enforcement zone or not. Ultimately, only two projects in our project sample were located in non-enforcement zones.

Recruitment Protocol

To recruit buildings into the project, we initially randomly sampled a set of Dodge Data that included the project types identified in our sampling plan. The recruiter reached out to project contacts as listed in the Dodge dataset through email, phone calls, or both. The recruitment protocol included a total number of attempts to be made to each project contact.

In developing our recruitment protocol, we learned that other new construction baseline projects encountered roadblocks in recruitment and difficulties meeting quotas when using random samples. We found similar challenges in our recruitment process. We found that design and construction firms were more likely to participate if they knew the person making the initial request for participation. Recruiting efforts were the least successful when cold calling design and construction firms. This was due to firms being hesitant to share information that they thought proprietary and confidential. Additionally, we found that some buildings in the sampling dataset were out of scope, misaligned in timing of construction, or simply not willing to participate in the study. Other buildings had non-responsive contacts. As a result, reaching out to a random sample of sites from that dataset turned out to be largely unsuccessful. When we realized that this approach would not allow us to meet project targets, we turned to other methods for recruitment.

Our modifications to our recruitment approach included an increased reliance on existing industry networks. Using the Dodge dataset as a starting point, our recruiting team targeted design and construction teams that were known by the project team to work on Minnesota projects. As we reached out to architects and general contractors, we used a recruiting tracker to ensure that participating projects met the intent of our sampling targets and represented a range of design and construction teams to reduce any bias that may be introduced through the construction or design practices of any one firm. To ensure that the firms and project teams who agreed to participate were committed, site visits for on-site verification were scheduled well in advance.

Data Collection

The data collection process consisted of two parts, plan review and on-site verification. Leveraging the experience of other recent studies from around the country, we used protocols and processes implemented elsewhere and adapted them to our study framework. For example, the Cadmus group originally developed data collection protocols and detailed instructions for plan review and on-site verification. Our project team modified these protocols to apply specifically to this study, including updates to the energy code elements applicable to the surveyed building types and climate zones. In addition to specific protocols detailing the plan review process, we also developed checklists specific to code elements on controls and commissioning to facilitate on-site verification.

We created a custom tablet-based form using a tool called iAuditor[3] which prompts the user to capture key energy code elements and organizes the data and photos collected. The tool helped field staff collect data for both the plan review and on-site verification.

Compliance Paths for 2015 Minnesota Energy Code

IECC 2012 and ASHRAE Standard 90.1-2010 are the two primary energy code compliance paths that can be used to comply with the 2015 Minnesota Energy Code, each with both a performance and a prescriptive path. This yields four possible paths for any building:

1. IECC 2012 prescriptive path, plus one of three additional efficiency packages specified in C406[4]
2. IECC 2012 performance path under C407 Total Building Performance (using energy modeling)
3. ASHRAE 90.1-2010 prescriptive path (includes envelope trade-off path)
4. ASHRAE 90.1-2010 Energy Cost Budget performance path (using energy modeling)

IECC 2012 and ASHRAE 90.1-2010 have different requirements on certain code elements; for this reason, it is important to have clear documentation of energy code compliance path. Significant differences also lie in the choice of prescriptive path and performance path as it effects the way code elements are

[3] iAuditor is an inspection application produced by SafetyCulture and is typically used for building or site inspections. https://safetyculture.com/iauditor/

[4] Section C406 under IECC 2012 prescribes additional efficiency package options including efficient HVAC performance, efficient lighting system, and on-site supply of renewable energy.

evaluated. The 2015 Minnesota Commercial Energy Code was in effect from June 2015 to March 2020 and was the applicable code to the new construction and major renovation buildings in the study.

For each site we sought to determine the compliance path to which a project was designed, however this was not always clear from the design documentation. Table 5 provides an overview of this study sample's documentation of energy code path. Over half of the projects documented the compliance path, although with some ambiguity. Thirty-six buildings included the option path selection. Nine buildings had documented IECC 2012 prescriptive as the code compliance path in drawings or other design documentation but did not specify the C406 path option chosen. For buildings where we were able to connect and inquire with project teams, they were unaware of the additional option path requirement in IECC. We assumed the Reduced Lighting Power option path, as it is most common and easiest option to comply with, thus favored by most project teams. The second most common option is the Efficient HVAC Performance option path; the On-site Renewable Energy option path is rarely chosen by project teams. Note that the difference in chosen option paths do not affect the lost savings or compliance rate calculations in this study, since interior lighting power and HVAC equipment efficiency are two elements for which almost all projects meet or exceed code.

Table 5: Energy code compliance path documentation

Energy code compliance path documentation	Number of Projects
Documented in plans, including prescriptive vs. performance and C406 option path (if applicable)	36
Documented in plans as IECC 2012, but C406 option path not specified	9
Not documented in plans, but able to confirm with project team	7
Not documented in plans, not able to confirm with project team	26

Just under half of the study sample did not document energy code compliance path in drawings or other design documentation. In many instances, 2015 Minnesota Energy Code was noted on drawings but there was no clear indication of path chosen. For 7 projects, we were able to connect directly with the project team to confirm the ASHRAE or IECC prescriptive compliance path. In cases where IECC was confirmed, assumptions still had to be made on the additional efficiency package option under Section C406 (we assumed Reduced Lighting Power Path). Many project teams seem to be not fully aware or clear of how this requirement works in IECC.

For 26 of the buildings, there was no final determination of path. In talking with design firms in Minneapolis, we have anecdotal evidence that project teams prefer to use the ASHRAE 90.1-2010 prescriptive compliance path due to Minnesota's long history with this Standard. For the projects where we were able to confirm compliance path, over 75% specified ASHRAE 90.1-2010 prescriptive. Based on this information, for projects where there was a lack of documentation on code compliance path, we assumed ASHRAE 90.1-2010 prescriptive path for our analysis. The energy implications between choosing ASHRAE or IECC as compliance path can be different for some code elements where requirements are different. For some elements such as roof insulation and window-to-wall ratio, IECC is more stringent. For other elements such as fenestration orientation, VAV ventilation optimization, exterior lighting control and receptacle control there are additional requirements in ASHRAE but not in IECC. Due to these energy implication differences between the two code pathways, our results may be overestimating lost savings for these ASHRAE-specific code elements on the projects that were assumed to be following ASHRAE 90.1-2010 prescriptive, and underestimating impact of code elements where IECC is more stringent.

Note that we did not find confirmation of a single project that chose the performance path. This fits the anecdotal evidence that performance path is rarely used in Minnesota and supports the assumption of prescriptive path compliance for the buildings for which we could not obtain confirmation. In total, we counted 63 projects that followed ASHRAE 90.1-2010 path and 15 projects that followed IECC 2012 compliance path, including both confirmed and assumed cases.

Plan Review

We conducted a detailed review of all available design documents that we could obtain from the project team, including architectural, mechanical, electrical and plumbing drawings, COM*check*[5] compliance documents, equipment submittals, and supplemental reports. The drawings that were available to us were primarily as-built construction drawings, although a few were permit drawings or bid drawings. For some buildings, we were unable to obtain the complete set of design documents. For example, in less than a dozen buildings, we were not able to obtain mechanical, electrical and plumbing (MEP) drawings, which in most cases were design-build projects. As a result, we could not confirm energy code elements pertaining to MEP aspects. In a few projects, we received the drawings but not the specifications document, which hindered the confirmation of code elements that typically show up in specifications duct and pipe insulation, HVAC and lighting control sequences, such glazing specifications, thermal insulation types, etc.

Where applicable, we conducted supplemental calculations to confirm compliance, including interior and exterior lighting power calculations, envelope area takeoffs, and fan power calculations. Weighted average calculations were applied to select code elements; for example, HVAC efficiency-weighted averages may be a simpler way of inputting data than inserting multiple pieces of various-sized equipment for a building. In areas where the design documents lacked sufficient details, the reviewers exercised engineering judgment based on information that was available. For example, while the window assembly U-value was generally not documented in drawings, in some cases the center-of-glass (COG) U-value and frame type was indicated in specifications. In those cases, the project team was able to derive the assembly U-value based on weighted average calculations using COG and frame insulation values.

[5] COM*check* is a software tool developed by the Department of Energy Building Energy Codes Program that is used to demonstrate energy code compliance with IECC, ASHRAE Standard 90.1, or state-specific codes.

In all cases, the level of documentation details available to us was carefully considered in how we viewed compliance and whether to even include a data point in the results. The outcomes of these choices are thoroughly discussed in *Plan Documentation and Compliance with Energy Codes*.

On-site Verification

We conducted on-site verification through a detailed walk-through of the building, examining aspects of the envelope, mechanical, electrical, and plumbing construction that are regulated by the energy code. As shown in Table 6, our site visits were distributed over different stages of construction, which provided us with a spectrum of code elements that we could observe. However, due to the timing of the site visits, not all energy code elements were observable for every site. For example, envelope insulation was not observable after the walls and roof were sealed. Lighting controls were not observable when equipment had not yet been wired in. In some cases where certain controls or procedures had not been implemented at the time of the site visit, we were able to get verbal confirmation from the facility managers or on-site contacts who already knew what was being planned. For example, mechanical commissioning was confirmed verbally with on-site engineers that a plan was in place and commissioning was scheduled. The goal was not to try to capture every site visit at the perfect time, but rather to observe each individual code element in enough total sites.

Table 6: Construction stage of surveyed buildings

Construction stage	Count of buildings
Less than 50% complete	19
50-75% complete	12
76-95% complete	20
100% complete or occupied	27

Classification of Energy Code Element Observation Level

From the outset of the project and based on our understanding of similar studies, we wanted to not only understand the energy code elements that new and renovated buildings were complying with but also the level of documentation provided by design and construction teams. This quality of documentation has implications in both the ability of the building team to communicate effectively through building plans as well as the ability of code officials to enforce the code. For these reasons, we included a question in our data collection protocols seeking to identify whether each code element was observable on drawings as well as the site visit. In many cases, the lack of documentation on drawings is considered not meeting prescriptive code.

In the plan review process, a code element – whether in compliance or not – would be marked as observed only when the plan reviewer saw it listed clearly in the drawings. For code elements that we generally understood to comply based on common engineering practice and other secondary indicators, we would categorize that code element as assumed to comply with code. For example, supply air temperature reset has shown high compliance ratings (Gunasingh 2019), demonstrating that design teams are familiar with the requirements of this code element. This element is typically shown in the HVAC Sequence of Operations document, which may not always be included in the drawing and specifications our team obtained. Similarly, we categorized those elements not observed directly on the drawings but understood to be less typically complied with as absent. Table 7 provides an overview of plan review observation indicators.

Table 7: Plan review observation level

Data collection input	Indication
Observed	Observed on drawings or other design documents as either in compliance or not in compliance
Assumed	Absent from the design documents we had access to, but assumed compliant based on combination of secondary indicators and common engineering and design practice
Absent	Absent from the design document it is expected on, assumed non-compliant based on common engineering and design practice

As noted in the section above, our field staff tried to verify the condition as expected from the plan review during their site visits, even though the timing of the site visit did not necessarily align with all code elements being available for confirmation. Where it was not possible to verify with certainty that a code element was being met, we categorized that element as either being inferred or unknown. If we categorized a code element as inferred, we may have seen documentation on plans but not observed directly in the field, or we may have inferred compliance based on a secondary indicator or our understanding of both common practice and indirect evidence. The code elements that were neither observed on plans nor on site, and without typical industry conditions or data collected to infer a common condition from, were categorized as unknown. Table 8 provides an overview of site visit observation indicators.

Table 8: Site visit observation level

Data collection input	Indication
Observed	Condition verified through observation or with evidence such as photos during construction; could mean verified to either comply or not comply
Inferred	a) On the plans or photographs, but not directly observed in the field; surrounding building elements built as designed or b) not shown on plans, not observed on site due to timing of site visit, but able to infer a specific condition based on combination of secondary indicators and common engineering and design practice
Unknown	Not shown on plans, not observed on site, unable to infer a condition due to a lack of data collected for this element

Analysis

All data, whether collected through the plan review or on-site verification process, was input into a spreadsheet tool that served as the analytical engine for this work. This spreadsheet was originally developed by the Pacific Northwest National Laboratory (PNNL) and was updated by the project team to adjust to the project's building types and Minnesota's climate zones. This spreadsheet calculates the lost energy and cost savings from non-compliance based on regression analysis models. The spreadsheet regression models were developed by PNNL to calculate energy savings between baseline and proposed conditions for each code element, based on prototype energy modeling data. We also added regression analysis for a few additional code elements that we suspected of having high potential lost savings in Minnesota based on industry common practices and related studies in other states.

For all adjustments and additions to the spreadsheet, we conducted DOE2-based whole building energy simulation in eQuest[6] using our own prototypical Minnesota building models based on building data collected in our study sample. Below we provide additional detail on the prototype modeling and the protocols for both plan review and on-site verification.

The spreadsheet model calculates lost savings accurately only if the project is following a prescriptive compliance path. Of the 78 buildings in our sample, we did not find any confirmed to be following the performance path. As such, we assumed that all the buildings followed a prescriptive compliance path and we completed the spreadsheet model for each of the 78 buildings. For the few projects that demonstrated envelope compliance through COMcheck, we assumed they had followed the envelope trade-off path in ASHRAE 90.1-2010, and did not count lost savings if certain envelope elements did not meet code, assuming envelope trade-offs were used.

We extrapolated the lost savings from the spreadsheet model outputs to statewide commercial construction start data for the building types in our sample. Each building segment was assigned a population weight based on square feet from the Dodge Data population frame that was limited to approximately one year of commercial construction starts (2018). We used square feet instead of counts of building category because commercial buildings vary considerably in terms of size, and many code elements have energy impacts that vary based on size. Where Dodge Data did not have square feet of a project available, we estimate a building size based on a regression of building type and listed project value. To estimate construction data for one year, we limited the number of projects to those that either listed an estimated construction start date in 2018 or those projects that were published in 2017 when a start date was not listed. Table 9 shows the building square feet estimates that were used as the basis for this study's extrapolation.

[6] eQuest is a DOE-2 engine based, whole building energy performance simulation software developed by James J. Hirsch. It can be used to perform detailed analysis of building design technologies. http://www.doe2.com/equest/

Table 9: Dodge Data statewide building square feet estimates from 2018 construction starts by building category

Building segment	Estimated statewide building square feet for 2018
Small high-rise multifamily (<100,000 SF)	3,360,000
Large high-rise multifamily (>=100,000 SF)	8,260,000
Small office (<100,000 SF)	3,220,000
Large office (>=100,000 SF)	23,670,000
FS/retail - any size	4,060,000
Small educ/other (<100,000 SF)	11,040,000
Large educ/other (>=100,000 SF)	2,990,000
Total	56,600,000

Margins of error (confidence intervals) are reported for certain results and we highlight cases where there is a statistically significant difference between building segments. These reflect uncertainty from variation across the study sample: they do not account for potential recruitment bias, modeling error or other non-random factors that could affect the accuracy and ability to generalize the results from the study sample to the larger population of commercial construction market. All error margins and significance tests are at a 90 percent confidence level. This means that in theory, if we repeated the study 100 times with different samples, the confidence intervals for 90 of the 100 sets of results would contain the correct population average.

Prototype Modeling

Prototype energy models were created in eQuest for high-rise multifamily, office and food service/retail building types to serve as the database for the regression analysis. For education/other building segment, we determined that its operation and systems types were very similar to an office building and as such, applied the results from the office prototype.

We based the prototype models' input assumptions on project data trends found in our study sample, including building size, schedules, HVAC system type and internal loads. As the lost energy and cost savings are calculated from regression analyses that are set up based on the prototype modeling, the savings are dependent on the input assumptions of the prototype models. The baseline conditions matched Minnesota 2015 Energy Code minimum requirements (via ASHRAE prescriptive path), and the proposed conditions were kept consistent with PNNL's inputs for proposed performance.

HVAC system type, especially the choice of heating fuel source, strongly impacts the electricity and natural gas savings results, and we determined the most prevalent system type from our study sample to apply to the model. The major heating fuel source for buildings in our study sample is natural gas, with around 15% electrically heated (either with heat pump or electric resistance heat). Office and education/other segments include a high percentage of larger buildings with detailed space zoning, thus are mostly variable air volume systems with terminal box reheat in each zone. High-rise multifamily typically includes split or packaged systems for each dwelling unit and packaged constant volume systems for common areas. Food service/retail segment typically uses packaged constant volume systems.

We conducted whole building parametric energy modeling for each energy code element to account for building type and climate zone adjustment, and to incorporate additional code elements that were not originally included. Some of the most important modeling assumptions are listed in Table 10.

Table 10: Prototype model input assumptions

Building type	Conditioned area (square feet)	Number of stories	Window-to-wall ratio	HVAC system type
High-rise multifamily	80,000	6	29%	1) Split System Air Conditioner with Gas Furnace 2) Split System Heat Pump
Office	50,000	3	31%	1) Packaged VAV with Hydronic Reheat 2) Packaged VAV with Electric Resistance Reheat 3) Packaged Rooftop with DX Cool and Gas Heat
Food service/ retail	25,000	1	11%	Split System Air Conditioner with Gas Furnace

Opportunities and Recommendations

The final major task of the project was to identify program (and in some cases, policy) opportunities to either improve energy code compliance or improve performance beyond code. We based these conclusions on the quantitative and qualitative results and lessons learned from our primary data collection and subsequent analysis.

We also conducted secondary research on successful initiatives that support code compliance and beyond-code efforts in other states. We gathered input from local professionals involved in code-related efforts to help frame existing challenges and develop potential opportunities. These research efforts to understand current and future national energy code trends helped inform how our recommendations could support long-term energy code efforts in the state of Minnesota.

Results

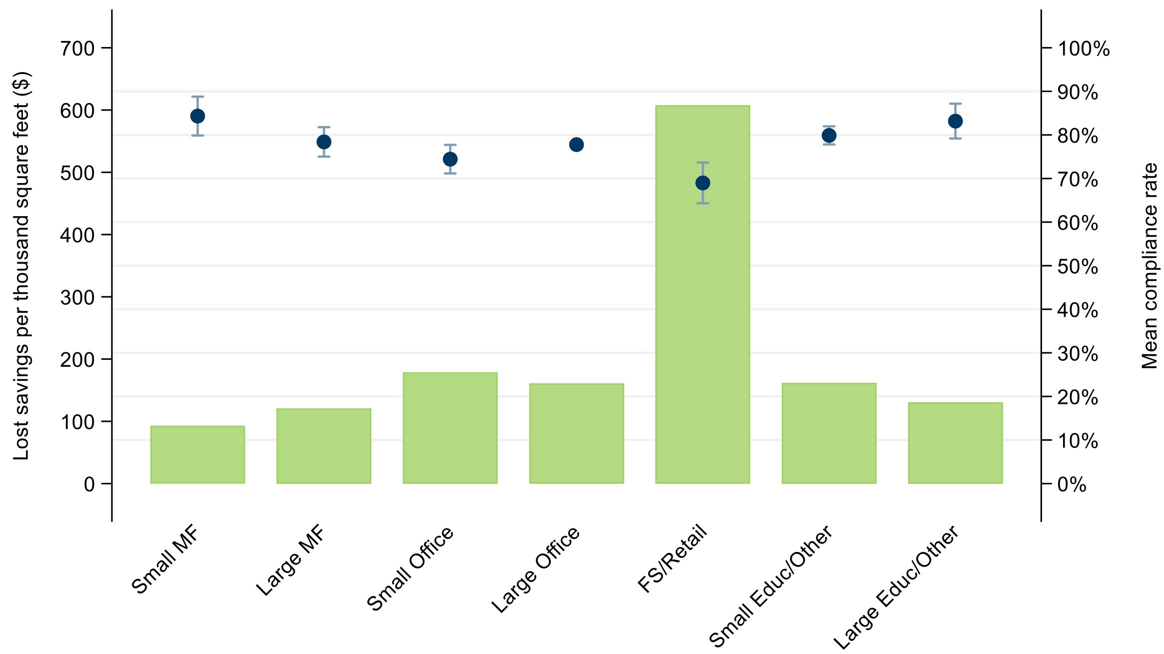
In total, we reviewed plans and visited the building construction site for 78 projects. Below we provide the results of this study in several sections. After providing summary statistics on the projects in our sample, we summarize the as-built energy compliance relative to prescriptive code and the energy savings that could be gained if a project were to be built to energy code. We further expand on the code elements by major end use that we found to have the greatest lost savings potential. We then explore the relationship of code elements that are well- or poorly-documented and compliance of those code elements. Finally, we present the results of our analysis that quantifies the estimated potential savings if all buildings were built to the best-case condition found in our sample.

As-Built Energy Compliance Relative to Prescriptive Code

We present the results of this research in several ways. For each energy code element, we calculated to what extent each project was designed and built according to prescriptive code and quantified the associated lost savings. The envelope insulation elements for two projects were an exception, we found that they used the Envelope Trade-Off option path in compliance with ASHRAE 90.1-2010 through COM*check* documentation, hence we did not count lost savings for the few below-code wall insulation elements as the overall envelope system passed code minimum requirements. We present overall compliance rate by building type using a weighted average of each code element. For example, if a building design included two types of cooling equipment, one of which met prescriptive code and one that did not, that code element's compliance value was weighted based on total tons of cooling between the two pieces of equipment. While we report our results as a percentage compliance rate, we recognize that raw compliance rates are of limited usefulness because it treats all code elements as equal. For this reason, we also present results in terms of lost savings for electricity, natural gas, and energy costs. We also present this comparison normalized to building size.

Figure 3 illustrates the results of both the compliance rates and the lost savings normalized to building size. We see that all building segments demonstrated average compliance rates exceeding 65%. Small high-rise multifamily and both small and large education/other building segments showed a statistically significantly higher level of energy code compliance when compared to others. We found that design documents that were available to us were more complete for these building segments, compared to Food Service/Retail and Office, which may be contributing to the higher compliance rate. Additionally, since multifamily buildings operate 24/7, code elements including thermostat setbacks and exterior lighting control are not applicable, whereas these code elements commonly showed low compliance rates in other building types.

Figure 3: Mean compliance rate and average lost savings per thousand square feet by building segment and end use (weighted population estimates)



Vertical lines are 90% sampling error margins
Large office does not have error bars because it is a sample of one

The food service/retail segment has a lower level of compliance and higher level of lost savings than other segments; this may be partially due to the unique characteristics of the buildings in our sample. In addition to challenges of low recruitment for food service/retail projects (with only 6 projects in our sample), we also found that the projects in our study had unique choices for building design that affect energy code elements for which we would have expected higher compliance rates. These code elements include night fan control, single zone variable air volume (VAV) and automatic time switch control, all of which have high energy implications when not complied with. Due to these uniquely non-compliant elements, the extrapolated lost savings may be an overestimate that does not fully represent the typical conditions of the food service/retail segment in Minnesota.

To look more closely at the breakdown of lost savings by building segment, in Table 11 we provide additional detail on expected electricity and natural gas lost savings with values that are population-weighted to represent Minnesota's volume of commercial new construction. We again note that the large office segment only included one project and the results should be considered with that in mind.

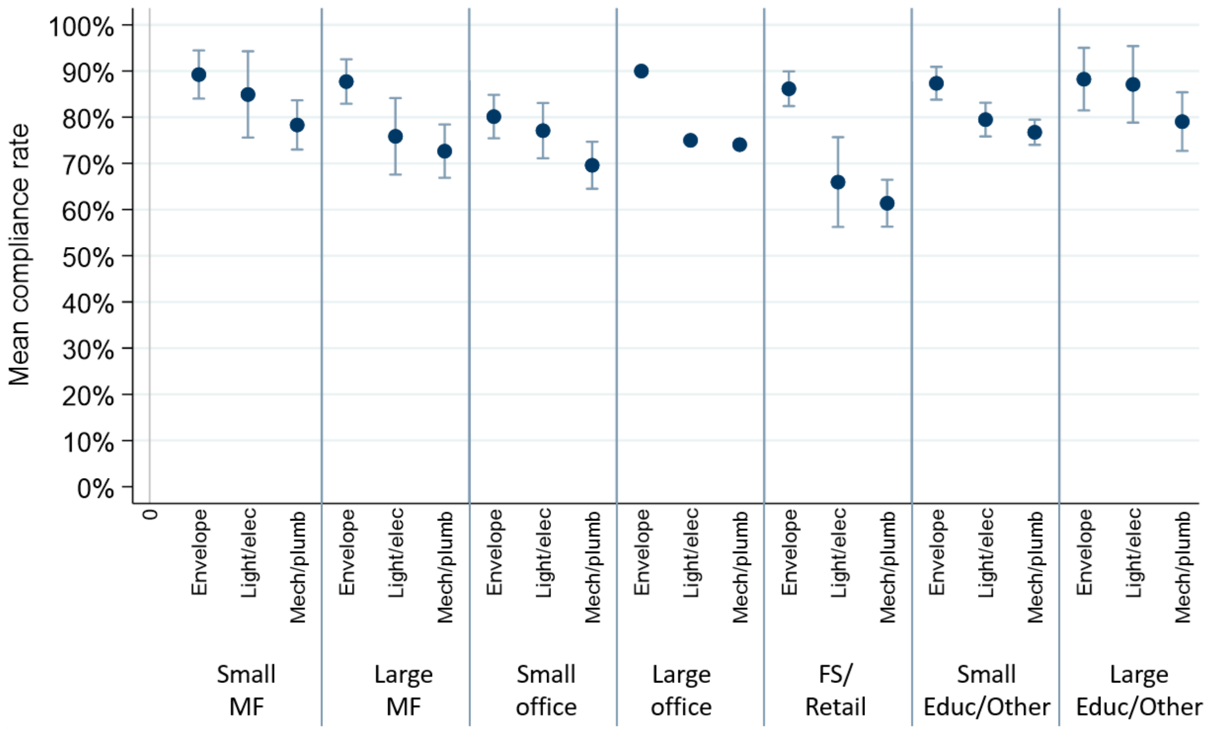
Table 11: Lost savings by building segment (weighted population estimates)

Building segment	Lost savings - kWh	Lost savings - therms	Lost savings - $ annual	Average annual lost savings per KSF ($)
Small high-rise multifamily (<100,000 SF)	2,847,500	30,000	$312,800	$17
Large high-rise multifamily (>=100,000 SF)	8,510,600	180,400	$996,700	$15
Small office (<100,000 SF)	4,111,000	226,000	$575,900	$28
Large office (>=100,000 SF)*	33,384,100	567,700	$3,814,600	$39
FS/retail - any size	20,891,700	476,800	$2,469,800	$67
Small educ/other (<100,000 SF)	7,648,800	1,470,400	$1,785,400	$19
Large educ/other (>=100,000 SF)	1,498,900	347,500	$390,300	$16
Total	78,892,600	3,298,800	$10,345,500	n/a

*Note: this building segment comprised of one project and is extrapolated using the population mean rather than the segment mean.

We break down our results further to understand the variations between energy code elements by their end use (Figure 4). We see that envelope code elements tend to be complied with more often than mechanical/plumbing and lighting/electrical, although the error bars suggest that for some building segments the differences are not statistically significant. With regards to envelope insulation, it appears that design teams specify at least code minimum insulation levels for wall and roof assemblies or adopt the envelope trade-off option path and ensure the whole envelope assembly meets code. Mechanical code elements generally yielded the lowest compliance rates. Much of the non-compliance in this category comes from control and configuration elements, as opposed to equipment or hardware. Control code elements tend to be more complex in nature and are more prone to programming error. There is not an industry standard on drawing documentation, thus in cases where documentation was not adequate, many control elements were then left to operate at default settings or based on the previous experience of the controls' contractor. We provide additional discussion on these code elements further in the report.

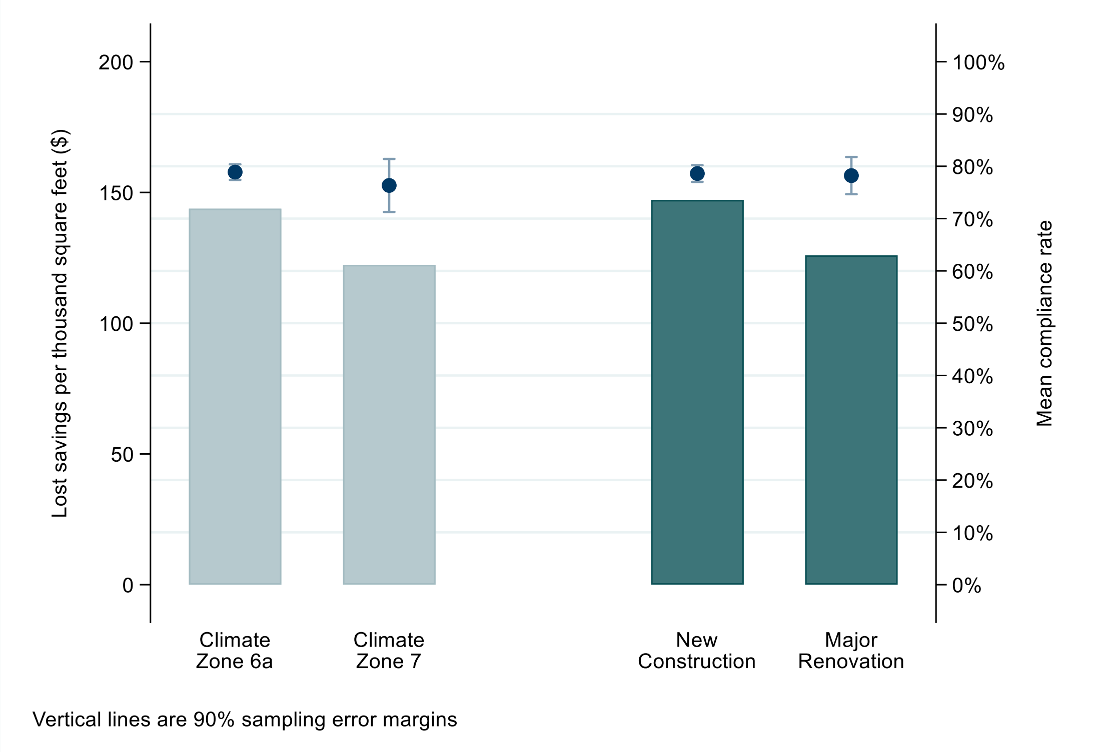
Figure 4: Mean compliance rate by building segment and end use (populated weighted estimates)



Vertical lines are 90% sampling error margins
Large office does not have error bars because it is a sample of one

We also show results comparing average compliance rate and normalized lost savings broken out by construction scope and by climate zone (Figure 5). Neither the climate zone nor the construction scope shows significantly different compliance rates, although the low numbers in our sample for climate zone 7 (n=12) and major renovation projects (n=20) may be contributing to the lack of statistical significance. We do see fewer lost savings per thousand square feet in climate zone 7 which in addition to weather differences, may also be attributable to a difference in building types and/or HVAC types in the study sample and associated differences in the energy code elements that are applicable to the project. Similarly, we see slightly higher normalized lost savings for major renovation, which may be driven by not only building type and HVAC type but also the project scope of work of the new construction projects.

Figure 5: Mean compliance rate and average lost savings per KSF by climate zone and construction scope (population weighted estimates)



In Figure 6, we provide a list of top lost savings energy code elements by building segment. Some code elements such as mechanical commissioning and thermostat deadband appear to be consistently non-compliant across building types, while others are more specific to each building type and predominant HVAC system type. For high-rise multifamily, window properties had a larger overall energy impact compared to other building segments due to multifamily buildings generally having more window area. For education/other, many buildings had variable air volume systems with DDC control, where the VAV ventilation optimization code element was applicable but showed very low compliance rates. The office segment reflected larger lost savings impact for receptacle controls, which is a code element that is more targeted towards office space types. Both office and education/other showed significant lost savings in VAV system fan power limit, as both segments commonly use VAV systems as the predominant HVAC type. Some code elements, including optimal start controls, showed low compliance rates, but also have low energy impact so they did not appear on the top lost savings contributor list.

Figure 6: Top lost savings energy code elements by building segment

High-rise multifamily

- Mech Cx
- Tstat deadband
- Light Cx
- Fenestration orientation
- Window SHGC
- Window-to-wall ratio

Office

- Parking garage fan control
- Light Cx
- Tstat deadband
- Fenestration orientation
- Receptacle control
- VAV ventilation optimization
- Mech Cx

Food service/retail

- Night fan control
- Single zone VAV
- Economizer high limit shutoff
- Mech Cx
- Automatic time switch control
- Daylighting control
- Exterior lighting control

Education/other

- VAV ventilation optimization
- Fan power - pkgAC
- Tstat heating setback
- Demand control ventilation
- Tstat deadband
- Energy recovery requirement
- Indoor pool cover
- Light Cx

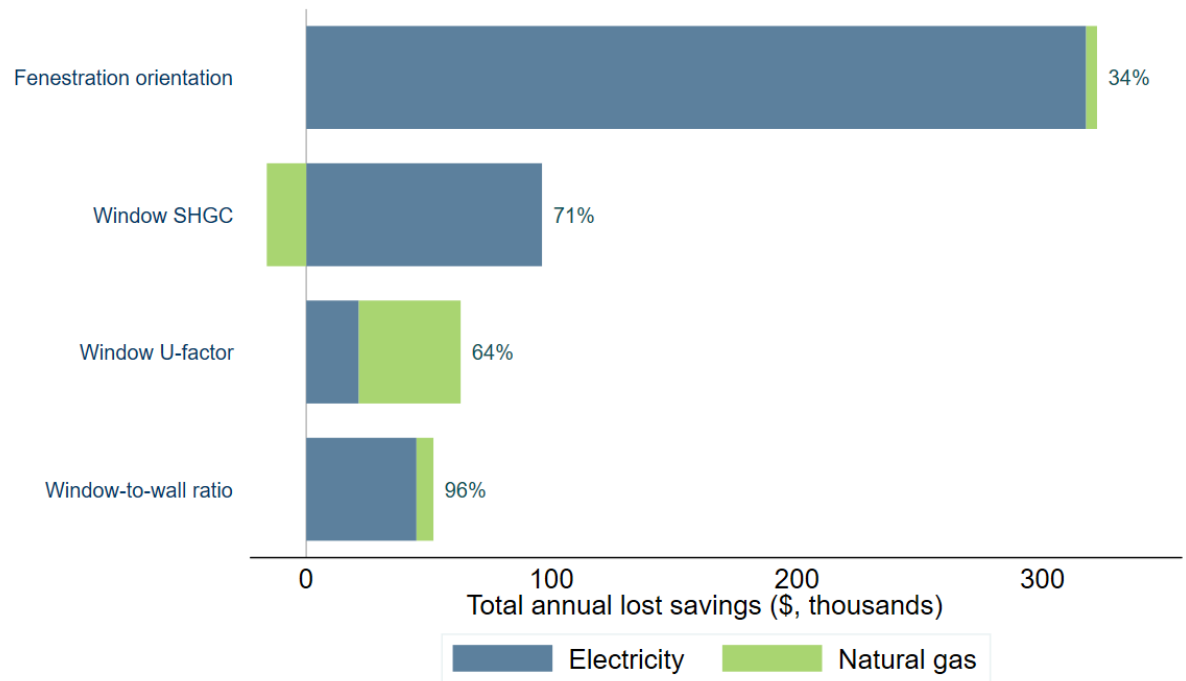
Top Lost Savings Energy Code Elements by End Use

Diving further into the results, we explore specific energy code elements by the three major end uses (envelope, lighting/electrical and mechanical/plumbing). We discuss the code elements that contributed the most to lost savings, general findings on typical building characteristics, and observations regarding compliance of certain code elements.

Envelope

As mentioned above, we found that envelope energy code elements tended to the most complied with in comparison to other end use categories. However, there were four code elements that drove the majority of the lost savings, shown in Figure 7 and described in more detail below.

Figure 7: Lost savings and compliance rate for most common envelope elements (population weighted estimates)



Percentages indicate overall compliance rate for all building segments

Fenestration orientation requires the building to have more window area on the south façade than either the west façade or east façade, to maximize solar heat gain benefits. This code element had a very low compliance rate. Meeting this element can be difficult for buildings that are designed to be longer in the north-south axis, but that is not the case for many buildings for which we observed non-compliance. This code element is relatively easy to evaluate during design and should be addressed by code officials and designers at that time. This requirement is in ASHRAE 90.1-2010 but not in IECC 2012.

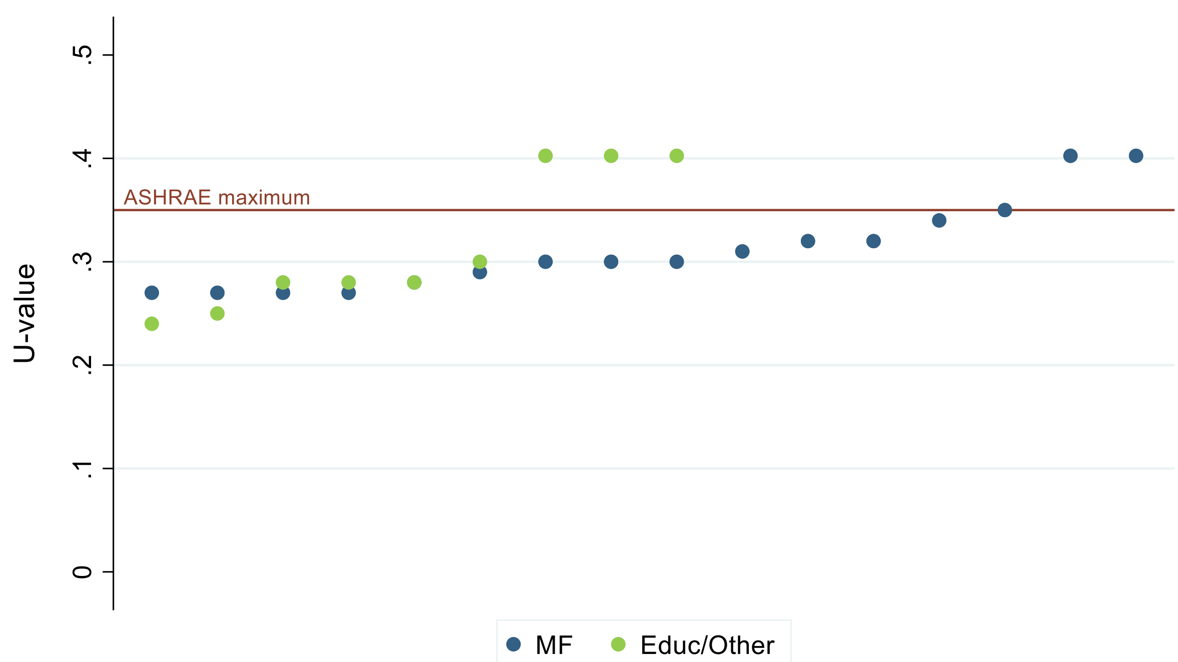
Fenestration U-factor and SHGC. Two other low-compliance code elements were fenestration properties (U-value and SHGC) for custom-built glazing, such as storefront and curtainwall glazing. For these building components, documentation of performance was rare, especially for full assemblies. Lack of information on drawings and specifications likely led to more common non-compliance when glazing and frames were selected.

This is compounded by some related issues. First, fenestration performance needs to be specified as a full assembly, with both the glazing and the frame. This is a common point of confusion in the building design and construction industry. Often the glass performance values are reported without consideration for the frame, because glass-only performance is easy to identify and report. Full assembly performance requires an independent analysis (i.e. thermal modeling) on most projects. This analysis is often conducted or available, but not communicated to key design team members and code officials. When it is communicated, its often not in a timely manner. Unfortunately, most frames significantly degrade overall performance, so this practice needs to improve.

The issue is also compounded by these properties being difficult to inspect on-site – nearly impossible, with any accuracy, in the case of U-value. Coupled with the fact that the window frames are long lead-time items and integrated with the building structure, waiting for site inspection to confirm this item is highly problematic. Assembly thermal reports based on shop drawings from the vendor are a better place to address this code element. Note that this last issue, the fact that it is difficult to inspect on site, is not generally true for factory-built windows, common in high-rise multifamily buildings – these are typically NFRC-rated and come with NFRC-stickers and documentation that improves verification on site. The NFRC rating system generally helps reduce the implementation of non-compliant windows, as it makes it easier for design teams to specify products without having to require thermal modeling analysis to confirm that the assembly U-value meets code.

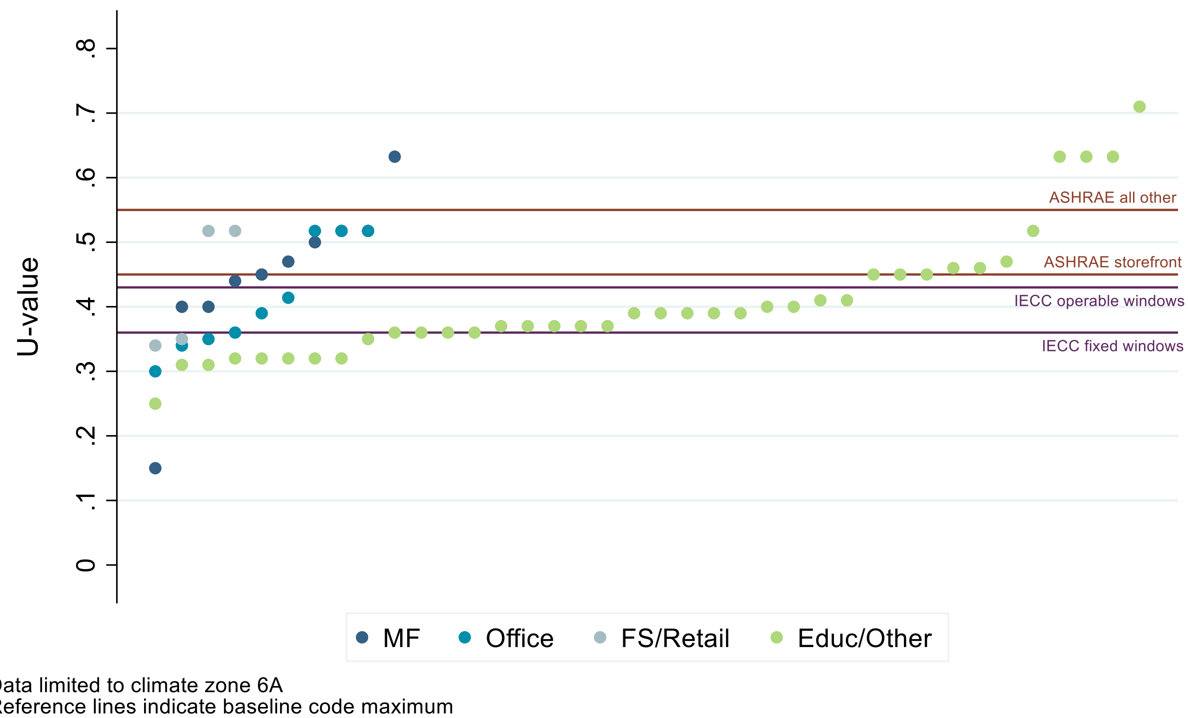
There are different code requirements for windows with metal versus non-metal framing, reflecting the relatively lower heat transfer rate of non-metal framing materials. Windows with non-metal framing, such as fiberglass vinyl, are most commonly found in high-rise multifamily buildings. The U-value of non-metal framing windows are typically lower than metal framing, due the lower heat rate transfer of vinyl as compared to aluminum. As such, the code requirement for non-metal framing windows is more stringent than metal framing windows. Figure 8 and Figure 9 illustrate the U-value distribution for non-metal and metal framed windows by building segment. Reference baselines for ASHRAE and IECC are listed where applicable.

Figure 8: Distribution of non-metal framing window U-value by building segment



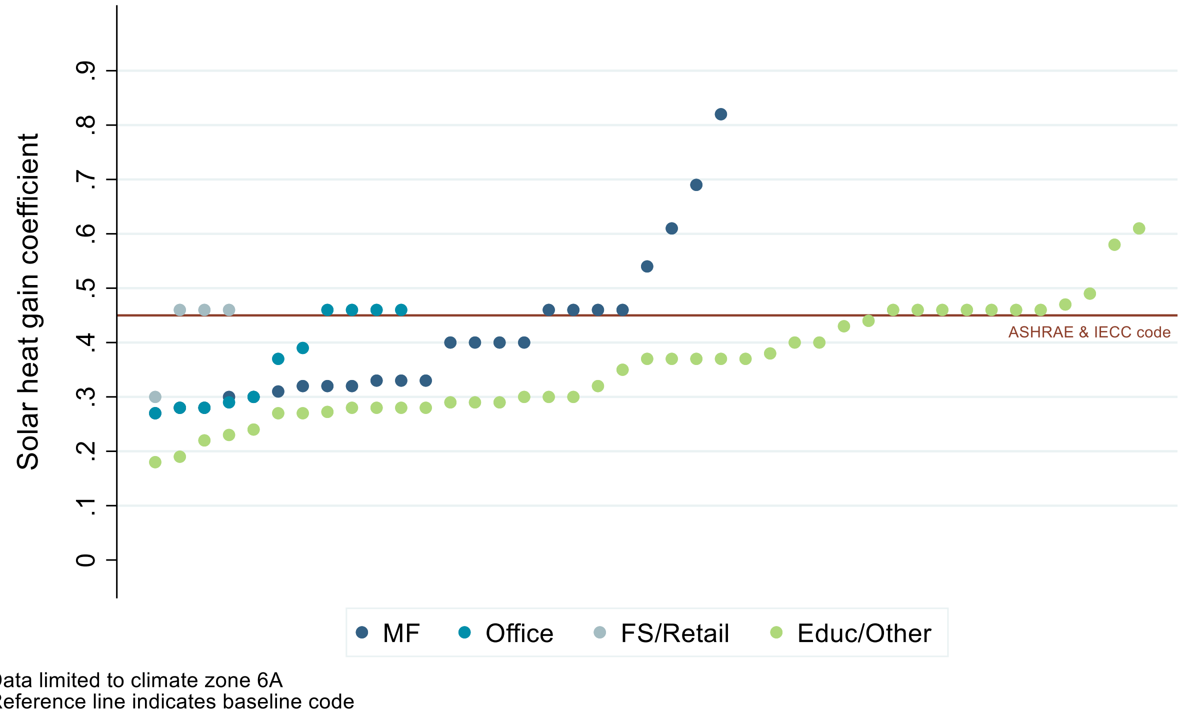
Data limited to climate zone 6A and projects that follow ASHRAE baseline
Reference lines indicate baseline code maximum

Figure 9: Distribution of metal framing window U-value by building segment



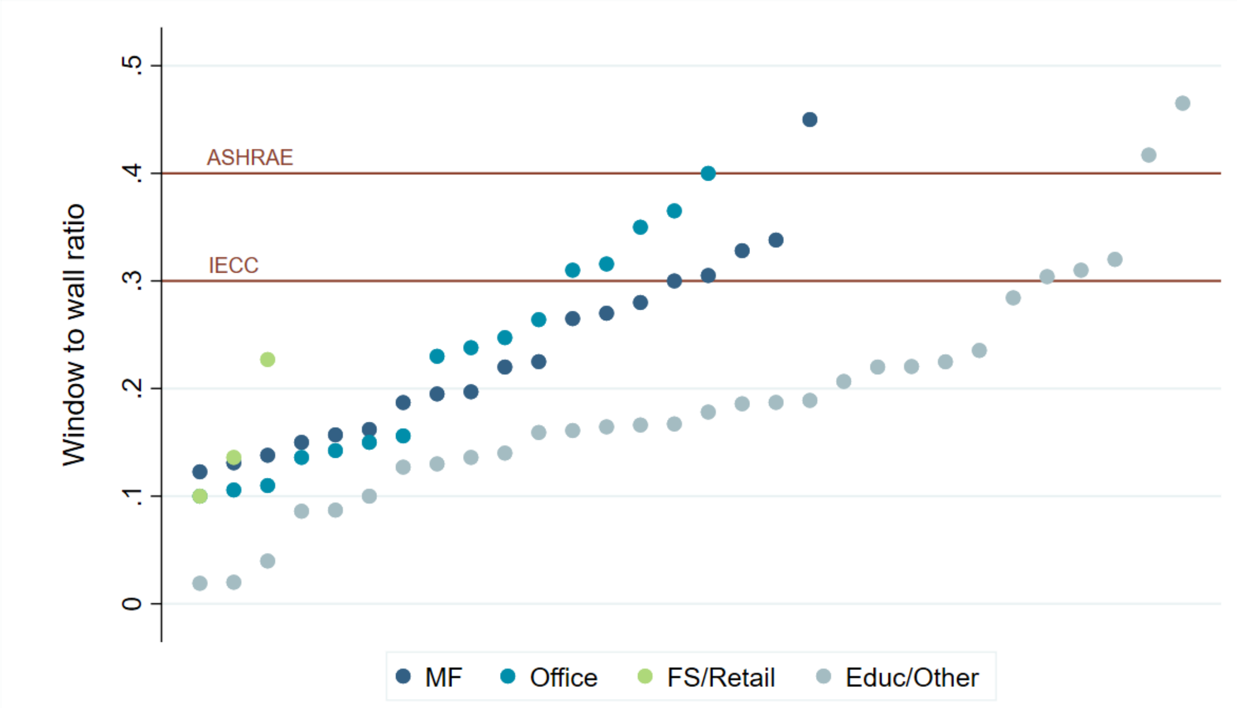
Window SHGC is solely dependent on glass type and not affected by framing type, which makes it an easier element to check for than U-value as additional thermal analysis is not needed. This element measures the amount of solar heat gain through glazing. Figure 10 illustrates the window SHGC distribution by building segment in comparison to ASHRAE and IECC code requirements.

Figure 10: Distribution of window SHGC by building segment



Window-to-wall ratio had a higher compliance rate than other fenestration elements, but there were instances of non-compliance, where the amount of glazing exceeds code limits. And this element has a large energy impact, so even small amounts of non-compliance add up to substantive lost savings. This code element impacts the aesthetics of the building design and can therefore be a challenge for design teams to meet if building owners and developers are requesting a certain building appearance. It is, however, an easy element to enforce at the design stage and should be addressed at that time. The maximum requirement is 40% in ASHRAE 90.1-2010 and 30% in IECC. However, IECC does have an exception to increase the requirement to 40% if daylighting controls are present in at least 50% of the conditioned floor area, which was not found applicable in any of our study sample. Figure 11 illustrates the window-to-wall ratio distribution across all four building segments.

Figure 11: Distribution of window-to-wall ratio by building segment



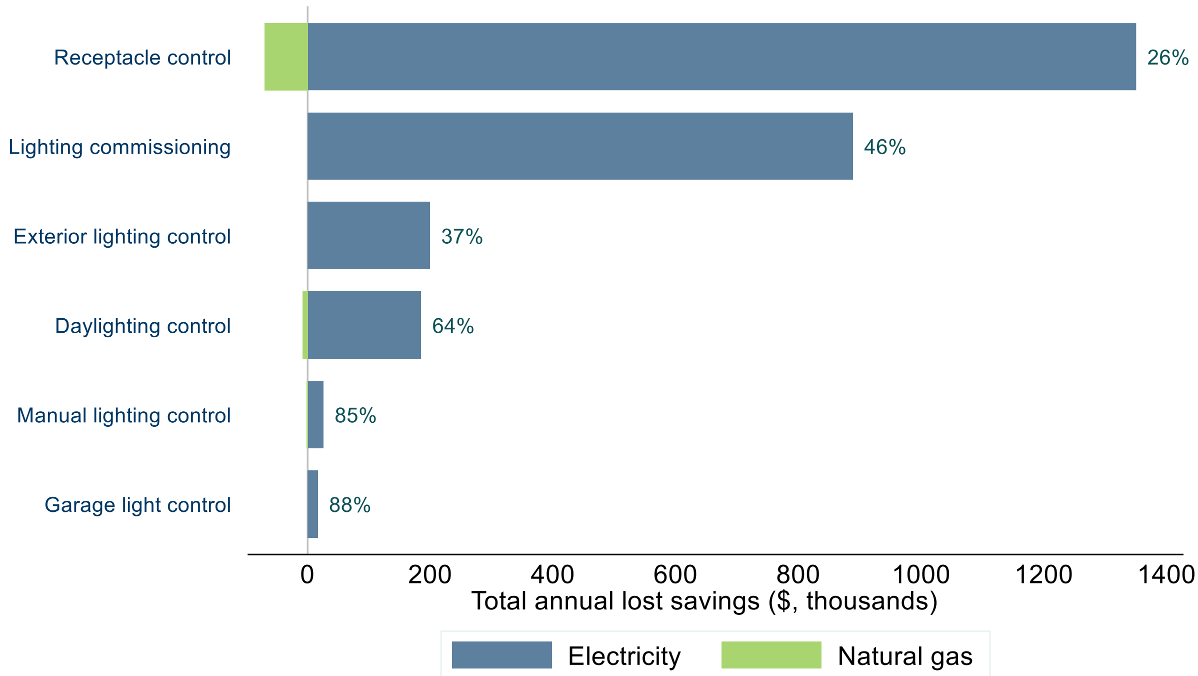
Continuous air barrier. The detailing of a continuous air barrier was also completed properly on a relatively high number of buildings but result in significant lost savings due to large energy impact per instance of non-compliance. This element manifests itself in many different parts of both the design documentation and the construction process, so it is very difficult to enforce. There may be benefits to educating both designers and code officials on the most common errors made.

For the same reasons, the scope constraints of this study prevent us from field inspection of a large enough number of different air barrier details to have identified all possible construction issues. It is therefore possible that lost savings is higher than reported for this element.

Lighting and Electrical

For lighting and other electrical end uses, lost savings predominantly result from control elements rather than power density or equipment efficiency (Figure 12). With LED fixtures being widely and commonly used, interior and exterior lighting power code requirements can be easily met, but specific lighting controls and commissioning appear to be areas that are often overlooked. We see small natural gas penalties from reduced heat gain from some lighting and electrical energy code elements.

Figure 12: Lighting and electrical: lost savings and compliance rate for most common elements (population weighted estimates)



Percentages indicate overall compliance rate for all building segments

Receptacle control was one of the least compliant code elements and applicable to half of the buildings in the study. ASHRAE 90.1-2010 requires at least 50% of all receptacles installed in private offices, open offices and computer classrooms be controlled by an automatic control device that functions on a schedule or occupant sensors. This element is often not documented well on electrical drawings. As this is a relatively straightforward hardware component, it would seem that many design teams are either unaware of the receptacle control requirement or have chosen not to comply. Conversation on this element is needed in the industry. Note that receptacle control is not required in IECC 2012.

Lighting testing and commissioning appears to be less widely implemented than mechanical commissioning. Lighting commissioning has not been a common practice as long as mechanical commissioning has, given that advanced controls are newer to the industry. The energy impact can be significant, as lighting is still one of the highest energy consumers in commercial buildings.

Documentation of a lighting commissioning plan is lacking in many instances, which suggests that it was not planned for during design and not carried out in the field. In a few cases, lighting commissioning was included in the design specifications, but ultimately removed during construction due to building owners' concern about cost.

Exterior lighting control was also commonly non-compliant. This was an issue common to many non-24/7 building types. While exterior photocell controls are very common now, the current code includes an additional element requiring either timeclock controls or motion sensors to implement an additional percentage reduction of total connected power during unoccupied hours (for example, midnight to 6am), so that lights are not on at full power all night. This element appears to be easily neglected. It should be noted that the additional power reduction requirement exists in ASHRAE 90.1-2010 but not IECC 2012.

Daylighting control. This code element was applicable to over half of the buildings in our dataset. When daylighting control is installed, it generally exceeds code by having specified continuous dimming compared to code-required stepped dimming controls. However, there are many spaces with good side lighting that are mistakenly not identified by project teams as potential daylighting zones, and these result in non-compliance. Photocell control can potentially save more energy than occupancy sensor control if the space is lit adequately during occupied periods, and should be prioritized during design especially for spaces that are adjacent to glazing.

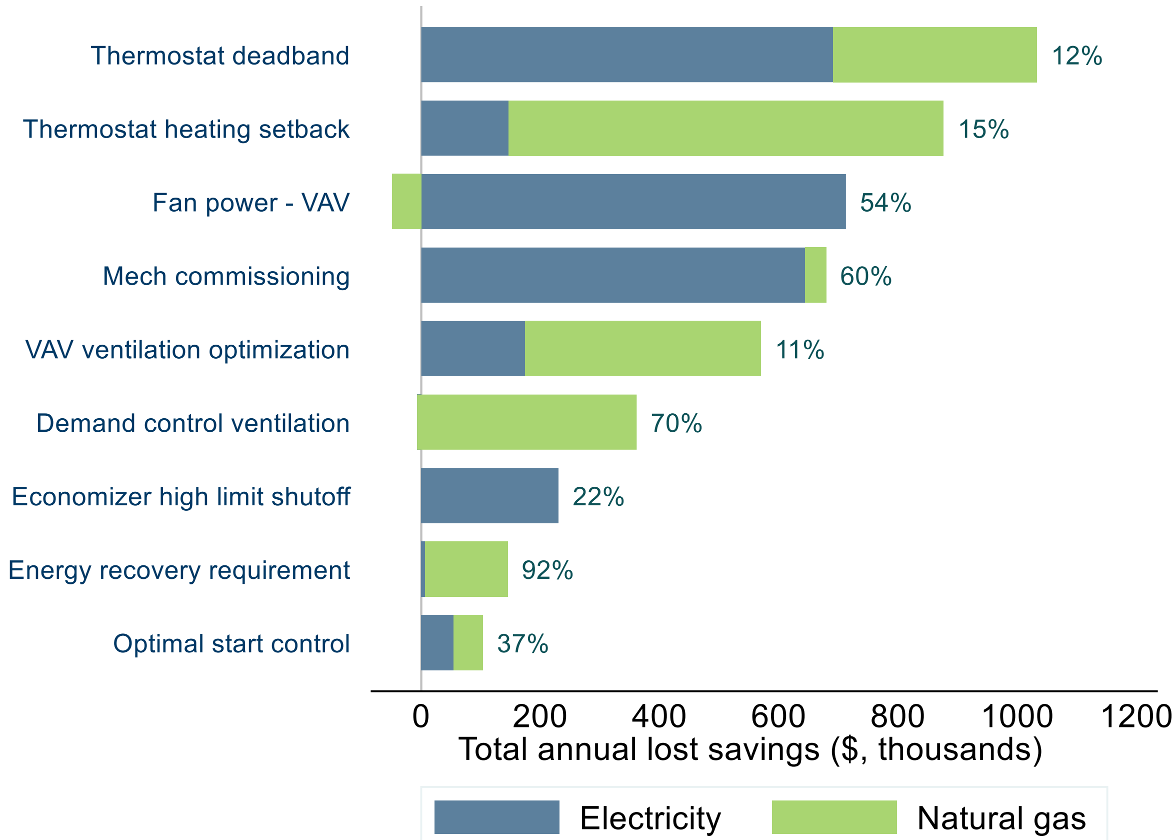
Manual lighting control entails bi-level switching for light fixtures instead of only on/off controls. It appears that this element tends to be overlooked by design teams as in many cases the spaces only included a one-level on/off switch. With LED technology, this requirement can be easily achieved through dimming controls.

Other lighting and electrical code elements with high energy impact include automatic time switch control and occupant-based parking garage lighting control. Both elements are typically complied with; but each showed one instance of non-compliance in our dataset, which resulted in significant energy impact once extrapolated to the Minnesota population. Automatic time switch control may be a design oversight for the one building in our sample. Regarding garage lighting controls, there may be some level of security concern among building owners, as a common misconception is that lights will all turn off during periods of unoccupancy. However, the code intent is to reduce lighting power by at least 30% during unoccupied periods, so it is high/low control rather than full on/off.

Mechanical and Plumbing

For mechanical and plumbing end uses, lost savings predominantly result from control elements rather than equipment efficiency (Figure 13). The market for HVAC equipment has shifted enough that commonly-available product lines meet energy code efficiency ratings. For controls on the other hand, many settings and sequences are still programmed manually during installation, making them prone to error, especially where the Sequence of Operations is not well documented.

Figure 13: Lost savings and compliance rate for most common mech/plumb elements (population weighted estimates)



Percentages indicate overall compliance rate for all building segments

Thermostat deadband and setback controls are often not indicated on drawings and specifications, especially if the sequence of operations is not included with the drawing set. This leads a higher likelihood of non-compliance during field installation and programming. Code requires 5F thermostat deadband and heating setback controls adjustable to 55F or lower. Lost savings are significant, and this is a relatively easy element to check, so it should be addressable.

Fan power limits for packaged systems have a high energy impact, especially if building operating hours and corresponding fan run hours are long. This element requires a calculation on behalf of the designer; the calculation is moderately complex but ends in a single number for the possible size of each fan system. Fan selection software can aid in this calculation. Whether or not this calculation is always performed, it is rarely documented in the drawings, making this more difficult for the code official to evaluate compliance.

Mechanical commissioning is critical to ensuring that the system is operating at optimal conditions and with the proper control sequences. It has been demonstrated in the field to have a significant impact on energy consumption, in just about any size of building. We found that in many instances there was a lack of a commissioning plan, which suggests that commissioning was not planned for in the design and not carried out in the field. In a few cases, mechanical commissioning was included in the design specifications, but ultimately removed during construction due to building owners' concern about cost. IECC 2012 includes an exception on conducting mechanical commissioning if the mechanical systems in project has a total capacity less than 480 MBH cooling capacity and 600 MBH heating capacity. ASHRAE requires mechanical commissioning for projects over 50,000 square feet in conditioned area; for projects under 50,000 square feet, the requirement is to conduct HVAC control system testing and balancing, but not explicitly required to be commissioned.

VAV ventilation optimization entails resetting the outdoor air flow in response to ventilation efficiency through DDC control systems. This code element showed very low levels of compliance, while being relevant to almost half of the buildings in the dataset. It is a complex element in the energy code, is easily confused with demand control ventilation, and is not yet part of many design firms' standard sequence of operations. Significant education is needed on this element.

Demand control ventilation (DCV) entails varying the amount of outside air flow supplied to the space based on occupancy. DCV requirements are usually met when a dedicated outside air system (DOAS) is involved. However, when the HVAC units are not 100% outside air, which is true for the majority of systems, DCV seems more often neglected. The application of this element is dependent on occupant density in spaces; identifying these select spaces may be overlooked. It is possible that a more consistent, streamlined method of reporting code ventilation requirements that includes the DCV-occupant-density calculation could be helpful. This code element was applicable to half of the buildings in the dataset.

Economizer high limit control entails shutting off economizing mode when outdoor air temperature or enthalpy exceeds a certain high limit. This control setting is often not indicated on drawings, especially if the sequence of operations is not included with the drawing set. This leads to a higher likelihood of non-compliance during field installation and programming.

Energy recovery requirement can reduce the need to preheat or precool outside air before being brought into a space by recovering energy from the exhaust airstream. For dedicated outside air units (100% OA), this element shows a higher level of compliance. However, for non-dedicated OA systems, there is a tendency for design teams to overlook the energy recovery requirement when the system reaches a certain OA and supply air threshold. This code element was applicable to half of the buildings in the dataset.

Optimal start controls have minimal energy impacts per instance, but also have a low compliance rate and are relevant to two-thirds of the buildings in the dataset. Adjusting the start time of an HVAC system to bring the space to desired occupied temperature levels immediately before scheduled occupancy can reduce energy loss from starting up the system too early and maintaining occupied temperatures during unoccupied periods. ASHRAE 90.1-2010 includes a minimum equipment size below which the controls are not required, whereas IECC 2012 has no lower limit on equipment size.

Pool covers. While we only saw 5 pools in our study sample, four of them did not have a pool cover. Lack of a pool cover is a significant contributor to lost savings, especially for heated pools. Pool covers not only reduce the need to heat the make-up water via pool heaters, but they also reduce the amount of water evaporation. This also results in savings in dehumidification energy due to less moisture being released into the space. Pool covers can be viewed skeptically by building owners given that they require extra storage space and operational time to place and remove the cover each day. Given that, this element can be a challenge for design and construction teams, even while being a straightforward code requirement.

Other mechanical elements with high energy impact include parking garage fan controls, night fan controls and single zone VAV, which were part of the drivers for the high lost savings potential in the large office and FS/retail segment. Although these elements were each found to be non-compliant for only one instance, the high energy impact significantly drove up the extrapolated lost savings. Parking garage fan control should be in the form of variable speed drives to modulate airflow based on contaminant (CO and NOX) sensors. Continuous full-speed operation of garage fans can sharply increase energy use. This is one example of a hardware element that has lower compliance. This code element was relevant to 15 buildings in the study.

Heat pump supplementary heat control entails locking out electric resistance heat when heat pump can meet the heating load. This control setting was marked as “unknown” for site visit observation levels for many projects that included heat pump systems. This was due to this code element not being observed in design documentation and not accessible for verification on site, thus no evidence exists to make engineering judgement for the level of compliance. This element appears to lack proper documentation across all building types and is also one of the harder elements to observe on site. Typically, it is programmed by contactors during installation and difficult for facility managers to change control settings. Lost savings were not calculated for this particular element due to the uncertainty of compliance level. Currently there is no related research available that can suggest what the typical condition is for commercial buildings.

Observations on Commissioning and Controls

We found that good documentation of HVAC and lighting control sequences in drawings and specifications generally correlates with a clear indication of a mechanical and lighting commissioning or testing and balancing plan. In most cases, HVAC and lighting control elements and commissioning plans appear in the same sections of the specifications and it is less common to see one included and not the other. Based on our dataset, the average percent of non-compliant HVAC control elements was lower when mechanical commissioning was found compliant than when mechanical commissioning was non-compliant.

We found it difficult to determine the quality level of mechanical commissioning in sampled buildings. In most cases, we were only able to review a commissioning plan in the drawings or specifications, but not a completed report. Even if a report was provided, it is not a direct indication of how well the commissioning was carried out. As a result, documentation of compliance for mechanical commissioning was based solely on whether a commissioning plan was indicated in the drawings or specifications.

Lighting and HVAC controls are prone to error due to both their complexity and the fact that they are programmed manually after installation. Without a well-documented Sequence of Operations, equipment may be left to operate at default settings or based on the previous experience of the controls' contractor. This can contribute to losses in energy savings that are not remedied through commissioning activities, which also require a Sequence of Operations as a point of comparison. Our study found that only 4 of the 78 projects were compliant with all applicable HVAC control code elements. Similarly, only one building complied with all lighting control measures.

There is also potential for lost savings even when compliant documentation is included in the construction documents if control code elements are not implemented according to the design. However, our study was not able to observe most of these elements on-site due to many of the site visits occurring before control sequences had been implemented.

Project teams may also be unsure how to interpret the code requirements for commissioning, especially when using ASHRAE 90.1-2010. Unlike IECC 2012, which includes specific requirements for commissioning plan content and submission to the building owner and code official, ASHRAE 90.1-2010 intentionally lacks specificity to accommodate variation in building system complexity, criticality, and the owner's desires and constraints (ASHRAE 2011). It also has minimal guidance for projects under 50,000 square feet, which appear to be required to conduct HVAC control system testing and balancing but are not explicitly required to be commissioned. This lack of guidance could result in projects – especially those under 50,000 square feet – conducting minimal in-depth functional testing and balancing. Our study did find projects under 50,000 square feet using ASHRAE to have lower compliance rates for control code elements than larger buildings, but variables other than commissioning may have contributed to this, such as code element requirement differences between smaller and larger projects.

Participation in Utility Conservation Improvement Programs

Xcel Energy, CenterPoint Energy, Otter Tail Power Company, and Bright Energy Solutions offer CIPs that provide free energy consulting services to qualifying new construction and renovations projects in Minnesota. Xcel's program, Energy Design Assistance (EDA), offers two services tracks, Standard and Enhanced, each providing customized energy modeling to demonstrate options to reduce energy costs, assistance with identifying and evaluating energy saving strategies, on-site verification of installed strategies, and analysis of energy costs and project paybacks (Xcel Energy 2020a).

During our communications with the design or construction teams as we collected data, we asked about participation in utility conservation improvement programs. In many instances, our contacts for the building were unaware of participation; this lack of awareness was likely due to our contact person not being familiar with project details that the owner or others on the building team may know. We were able to confirm directly that 10 sites participated in the EDA program and 4 sites did not; the majority did not know.

Due to privacy issues, we could not request participation levels for any specific project from the utility directly. As such, we could not compare compliance or lost savings specifically to participation in EDA. However, per conversations with Xcel Energy representatives, we were able to summarize overall participation in Xcel's new construction programs (not attributed to a particular building) as shown in Table 12 where we see that a large portion of projects have participated in Xcel's utility programs.

Table 12: Participation levels in Xcel Energy utility conservation improvement program

Participation level	Count of projects
Participation in Xcel EDA, EEB or received new construction prescriptive rebates	43
Not in Xcel Energy service territory	23
In Xcel territory, but unable to confirm participation	12

Plan Documentation and Compliance with Energy Codes

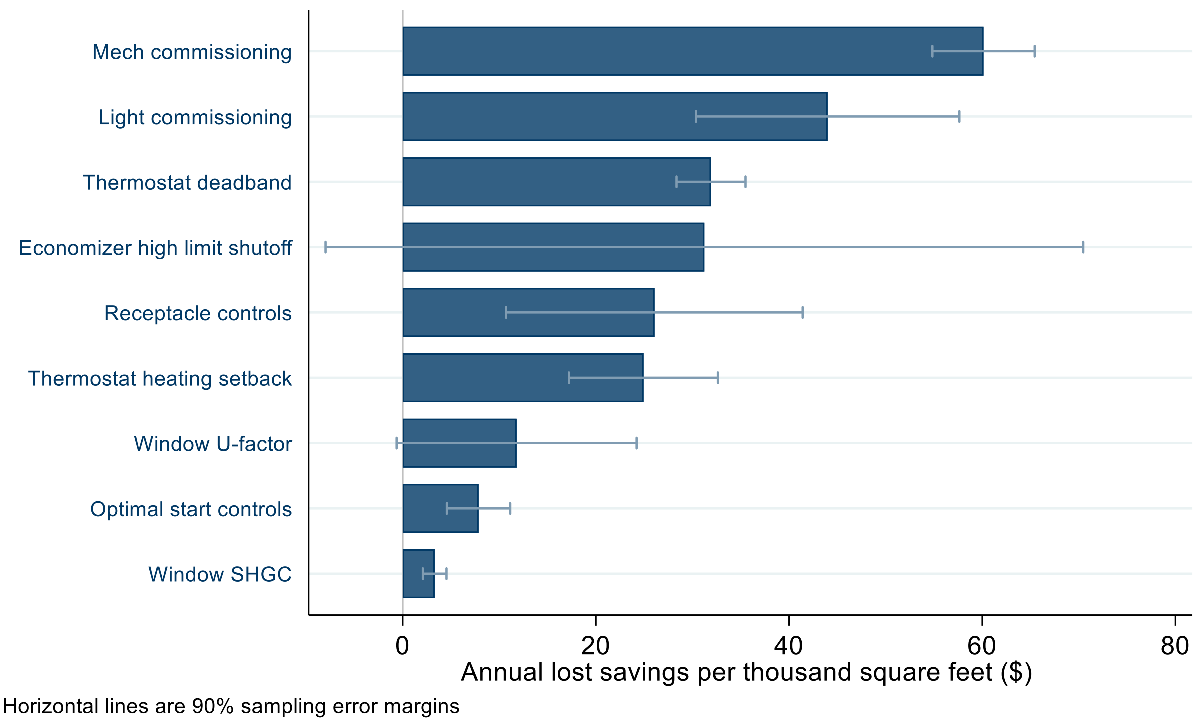
Plan documentation has the potential to affect whether a building is designed to energy code because it is by definition the method to convey to the construction team what is to be built. If an element is poorly documented in the plans and specifications, there is risk for confusion in how the building actually gets built. In order to explore this relationship – good plan documentation versus poor documentation and its effect on building energy code compliance – we summarized the lost savings and number of instances for the two levels of documentation, first for code elements that tended not to be code compliant and then for code elements that did tend to comply.

There are several details to highlight again here regarding how this study reviewed and recorded data. As noted in the section on data quality, we assumed non-compliance if a code element was not observable on-site and not observed on documentation, any compliance that happens to be achieved would be accidental or due to a contractor's knowledge of the code. A few exceptions were made for some control sequences for complex mechanical systems in instances where we were not able to obtain the control sequence documentation, including night fan cycle control, static pressure reset, supply air temperature reset, etc. Based on industry common practices and published research, these control sequences are likely to be implemented (Gunasingh 2019).

Non-compliant energy code elements – poorly documented

In several projects, the energy code elements shown in Figure 14 were poorly documented on drawings and specifications, and were found to have lower levels of compliance during site verification. There are a variety of reasons why code elements may not be well documented, from traditional design practice to rushed designers to lax enforcement on plan review by building code officials. A lack of proper documentation may have contributed to levels of low compliance. In Figure 14, we illustrate the impact of poor documentation through the metric of lost savings per thousand square feet.

Figure 14: Most common poorly documented code elements not built to code (population weighted estimates)



Mechanical commissioning and lighting commissioning are at the top of the list as there is a strong energy implication when there is a lack of commissioning plan or testing and balancing in the design documentation. As mentioned in *Observations on Commissioning and Controls,* commissioning documentation was sometimes difficult to determine. In a few cases, we were able to confirm verbally with an on-site contact that commissioning was not included. In general, if not documented on plans and specs, we assumed non-compliance for both commissioning elements.

Many of the code elements listed above are related to mechanical and lighting control settings such as thermostat deadband and setback controls, economizer high limit shutoff control, receptacle controls and optimal start controls. Without proper documentation, these controls settings are often left at their default settings when equipment is installed and controls programmed on site. Additionally, if the building does not have a building automation system, which is the case for half of the buildings in our dataset, it would be challenging to adjust control settings post-installation without bringing service providers on site.

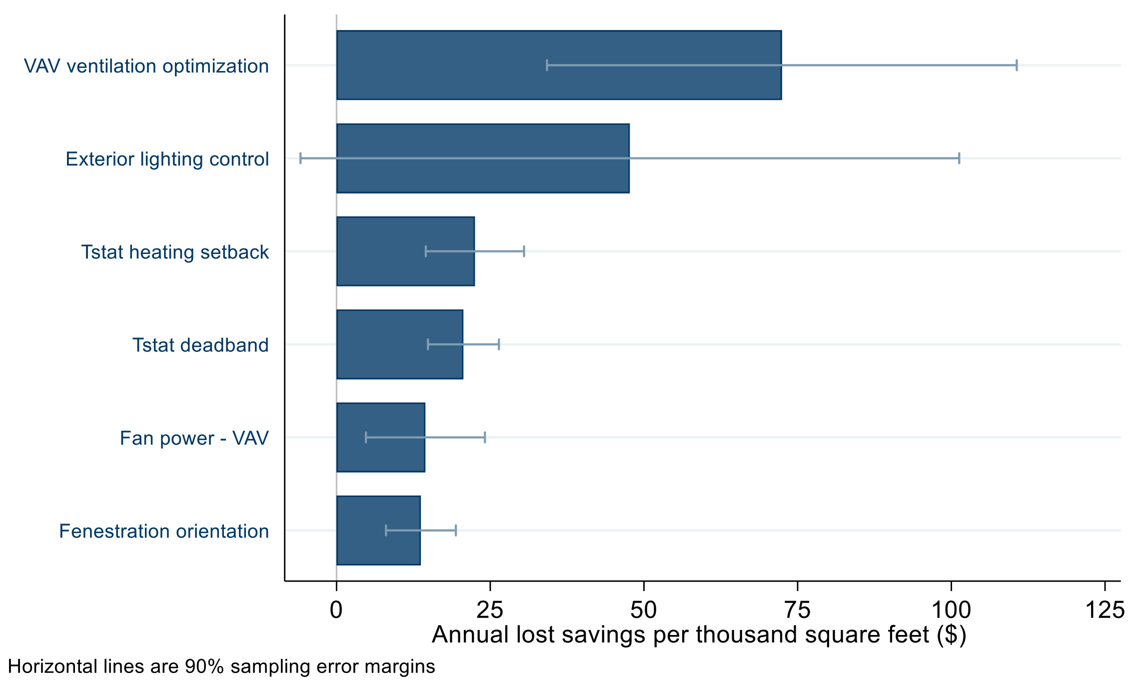
The window properties code elements identified as poorly documented and not built to code are specifically for custom-built windows, for example storefront or curtainwall windows. In these instances, U-value and SHGC values were not indicated on the drawings or specifications. In some cases, the drawings noted that the glazing unit is insulated, but the framing type was rarely included. For custom-built windows, the assembly U-value should be determined by both the glazing unit and the framing type specifications. We obtained envelope COMcheck files for some of the projects, and it appears that there are instances where the documented U-value is not for the overall assembly but rather center-of-glass, which gives a false impression that the glazing assembly is meeting code. Furthermore, ASHRAE 90.1-2010 and IECC 2012 has different requirements on window properties, thus care should be taken to ensure the specified properties are in line with the permitting code.

Receptacle control in most cases did not show up on electrical drawings and specifications and it was unclear how and if it would be controlled. The plans and specifications were not clear about whether the design team had purposely left it up to the occupants to install plug-and-play receptacle control devices. On site, we rarely found that receptacle controls were implemented.

Non-compliant energy code elements – as documented

We found several energy code elements for which non-compliant conditions were documented in drawings or specifications (Figure 15). These reflect cases where the designer likely does not fully understand requirements.

Figure 15: Most common non-compliant code elements – as documented (population weighted estimates)



For buildings that had variable air volume (VAV) HVAC systems, largely in education/other and office building segments, ventilation optimization was not typically specified in design documentation. As this is a more complex element in the code, we believe that the designer may not fully understand the requirements. This is a requirement in ASHRAE 90.1-2010 but not in IECC 2012.

For exterior lighting control, most buildings documented photocell and/or timeclock control in drawings and specifications but did not specify any additional power reduction between the hours of midnight to 6am. This is a requirement in ASHRAE 90.1-2010 but not in IECC 2012. It is one of the most common non-compliant elements across all building types except high-rise multifamily (multifamily is exempt as it is considered operational 24/7). In most cases, project teams did not appear to be aware of this requirement.

In some cases where thermostat deadband and heating setback were documented on drawings and specifications and specifications, the values were not code-compliant. This suggests that design teams may not be familiar with the requirements of these code elements.

Compliant energy code elements – poorly documented

We found several instances of code elements which appear to be non-compliant or missing in design documents, but were observed to be built in accordance with energy code requirements (Figure 16). This may result from the contractor having implemented these elements enough on other projects to build to the code requirements even if not shown on drawings; the element has become institutional knowledge. This may be an issue with the adoption of a new code in Minnesota, as new additions to the code are much less likely to be known and followed by contractors without proper documentation.

Figure 16: Energy code elements that are compliant as built, though not documented

Envelope	Mechanical and plumbing
•Window U-value •Window SHGC •Fenestration air leakage	•SWH Pipe Insulation •Night fan control •Duct leakage requirement •Hydronic Piping HW Insulation

The window properties code elements (U-value and SHGC) Figure 16: Energy code elements that are compliant as built, though not documented are specifically for factory-built windows. Factory-built windows are typically found in high-rise multifamily buildings and are generally NFRC-rated with compliant U-value and SHGC. NFRC-rated windows come with a factory-applied sticker which makes verification of window properties easy.

For mechanical and plumbing code elements, there are several reasons why we see compliance despite poor documentation. Night fan cycling control is a very common code element and easy to implement, to a point where almost all non-24/7 buildings with programmable thermostats have set their HVAC fan run schedule based on occupied and unoccupied hours. Whether it is included in drawings or not does not appear to be decisive factor for as-built compliance.

Service hot water and boiler hot water pipe insulation was observed to often be present in the field. The insulation thickness had to be estimated where it was not documented but it appeared to be compliant with code.

Compliant energy code elements – as documented

This last case focuses on energy code elements that are being addressed well by both designers and builders (Figure 17).

Figure 17: Energy code elements that are compliant both as built and documented

Envelope	Lighting/electrical	Mechanical/plumbing
•Continuous air barrier	•Occupancy sensor control	•Packaged AC efficiency
•Roof insulation	•Interior lighting power	•Gas furnace efficiency
•Window-to-wall ratio	•Exterior lighting power	•Economizer present
•Enclosed vestibule	•Manual lighting control	•Duct insulation
•Frame wall insulation		•Fan power - PkgAC

There are a few envelope measures that have become common industry practice and tend to be well-documented in the plans. For example, in most project drawings we saw evidence of continuous air barriers. Roof and wall insulation are typically built to code or to exceed code requirements. Insulation is almost always documented in drawings as wall sections and detail sections that are part of the standard architectural drawing set.

Efficient LED lighting and occupancy controls are commonly available and have been required in the energy code for almost a decade, which has made it one of the first things project teams specify in a lighting design. With LED technology, dimming controls are easy to specify and implement, which can achieve the bi-level control requirements of the manual lighting control code element.

Available HVAC equipment is constantly shifting towards more efficient options, which has made it easier for design teams to specify products that go beyond code minimum requirements. Gas furnace efficiency almost always meets or exceeds code requirements as it is rare to find a non-compliant piece of equipment on the current market.

Beyond Code Savings

Our study revealed multiple instances where projects are achieving energy savings above and beyond code requirements. Below, we describe the best-case examples seen in our sampled projects, which represent opportunities for expanded beyond-code savings. We also identify code elements that were observed to go beyond code for the majority of projects, indicating beyond-code savings that are already being realized.

Energy Saving Potential Relative to ASHRAE 90.1-2010 Prescriptive Code

We assessed the potential energy savings for Minnesota commercial building projects to build above and beyond code minimum requirements. To do this, we modeled a typical building for each of the office, multifamily and food service/retail segments, and for each energy code element applied the best-case conditions that our study found at any one site in each segment. There were a few outliers, namely interior and exterior lighting power, that we removed because our experience suggests the best-case condition would be unrealistic for most buildings.

Applying the same methods as in the development of the lost savings calculations and using modeling assumptions based on site data, we calculated total energy savings for each building type using ASHRAE 90.1-2010 prescriptive as the baseline. Assumptions included in this analysis can be found in Appendix E.

For some code elements such as lighting and HVAC equipment efficiency, most buildings typically already exceed code minimum requirements. As such, the beyond-code savings potential listed below are based on the perspective from green building programs or utility programs where the energy code is the calculation baseline. If using an average as-built condition as the calculation baseline for each code element, the beyond-code savings potential would be reduced.

Analysis showed that if buildings were built to the best-case condition for each code element, significant energy savings can be achieved. Table 13 lists the total potential savings by building segment.

Table 13: Potential savings beyond ASHRAE prescriptive code, by building segment (population weighted estimates)

Building type	MN total - kWh savings	MN total - therms savings	MN total - annual dollar savings	Average $ savings per KSF
High-rise multifamily	17,489,200	562,900	$2,178,900	$18
Office	9,688,500	263,100	$1,173,900	$8
Food service and retail	20,872,900	1,302,000	$3,029,000	$22
Total	48,050,600	2,128,000	$6,381,800	n/a

To understand which energy code elements are the largest contributors to overall potential savings, we looked at savings by end use, as shown in Table 14. Lighting and mechanical elements showed the highest potential in energy savings for office and food service/retail. This is primarily due to the nature of these two building types having a higher interior lighting allowance and higher occupant densities and ventilation loads. While there is less lighting savings opportunities in high-rise multifamily, due to lighting control elements not applicable in dwelling units and lighting power savings which can only be claimed for hard-wired fixtures and not resident-provided plug-and-play lighting, there is still large potential in mechanical and envelope elements. High-rise multifamily typically has a good amount of glazing area, which provides energy saving opportunities for low U-value and SHGC windows.

Table 14: Potential savings beyond ASHRAE prescriptive code, by end use (population weighted estimated)

Building type	End use category	MN total - kWh savings	MN total - therms savings	MN total - annual dollar savings	Average $ savings per KSF
High-rise multifamily	Envelope	6,180,000	112,900	$711,500	$19
	Mech/plumb	8,903,900	450,000	$1,220,400	$23
	Light/elec	2,405,300	(40)	$247,000	$7
Office	Envelope	735,100	199,800	$211,300	$6
	Mech/plumb	3,641,500	125,600	$459,400	$6
	Light/elec	5,311,900	(62,200)	$503,200	$16
Food service and retail	Envelope	655,200	89,700	$128,300	$3
	Mech/plumb	10,803,600	1,308,300	$1,999,200	$33
	Light/elec	9,414,100	(96,000)	$901,600	$25

Within each building type, the energy code elements with the highest energy saving potential are listed in Figure 18.

Figure 18: Top code elements with highest energy saving potential for beyond-code opportunities

High-rise multifamily

- Fan power - packaged AC
- Continuous air barrier
- Parking garage fan control
- Fenestration air leakage
- Roof insulation

Office

- Interior lighting power
- Parking garage fan controls
- Fan power - VAV systems
- Continuous air barrier
- Roof insulation

Food service and retail

- Interior lighting power
- Gas domestic water heater efficiency
- Parking garage fan controls
- Fan power - packaged AC
- Exterior lighting power

LED fixtures and controls can greatly reduce electricity usage not only because of less fixture power consumption, but also its reduction of cooling energy to offset the heat generated by lighting fixtures.

Large energy saving potential lies with fan power reduction in constant and variable air volume systems. Correct sizing of fan horsepower and use of VFDs where applicable is essential in reducing energy use through fans.

Well-insulated buildings with tested infiltration rates below code-minimum requirements can have a significant impact on energy performance, as low infiltration reduces the need to heat and cool excessive outdoor air.

For buildings with high domestic water heating demand such as food service, high-performance water heaters can have great potential in energy reduction.

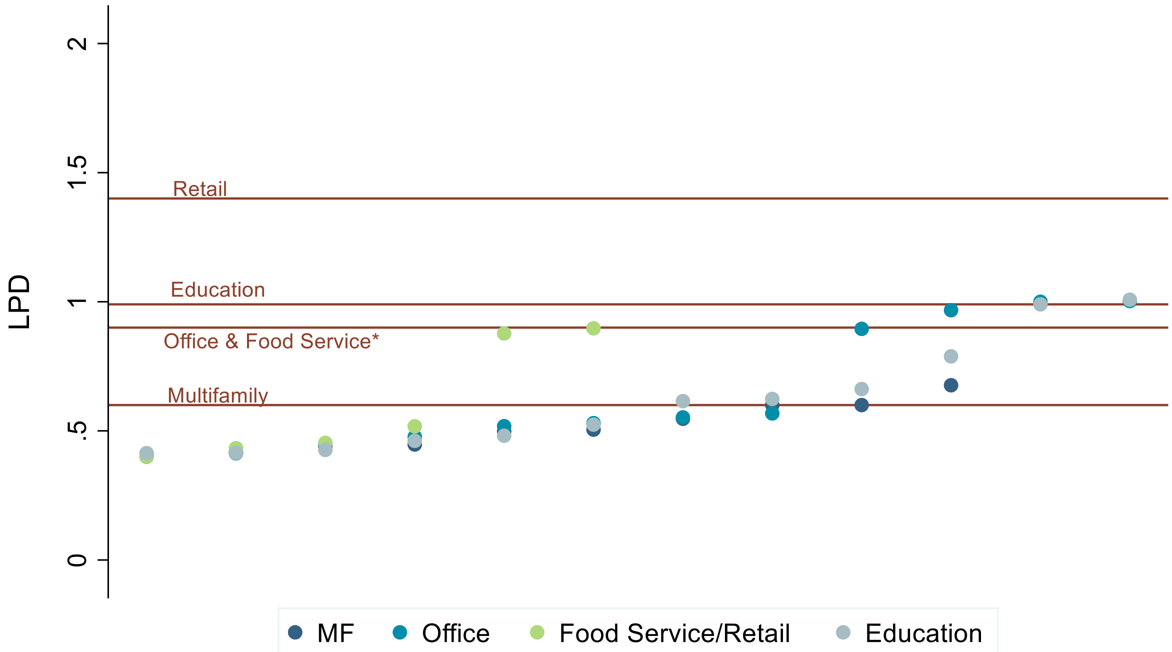
Common Energy Code Elements Typically Above Code

Currently technologies available on the market have made it easier for project teams to specify high-efficiency equipment that goes beyond code-minimum requirements. While the section above highlights high-impact strategies that may have only been implemented in one or two of the sampled projects, we also found several energy code elements that commonly go beyond prescriptive code requirements, suggesting that in these instances, code may be lagging industry standards and/or market capacity.

Mass wall insulation is one envelope element that shows a tendency to go above code-minimum requirements. Additional continuous insulation is one of the easier items to specify and thus more commonly seen. Envelope insulation generally does not have as big of an impact as lighting and mechanical elements, but can still amount to a significant energy savings if there is a large exterior façade area.

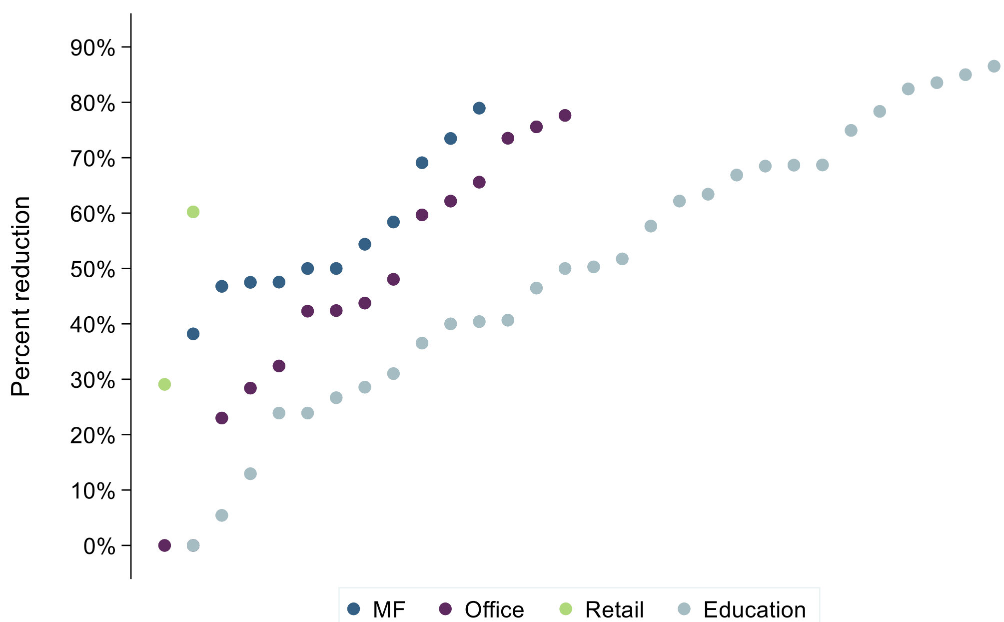
Interior and exterior lighting power are two code elements that are typically found to be much better than code-minimum requirements. Lighting energy end use continues to be among the largest percentages of building total energy use; efficient lighting design and retrofit is commonly known as the “low-hanging fruit” of energy reduction. LED fixtures are commonly available on the market, such that with a reasonably good lighting layout design, lighting power can easily exceed code requirements. IECC 2012 and ASHRAE 90.1-2010 came out nearly a decade ago when LED technology was not as prevalent as it is today, during a time when fluorescent fixtures were considered an efficient alternative to incandescent bulbs. Thus, the lighting power allowance in the code is much higher than what is needed to fully illuminate a space if LED technology is used. As shown in Figure 19 and Figure 20, interior lighting power and exterior lighting power commonly exceed code. We show interior lighting values in Figure 19 as lighting power densities. Since lighting power baseline can be variable in exterior lighting, we show that distribution as a percent reduction from code minimum.

Figure 19: Distribution of interior lighting power density across building type



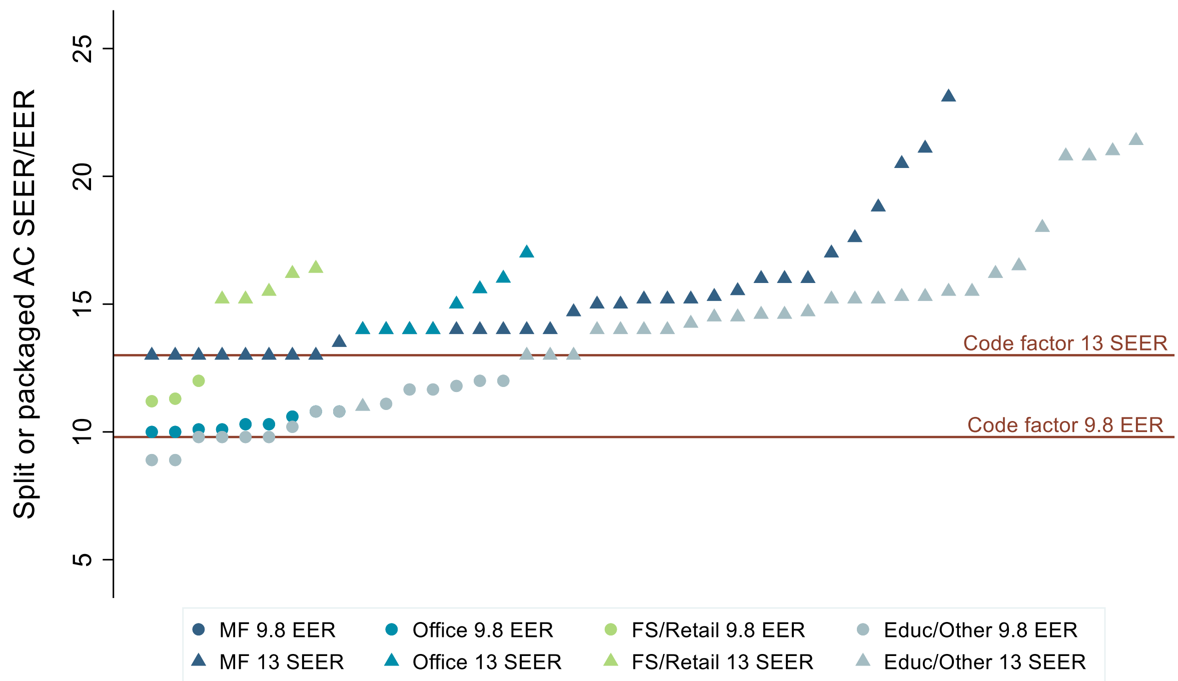
Reference lines indicate baseline code
*Office and food service have the same baseline code; however, this grouping does not reflect the study's building segments

Figure 20: Distribution of percent reduction from code minimum in exterior lighting power across building segments



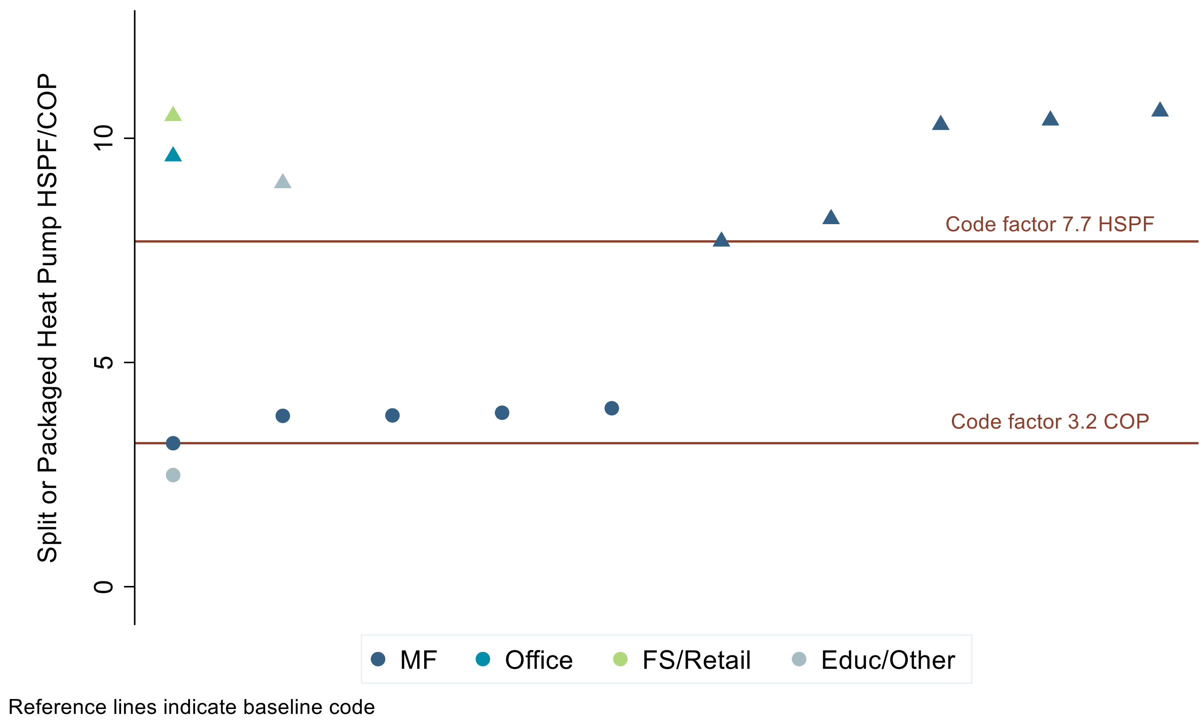
HVAC equipment efficiency typically shows a high tendency to exceed code-minimum requirements. Efficient equipment for all system types is commonly available on the market, which simplifies the process of equipment selection and ensuring code compliance. Figure 21 shows the cooling efficiency distribution of split or packaged DX equipment for < 65 MBH (SEER reference) and ≥ 240, < 760 MBH (EER reference) equipment size categories. Figure 22Figure 22 shows the heating efficiency of split or packaged heat pumps for < 65 MBH (HSPF reference) and ≥ 135 MBH (COP reference) equipment size categories.

Figure 21: Distribution of efficiency (SEER/EER) of air conditioning units across building segments



Reference lines indicate baseline code

Figure 22: Distribution of efficiency (HSPF/COP) of packaged heat pumps units by building type

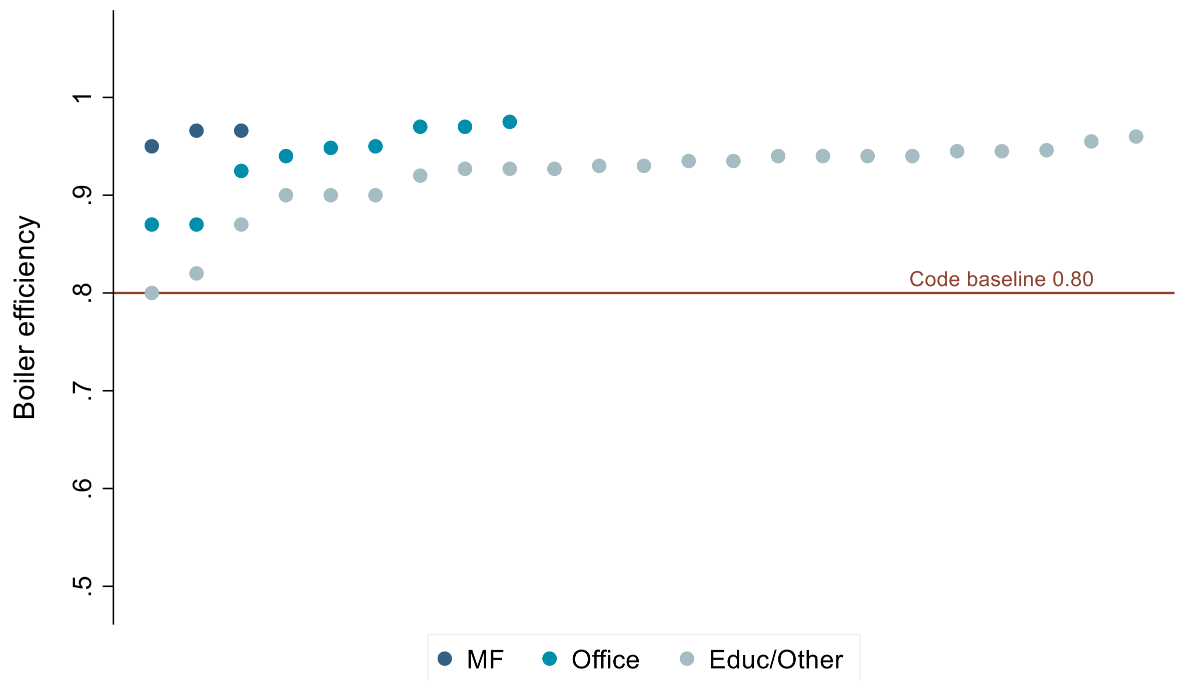


Energy recovery type and effectiveness is another efficient technology that when implemented, typically goes beyond code-minimum requirements. Code requires an enthalpy plate with minimum 50% effectiveness for when energy recovery is applicable, which is a relatively easy target to hit especially when specifying enthalpy wheels. Most available energy recovery equipment on the market is energy efficient and meets code standards, so it is rare to see energy recovery implemented but not up to the required efficiency level. Associated bypass controls for economizer lockout is typically provided. The non-compliant aspect of this element is the lack of energy recovery where required, but when energy recovery is included in design, then it is usually above code-minimum requirements.

Gas domestic water heater efficiency is commonly found to be above code-minimum requirements. As manufacturers move towards condensing gas water heaters, high efficiency options are more readily available. Domestic water heating equipment with below 80% thermal efficiency may not even be commonly available on the market, which makes choosing compliant equipment an easy task for design teams.

Gas space-heating boiler efficiency is also commonly found to be above code-minimum requirements. Similarly to gas water heaters, condensing boilers with thermal efficiency ≥ 90% are becoming a more common option as more products are available on the market. Figure 23 shows a high percentage of boilers found in our dataset that are ≥ 90% in thermal efficiency.

Figure 23: Distribution of boiler efficiency by building type



Reference lines indicate baseline code

Opportunities and Discussion

Our study found that current commercial building design, construction, and energy code enforcement practices in Minnesota are missing significant energy saving opportunities. The Next Generation Energy Act of 2007 (NGEA) identifies energy codes as a strategy for achieving the 1.5 percent energy-savings goal, so Minnesota utilities have the capability to implement programs that target these savings. However, there are currently no programs that capture savings from improved code compliance. There are also additional 'beyond code' savings available to supplement those already targeted by current new construction programs. The subsequent sections identify specific opportunities that can be leveraged within Conservation Improvement Programs (CIPs) – including a future Codes and Standards Program – to increase savings from energy code compliance and improve future code impacts in Minnesota.

Key Opportunities for Reaching the Full Potential of the Current Energy Code

Previous CARD-funded research has found that Minnesota's "current energy code and utility program regulatory environment appears to be ripe for the adoption of energy code compliance program approaches used in a number of other states, or the application of new program models" (Landry and Hoye 2018a). Our study's findings agree that there is considerable potential savings available associated with commercial building energy code compliance. Here, we use these findings to suggest three key focus areas for programs that could support the compliance and enforcement process:

- **Support for code officials:** Support the plan review and inspection process to improve code compliance and enforcement.
- **Support for design teams:** Provide guidance for design teams to improve understanding of code elements and documentation practices.
- **Support for controls documentation and commissioning:** Support improved documentation of mechanical and lighting control code elements and improve commissioning efforts.

Support for Code Officials

This study found that although many energy code elements are achieving high rates of compliance, there are still areas for improvement. Code officials can help projects attain additional savings by educating design teams about code requirements, catching non-compliant and/or undocumented code elements during plan review, and verifying commonly non-compliant elements through on-site inspections and commissioning report review (see Figure 14 and Figure 15). However, due to limited financial and human resources, other codes that support the health and safety of the public are often prioritized and code officials lack the time, tools, and resources needed to *also* strongly enforce complex energy code provisions (Landry, Hoye, and Su 2018; McCowan et al. 2014). These challenges are compounded as the complexity of energy codes increases over time.

To address these issues, some code compliance studies have emphasized the need to develop additional classroom-based training for code officials, but there is evidence that classroom-based training is not as effective as tailored technical assistance to support resource-constrained code officials (McCowan et al. 2014; Landry and Hoye 2018b). Programs that focus on applying knowledge to specific projects have a higher impact on energy savings (McCowan et al. 2014). Two examples of this are circuit rider and third-party programs.

Circuit rider programs are designed to give tailored technical assistance and training for code officials to support plan review and on-site verification efforts. These programs provide applied learning opportunities for code officials, which enables better concept retention than classroom-based learning (McCowan et al. 2014). Circuit rider programs also provide a mechanism to share resources for code officials; our study found that code officials are likely to benefit from resources such as documentation checklists for project teams and prioritized lists of high-impact code elements to confirm during plan review and site inspection. The circuit rider model has had success in improving energy savings derived from codes in Florida and Massachusetts. In Minnesota, a pilot program that provided technical assistance to code officials found per-building energy savings of 22,066 to 74,931 kWh and 433 to 1,301 therms, with an estimated per-building cost for a full-scale program of $4,520. The utility program cost-benefit ratio is projected to range from 9.0 to 15.6 for electric utilities and 2.81 to 9.4 for gas utilities (Landry, Hoye, and Su 2018).

While circuit rider programs typically provide technical support to local government code officials, third-party programs outsource energy code plan review, on-site inspections, and/or performance testing to third-party experts, helping to rapidly increase energy code compliance while reducing city staff workload. These types of programs have been implemented across various jurisdictions and have been found to have higher levels of quality assurance, cost savings, and quicker project processing times than traditional enforcement and verification models (Meres and Krukowski 2013; Meres et al. 2012; Williams and Price 2014). Circuit rider and third-party review services can be provided by the same organization(s), with certification and continuing education requirements ensuring the qualifications of individual providers. More information about successful circuit rider and third-party programs can be found in Appendix E: Guidance for Program Development.

Support for Design Teams

Design teams play a key role in maximizing energy savings from code elements through design decisions and clear documentation. However, our study found significant lost savings due to code elements that were either not specified in the design documents or were specified but did not meet energy code requirements. We found that 33 of the 78 projects in our study sample did not indicate whether IECC 2012 or ASHRAE 90.1-2010 was used; an additional nine projects indicated IECC 2012 but did not specify the C406 option path (see Table 5). Moreover, nearly all projects were missing documentation for at least one of the studied code elements and several code elements were well-documented in plans or specifications but did not comply with the energy code. This scenario of non-compliant design information was common for code elements requiring calculations, such as fenestration orientation, window-to-wall ratios, and fan power limits. In these instances, including supplemental calculations in the documentation would increase the capacity for quality control by both the design team and the code official. These issues span architectural, mechanical, and electrical items, indicating that this issue is not specific to a single professional discipline (see Results section on plan documentation and compliance). The lack of energy code information on design documentation has also been identified as a barrier to energy savings in other Minnesota and national studies (Landry, Hoye, and Su 2018; Hernick and Sivigny 2013; Lee and Tolgar 2015; U.S. Department of Energy 2013).

Programs that support design team training, education, and documentation of energy code pathways and code elements can both improve the industry's understanding of the energy code and help facilitate the plan review process. The most relevant example of such a program comes from Minnesota's 2018 Commercial Energy Code Compliance Enhancement Pilot (see Appendix E: Guidance for Program Development), which resulted in recommendations to deliver design team education through code officials and to prioritize early design-phase meetings and quick reference tools (Landry, Hoye, and Su 2018). Our study results support the usefulness of several of the resources developed for that pilot – such as the design team kick-off meeting, the applicability guide, and the documentation checklist – which could be updated to reflect specific lessons learned from our study. For example, design team kick-off meetings should include not only a discussion of the code pathways and option paths, but also a discussion of high-impact code elements based on building type/HVAC system, and education regarding commonly-missed or misunderstood code elements (such as receptacle controls, daylight zones, and VAV ventilation optimization).

Support for Controls Documentation and Commissioning

The implementation and commissioning of mechanical and lighting controls are critical to achieve the promised savings derived from energy codes. Since 2004, about 30 percent of energy code requirements have been related to building controls (M. Rosenberg et al. 2017). Our study revealed that non-compliance with control code elements and commissioning contributed to over three-quarters of total lost energy savings, primarily due to a lack of clear documentation in the design documents resulting in missed opportunities for energy efficiency measures during construction and operations. This aligns with the results of Minnesota's 2018 Commercial Energy Code Compliance Enhancement Pilot study, which found HVAC commissioning and lighting testing to be the top two code elements that contributed to lost savings from non-compliance.

As outlined in the results section of this report, a well-documented Sequence of Operations for a building's HVAC system is critical in ensuring that energy codes deliver savings. Without this, projects risk implementing control sequences that do not comply with code. Although commissioning of control systems is an additional method for ensuring building controls are performing well, our study found low compliance rates for both mechanical and lighting commissioning (60 percent and 49 percent, respectively).

Building owners may not fully understand the value of commissioning and may elect not to require this service for their projects. Studies have suggested that most owners implement commissioning to 1) ensure systems are performing properly, 2) meet LEED or other beyond-code program requirements, or 3) ensure that the construction and turn-over process runs smoothly (Lawrence Berkeley National Laboratory and Building Commissioning Association, n.d.). Yet, commissioning has been identified as "the single-most cost-effective strategy for reducing energy [and] costs" (Mills 2009, 2; U.S. Department of Energy 2019). Approximately 12 percent of a building's total energy cost could be saved if HVAC and lighting control code elements had higher compliance rates (M. Rosenberg et al. 2017).

A multi-pronged approach is needed to achieve effective implementation of controls and commissioning code elements. A program providing education to owners regarding the value of commissioning and the expectations for their project may help smooth the way for improved controls documentation and commissioning efforts. Providing additional guidance regarding commissioning requirements – as done in Washington State, California, and Austin, Texas – can help ensure proper documentation is submitted and cause commissioning agents to know that energy code compliance is included in their scope of work (M. Rosenberg et al. 2017). Programs supporting the enforcement of controls documentation through plan review, on-site spot checks of high-impact items, and review of a commissioning checklist could also capture some lost savings. Due to the complexity of control sequences and commissioning, a third-party expert may be better equipped than code officials on city staff to offer plan review and on-site inspection services.

Key Opportunities for Going Beyond the Current Energy Code

Although energy codes are an important tool in driving energy efficiency within the building sector, our data—along with other Minnesota and national studies—have indicated that "current energy codes are not delivering the level of building energy performance that is needed to meet energy and climate action goals" (New Buildings Institute 2017b). There are generally two pathways for meeting advanced energy goals beyond today's codes: 1) a prescriptive approach that continues to increase efficiency requirements or a 2) performance-based approach that is more holistic. These two approaches are already built into Minnesota's commercial energy code and more aggressive versions are being voluntarily adopted that could be utilized in programs to create greater savings. The subsequent sections identify three ways that Minnesota could further push beyond-code efforts:

- **Promote high-impact prescriptive strategies** to attain higher energy savings than current prescriptive baselines.
- **Promote energy modeling** to address non-regulated design decisions and help projects identify the most cost-effective strategies.
- **Address operational performance** to ensure promised energy savings are delivered and to capture additional savings from operational and behavioral strategies.

Promote High-Impact Prescriptive Strategies

Prescriptive strategies are relatively easy to understand and incorporate into construction documents, making them a useful tool for projects of all sizes and levels of sophistication. As described in the Results section above on beyond-code savings, many projects are achieving savings beyond prescriptive code requirements. Expanding the adoption of these market-ready, beyond-code elements to additional buildings can present a straightforward method to capture additional energy savings.

Our findings also suggest industry unfamiliarity with several code elements (such as receptacle controls, exterior lighting controls, and VAV ventilation optimization), as described in the Results section. Since this issue is likely to be compounded as prescriptive requirements become more complex, early exposure to future code requirements may contribute to higher compliance rates when these requirements become mandatory (New Buildings Institute 2017c).

Beyond-code prescriptive strategies – both the market-ready elements found in our study and the code elements found in the next code version – can be promoted through new construction CIPs like Xcel Energy's Energy Efficient Buildings (EEB) program, which offers customized rebate packages for new construction and renovation projects. Other utilities serving Minnesota offer similar programs.

Alternatively, some jurisdictions – such as New York State and Boulder, Colorado – are incorporating aggressive prescriptive approaches into their energy codes. The prescriptive path of Boulder's commercial energy code was initially based on the pre-assembled prescriptive design packages from the New Building Institute's (NBI) Advanced Buildings® New Construction Guides, which can deliver 15-35 percent energy savings over ASHRAE 90.1-2010 and IECC 2012 (Architecture 2030 2015). Similarly, New York State has developed a prescriptive stretch code option that can be adopted by local jurisdictions who are seeking to accelerate their energy savings. To read more about these examples, see Appendix E: Guidance for Program Development.

Promote Energy Modeling

As energy goals become more aggressive, the prescriptive approach of maximizing energy savings for individual building components is expected to soon reach its limits of cost-effectiveness for many building types (Northeast Energy Efficiency Partnerships 2017, 35; Nilles 2018). Several building elements that contain additional energy savings cannot easily be formulated prescriptively, such as choice of HVAC or placement of glazing. To combat this issue, energy modeling has emerged as an important tool for achieving more aggressive energy goals. Through an analysis of more than 10,000 buildings that submitted predicted energy use to the AIA 2030 Commitment in 2018, it was found that modeled projects achieve an average of 25 percent higher energy savings than non-modeled projects (American Institute of Architects 2019). Stakeholders across the country suspect that future commercial energy codes will rely more on modeled performance in order to achieve the next real gains in building efficiency (M. I. Rosenberg et al. 2015; Karpman 2016).

In the 2015 Minnesota Energy Code, there are two performance pathways that allow design teams to demonstrate compliance through energy modeling: IECC 2012 Section 407 and ASHRAE 90.1-2010 Section 11 (also known as Energy Cost Budget method). Although these performance pathways offer greater design flexibility than their prescriptive counterparts, our study sample of 79 projects did not encounter a single project that used them. Our conversations with local and national design professionals have suggested that these pathways are not often used because of the extra time and cost of meeting the requirements for a verification model – which occurs too late in the design process to cost-effectively impact design. Several reported using early energy models to drive design decisions while using the prescriptive path for code compliance, which they deem to be 'easier' than the performance path unless there are major conflicts due to existing conditions or design goals – such as large amounts of glazing.

There are several ways CIPs can use performance modeling to their advantage. Xcel's Energy Design Assistance (EDA) program is one example that uses whole-building energy modeling to capture beyond-code savings. Utility program implementers work directly with design teams to evaluate the energy impacts and cost-effectiveness of bundled efficiency strategies. While the program's Standard track primarily evaluates how far to push regulated building elements (such as insulation or equipment efficiency) beyond their code requirements, the program's Enhanced track also incorporates early design analysis of non-regulated elements such as massing, building orientation, daylighting, and HVAC system types, enabling deeper savings. As an alternative to incentive-based CIPs, a Codes and Standards program could push the adoption of a more performance-centric code, which may be necessary for some communities in Minnesota to meet their aggressive energy goals. Regardless of mechanism, if predicted performance pathways are to be used as a tool to enable more stringent code requirements in the future, the design community in Minnesota will need to expand its modeling capabilities. It may be best to begin transforming this market sooner by promoting modeling capacity and training.

Address Operational Performance

Taking the notion of performance one step further, additional savings can be captured by verifying performance in building operations. Current codes do not extend into the operational phase of new construction and renovation projects, making it difficult to verify whether the savings from code elements such as control sequences and commissioning are being fully realized. In fact, just over a third of code elements we reviewed are dependent on building operations to achieve ongoing savings. During project walk-throughs, operators and maintenance staff often indicated that their top priority is responding to occupant comfort, which commonly includes adjusting temperature controls and system schedules at the expense of energy savings.

In addition, our study found that several high-impact code elements are difficult to confirm through on-site inspections. For example, fenestration U-values are nearly impossible to confirm on-site for custom assemblies and verifying the continuous air barrier requires reviewing many different detail conditions before they are covered by the exterior finish material. Similarly, verifying control sequences is a complex task requiring specialized knowledge, and the quality of HVAC and lighting commissioning can be difficult to judge from a commissioning report. Programs and code pathways that focus on operational energy use can provide a method for jurisdictions to ensure that savings from these code elements are being achieved.

Voluntary Programs

One current approach that addresses operational performance in Minnesota is training operators and maintenance staff to support building energy efficiency through voluntary programs such as the Building Operator Certification® program (BOC). Xcel Energy currently offers partial tuition reimbursement for applicants who are operating buildings over 50,000 square feet. This program could complement future CIPs that focus on controls and commissioning to capture high operational savings.

Another approach is to focus on outcome-based performance. Outcome-based programs establish energy targets during design and use actual, measured energy performance to confirm that projects are meeting these targets. By approaching energy savings from a whole building performance perspective, all stages of the building process can be accounted for, including design, construction, operation, maintenance, and occupant behavior (New Buildings Institute 2017a). This would provide a way to remedy missed savings from controls and commissioning.

Minnesota utilities could adopt a voluntary outcome-based program for new construction and renovation projects using the pay-for-performance (P4P) model. P4P programs reward project savings on an ongoing basis as they occur versus providing up-front payments to fund energy efficiency measures (Szinai 2017). A recent study that investigated the potential for implementing a P4P program in Minnesota's commercial market found statewide energy savings potential for new construction and renovations of 16,000 MMBtu for electricity and 8,700 MMBtu for natural gas (Hoye 2020). See Appendix E: Guidance for Program Development for more detail.

Outcome-based Code Pathway

Outcome-based programs can also take the form of code pathways, such as those implemented in Seattle, Washington and Boulder, Colorado (see Appendix E: Guidance for Program Development). The potential benefits of an outcome-based code pathway include (Martin, Papamichael, and Colker 2016):

1) reduction of the economic overhead associated with complex rule-sets
2) increased latitude for creative and integrative solutions to design problems
3) increased opportunity for systems approaches to meet user needs
4) actual rather than theoretical achievement of owner and community energy use goals
5) increased feedback loops to support design and operation of high-performing buildings
6) rapid and simple adjustments to changes in technology.

Due to simplified enforcement mechanisms, outcome-based codes could also help jurisdictions reduce the strain on the limited resources available to support energy code compliance and enforcement (New Buildings Institute 2017a, 4).

Like in Seattle, an outcome-based code pathway could begin as a voluntary pilot program that tests enforcement mechanisms, assesses energy and financial impacts, and evaluates market acceptance. Potential enforcement mechanisms include financial incentives and penalties in the form of performance bonds, fee-bates, tax programs, or utility rate structures (New Buildings Institute 2017a; Frankel 2012). Alternatively, other mechanisms focus on offsetting non-compliance through installation of community solar resources, capital for a revolving green loan fund, or other funds for public building energy improvement (New Buildings Institute 2017a, 25). Although the outcome-based code pathway offers an opportunity to simplify the energy code compliance process, it does introduce new contractual risks between design teams and owners and therefore "new market mechanisms will be needed to effectively 'distribute' responsibility for building performance" (Frankel 2012, 11, 12).

In order to successfully implement an outcome-based code or program, achievable and reasonable performance targets must be established that closely align with current code and policy goals (Frankel 2012, 8). Performance targets can be based on modeled technical potentials or local or national building energy data (New Buildings Institute 2017a). Robust building energy benchmarking programs can strengthen outcome-based programs and codes as they can help inform performance targets and create a process for reporting operational data. In Minnesota, several cities have already adopted benchmarking ordinances – including Minneapolis, Saint Paul, Edina, St. Louis Park, and Rochester – and others are working to join them.

Recommendations

Recommendations for reaching the full potential of the current energy code

As outlined in detail in our study results and opportunities sections, there is significant potential for capturing energy savings through improvements in meeting the current energy code. Below we provide several options, based on our study's findings, to reach the full potential of the current energy code.

Offer a menu of support options for code officials. There are two methods of support that we recommend considering to ensure that both code officials and project teams understand and meet the current energy code:

- **Circuit rider model.** Circuit riders are individuals who deliver energy code resources and on-call project technical support to code officials. This model provides support to code officials without any one jurisdiction needing to invest in these kinds of resources.
- **Third-party energy code reviewer.** Qualified third parties can provide a la carte energy code review and/or inspection services. These services can be targeted toward high-impact items requiring significant time or expertise (e.g. energy model review for performance path, control sequence documentation review, commissioning report review, on-site spot checks of control code elements). Alternatively, comprehensive energy code review and site inspection by a qualified third party could be considered. In Minnesota these services may be most relevant for projects with more complex window, HVAC, or control systems.

Develop a shared set of energy code resources. To help ensure that all parties responsible for code compliance and enforcement have access to the information they need, provide a shared set of energy code resources. These resources could be developed and shared as part of a circuit rider program in consultation with the Department of Labor and Industry and the Department of Commerce, with code officials and/or third-party energy code reviewers disseminating to project teams as needed.

- **A sample agenda** for hosting early design kick-off meetings with design teams to discuss energy code requirements, compliance paths, and potential project challenges.
- **Phase-specific checklists** that highlight code elements with the greatest energy impact and enable users to easily identify energy code requirements that are applicable to a project, track energy code compliance through the design process, and identify documentation requirements. We also suggest considering requiring completed checklists to be submitted to the code official to assist with plan review and site inspection. Refer to Minnesota's 2018 Commercial Energy Code Compliance Enhancement Pilot and Appendix D: Phase-Specific Project Checklist for sample items to include.
    - The design phase checklist should be targeted at the design team and plan reviewer and should include energy code elements that are commonly designed to be non-compliant or frequently missing from documentation, which were two issues identified in our study.
    - The construction phase checklist should be targeted at the contractor and building inspector and shared with the commissioning agent. This should include energy code

    - elements with the highest potential to be implemented incorrectly on site, such as control sequences.
    - The testing and commissioning phase checklist should be targeted at the commissioning agent and code official, and should include high-impact commissioning items.
- **Energy codec interpretation guidance for HVAC commissioning** that identifies recommended enforcement pathways, documentation requirements, and example documents for projects using ASHRAE 90.1-2010, including for projects under 50,000 square feet. This may also include commissioning resources to share with building owners, including a cost-benefit analysis and sample requests for proposals for commissioning services.
- **Protocols** for code officials to request additional documentation from project teams for energy code elements that could not be verified on-site, and guidance for conducting spot checks for compliance with mechanical and lighting control code elements.

Leverage existing new construction programs. Existing new construction programs implemented by Minnesota utilities offer an already-established touchpoint with design and construction teams that could be leveraged to provide energy code support and resources. For example, early design team meetings for the Energy Design Assistance (EDA) program could include a discussion of energy code compliance pathways and provide the design phase checklist of high-impact code elements. EDA plan review and site visits could incorporate verification of these energy code elements, allowing the program to take credit for associated energy savings.

Recommendations to achieve savings beyond current energy code

In our study, we found that a number of building projects were including energy code elements that exceed code levels of performance. With that in mind, we recommend exploring ways to more broadly achieve savings beyond current energy code. As mentioned above, there are generally two pathways for meeting advanced energy goals beyond today's codes: 1) a prescriptive approach that continues to increase efficiency requirements or a 2) performance-based approach that is more holistic. The following recommendations incorporate these pathways into the Minnesota commercial market.

Expand prescriptive new construction programs. A number of Minnesota utilities already implement prescriptive new construction programs such as Energy Efficient Buildings (EEB). We recommend expanding such programs to take advantage of the market-ready beyond-code energy efficiency strategies identified in the Results section of this report. We also recommend incorporating prescriptive energy code elements from future code versions and/or offering different bundles or tiers of strategies into EEB-type programs, similarly to the EDA program and NBI's Advanced Building New Construction Guides. These types of program enhancements would allow more opportunities to incorporate beyond-code strategies for projects that cannot access or do not qualify for simulation-based programs such as EDA due to their location or small size.

Conduct a market analysis of commercial building energy modeling in Minnesota. Energy modeling serves as an important tool for achieving energy savings beyond energy code baselines. A market analysis of energy modeling practices would identify the barriers to using performance-based energy code pathways. The outcomes of a market analysis would allow state institutions to take steps to bolster the use of energy modeling for performance analysis in the state. This work can help inform future energy codes, enforcement approaches, design tools, and resources.

Expand reach and function of performance-based new construction programs. High beyond-code energy savings can be achieved through simulation-based new construction programs that include early design analysis of non-regulated elements, such as building massing, orientation, window placement, and HVAC system type. Xcel Energy's EDA Enhanced track is one example of this type of program. We recommend expanding these programs to utilities that currently do not provide such a service and working to increase participation by 1) easing eligibility requirements such as building size minimums and requirements to register for a third-party green building program, and 2) conducting additional recruiting.

Implement a voluntary whole-building pay-for-performance program. As described above, pay-for-performance programs reward project savings on an ongoing basis as they occur versus providing up-front payments to fund energy-efficiency strategies. Directed at new commercial construction projects, such a program can incentivize savings derived from operational energy use and inform the development of a future outcome-based energy code pathway.

Evaluate options for new energy code pathways within the recommended Codes and Standards program. The roadmap that is currently being developed with funding from the Department of Commerce will identify pathways for utility Conservation Improvement Programs (CIP) to create a statewide energy codes and standards program. While that roadmap is not yet published, we recommend that the following options are evaluated for achieving savings through future energy codes.

- Adopt more aggressive prescriptive and performance-based pathways as the state building energy code, including more specific commissioning requirements. As part of this, we recommend prioritizing the simplification of the number of compliance pathways to reduce confusion among designers and code officials around energy code requirements.
- Develop a step energy code option for adoption by local jurisdictions with both prescriptive and performance-based pathways that achieve higher energy savings than the base code. Consider starting with the next code version for the prescriptive pathway of the step energy code. This can offer an opportunity for building professionals to achieve savings beyond code and look ahead to the next code cycle, contributing to higher compliance rates when it is adopted into the base energy code.
- Develop a pilot outcome-based energy code pathway to determine if this could positively impact energy code enforcement, compliance, and energy savings in Minnesota. As part of the pilot, we recommend evaluating enforcement mechanisms, assessing energy and financial impacts, and collaborating with a diverse set of stakeholders to assess market barriers and opportunities.

Ideas for future research

Over the course of this research, we identified a number of additional ideas for future research to help support the understanding of the energy performance of the commercial new construction market. These ideas include:

- In-depth interviews of the following actors in the commercial new construction market:
    - Design teams to identify areas of new construction design and energy code that they may have trouble addressing, and the reasons behind the selection of code compliance pathway, ASHRAE vs. IECC, and prescriptive vs. performance.
    - Code officials to identify gaps in their understanding of the energy code elements and gaps they observe in their review of submittal documents. Interviews could also help identify energy code elements they struggle to verify.
- Future new construction baseline studies could consider recruiting a smaller number of new construction projects to collect data on design and construction practices ranging from early design through occupancy. The intent of such research would be to provide a holistic view of how the building energy codes are implemented in design and construction. This would address some of the limitation of this study that provided more of a snapshot view each building in our study sample. Such research could leverage lessons learned from this study, including recruiting, timeline, budgeting, and interaction with project teams and code officials.

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Appendix A: Data collection spreadsheet

Screenshots of the data collection spreadsheet are as follows. Note that the lost savings calculations for each code element is not shown.

Building Code Verification Record

Copy row: Select any cell on row, then hit this button. Copy rows when measures apply differently to parts of building.

Delete Dup Row

Code Required Factors or conditions must match actual code, option path chosen, or performance baseline.

Building Information

Conditioned Floor Area of Scope		sq ft
Building Type		
ASHRAE Climate Zone		
Number of stories		
Scope		
Which option path?		
Compliance Path?		

Initialize applicabilty after Equip, CZ or Bldg type is changed

Discrete code indicators (see comment):

IECC 2012: *

ASHRAE 90.1-2010: +

Building Identifier		
City/St		MN
Actual code		
HVAC System Type		
Occupancy		
Occ'pcy 2		
Occ'pcy 3		100%
Building Address		

Building comments:

Document project scope (important to note for renovation projects) and how the code compliance path was confirmed (i.e. confirmed through plans or through contacting project team, etc). Also document garage area if the building has parking garages. Indicate the role of the person you met on site (i.e. facility manager, contractor, design team

New Construction or Major Renovation	
Who did the plan review and site visit?	Name of person
Construction stage at time of site visit?	

Equipment in Building:

- DX cooling
- Gas Furnace
- Air-to-Air Heat Pump
- WSHP
- VAV Reheat System
- Gas/Oil Boiler
- Air-Cooled Chiller
- Water-cooled Chiller

0
1
1

73 Meas Incomplete

Total measure time:

				Code or Performance Requirement		***Plan Takeoff Condition***			***As Found Condition***						
Measure #	**Measure name** (see requirements tab for items included)	**Apply to Bldg**	**Factor Units**	**Factor**	**Discrete Condition**	**Observ.**	**Factor**	**Discrete Condition or Quality**	**Verif Lvl**	**Factor**	**Discrete Condition or Quality**	**Affected quantity**	**Applicabile units**		**Measure specific Comments**
5012	Roofs shall be insulated to meet CZ requirements	Y	U-factor								Select Condition		ft2 net roof area	X	
5014	Low slope roofs in CZ 1-3 shall be cool roofs	N	Reflectance										ft2 of net roof area		
5018A	Above grade frame walls shall be insulated to meet CZ requirements	Y	U-Factor								Select Condition		ft2 net opaque wall area	X	
5018B	Above grade mass walls shall be insulated to meet CZ and density requirements	Y	U-factor								Select Condition		ft2 net opaque wall area	X	
5023A	Exterior frame floors shall meet the insulation requirements	Y	U-factor								Select Condition		ft2 exterior floor	X	
5023B	Exterior mass floors shall meet the minimum R-value or U-value by assembly type	Y	U-factor								Select Condition		ft2 exterior floor	X	
5029B	Opaque rollup doors shall meet U-factor requirements	Y	Door U-factor										ft2 doors	X	
5034	Window-to-wall ratio shall meet maximum limits	Y	% window area										ft2 Gross Wall Area	X	
5035	Skylight to roof ratio shall meet maximum limits	Y	% skylight area										ft2 Gross Roof Area	X	
5042A	Windows shall meet U-factor requirements	Y	U-Factor										ft2 window affected	X	
5042B	Windows shall meet SHGC requirements	Y	SHGC										ft2 window affected	X	
5043A	Skylights shall meet U-factor requirements	Y	U-Factor										ft2 skylight affected	X	
5043B	Skylights shall meet SHGC requirements	Y	SHGC										ft2 skylight affected	X	

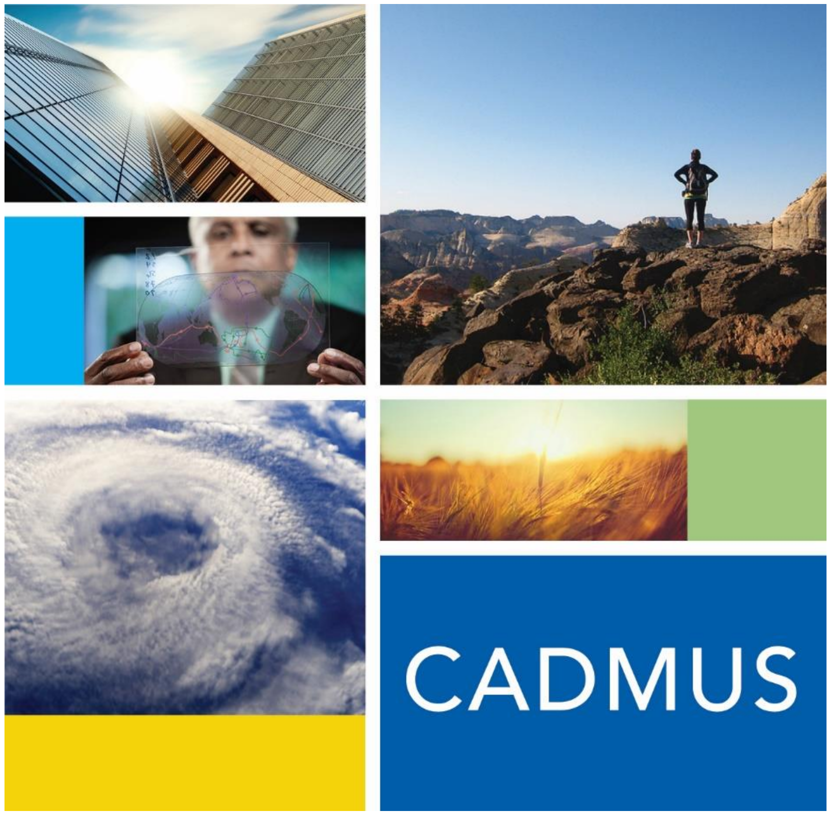
5056	Building shall meet continuous air barrier requirements	Y			(* ** + ++) Not tested; Mtls or assemb DO cmply; CAB sealed and intact			Select Condition			Select Condition		ft2 thermal envelope, excluding slab floor/UG walls	X	
5075	Fenestration assemblies shall meet air leakage requirements	Y			(^ * ** - + ++) Windows and doors labeled as meeting			Select Condition			Select Condition		ft2 fenestration	X	
5077	Stair and shaft vent leakage	Y			(^ * ** - + ++) Dampers normally closed; Good weather stripping and seals; Dampers meet leakage requirements			Select Condition			Select Condition		# of shafts and stairwells	X	
5083	Building entrances shall be protected with an enclosed vestibule	Y			(^ * ** - + ++) Vestibule Installed; Interior/exterior doors open different times			Select Condition			Select Condition		# of Entrances	X	
5089	Fenestration orientation	Y	ft2 of excess E + W window area	0									ft2 of total window area	X	
6005A	Packaged air conditioner efficiency	Y	EER										Tons cooling	X	
6005B	Packaged heat pump efficiency	Y	HSPF										MBh heating	X	
6005C	Gas furnace efficiency	Y	Ec										MBh heating	X	
6005D	Boiler efficiency	Y	Ec										MBh heating	X	
6005E	WSHP efficiency	Y	COP										Tons cooling	X	
6007A	Air-cooled Chiller efficiency	Y	EER										Tons cooling	X	
6007B	Water-cooled Chiller efficiency	Y	kW/ton										Tons cooling	X	
6017	Heat pump supplementary heat control	Y			(^ * ** - + ++) Lockout Sup Heat above OA setpoint >30F and <=40F; and Comp lockout below OA setpoint <=15F; or special t'stat with ramping setpoint						Select Condition		MBh heating (HP only, exclude supplemental)	X	
6018	Thermostat deadband requirement	Y	deg.F										ft2 floor area affected	X	
6019A	Thermostat heating setback	Y	deg.F										ft2 floor area	X	
6019B	Thermostat cooling setback	Y	deg.F										ft2 floor area affected	X	
6019C	Night fan control	Y			(* ** - + ++) Fan Cycles during Unoccp and warmup by Schedule or sensor; or DOAS with fan always cycling			Select Condition			Select Condition		Total supply fan CFM	X	
6023	Optimal start controls	Y			(* ** - +) Optimum Start; no OA sensor			Select Condition			Select Condition		ft2 floor area affected	X	
6026p	Freeze protection, snow and ice-melting system control	Y			(^ * ** - + ++) Snow Melt only if OA <40F or readily accessible manual; and Pavement <50F; and Percipitation sensor; Freeze protection when OA is above 40F			Select Condition			Select Condition		ft2 of heated surface area	X	
6029	Demand control ventilation	Y			(^ * ** - + ++) DCV installed			Select Condition			Select Condition		ft2 space area qualified for DCV	X	
6030	Energy recovery requirement	Y			(^ * ** - + ++) ERV installed; Egy Recvy Ratio =>50%; Bypass OA or control in Econo			Select Condition			Select Condition		cfm OA	X	
6033p	Duct insulation	Y	R-value of duct insulation										ft2 exterior duct surface	X	
6035	Duct leakage requirement	Y			(^ * ** - + ++) Sealed As Required			Select Condition			Select Condition		SA cfm affected (only applies to ductwork outside conditioned space)	X	
6042B	Hydronic Piping HW Insulation Requirement	Y	R-value of pipe insulation										Total pipe length (Lin ft) HWS + HWR	X	
6045p	Mechanical Commissioning	Y			(* ** - + ++) Commissioned; Satisfactory Quality			Select Condition			Select Condition	0	ft2 floor area	X	
6046A	Fan power limit requirement for PkgAC	Y	nhp or bhp										Total supply fan CFM	X	
6046B	Fan power limit requirement for VAV	Y	nhp or bhp										Total supply fan CFM	X	

6051	Outdoor heating: radiant and controlled	Y			Select Condition			Select Condition			Select Condition		MBh heating	X	
6056	Economizer supplies 100% design supply air	Y	OA% available for econo.										Tons mechanical cooling	X	
6058	Economizers should have appropriate high-limit shutoff control and be integrated	Y			(^ * ** - + ++) HiLim 75; Integrated			Select Condition			Select Condition		Tons mechanical cooling	X	
6066p	Water economizer capacity meets requirements	Y	Water Econo Cooling tons output									0.0	Tons cooling not covered at given conditions	X	
6070	Multi-zone reheat systems shall be VAV with appropriate zone minimums, and fans with motors ≥threshold hp shall be variable speed or pitch	Y	sum of zone reheat min cfm		(^ * ** - + ++) Variable speed fan with VSD; or vari-pitch axial fan			Select Condition			Select Condition		Total fan CFM	X	
6071	Static pressure reset for multi-zone VAV fans	Y			(^ * - +) Static pressure reset at least 0.5" w.c.; with the max setpoint ≤1/3 of design pressure			Select Condition			Select Condition		Total fan CFM	X	
6089	Each WSHP in a system exceeding 10 hp pump shall have a two-position valve	Y			(^ * ** + ++) Individual WSHP valves; VSD on pumps			Select Condition			Select Condition		pump nameplate HP	X	
6090	Hydronic systems > 300 MBH shall reset supply water temp or reduce system flow	Y	% min flow										Heat + Cooling Pump nameplate hp	X	
6091p	Multiple chiller shall reduce flow when a chiller is shut down	Y			(^ * ** - + ++) Individual chiller valves; and separate pumps for each chiller or VSD on common pump			Select Condition			Select Condition		Tons cooling	X	
6094	Tower Fans ≥ 7.5 hp shall have variable speed control	Y	% min fan speed										Tower fan nhp	X	
6101	Multiple zone HVAC systems shall have supply-air temperature reset controls	Y			(^ * ** - + ++) SAT is reset; ≥ 25% des SA to Space reset			Select Condition			Select Condition		Total fan CFM	X	
6106AS	VAV ventilation optimization	Y			Select Condition						Select Condition		OA cfm	X	
6108AS	Single zone VAV	Y	% min fan speed										Supply cfm	X	
6109pAS	Parking garage fan controls	Y			Select Condition			Select Condition			Select Condition		Fan hp	X	
6110pAS	Zone Isolation	Y			Select Condition			Select Condition			Select Condition		ft2 spaces not isolated and running during off hours	X	
7002A	Water heater efficiency, Gas	Y	Heating efficiency										SWH MBh	X	
7006	SWH Pipe Insulation	Y	R-value of pipe insulation										LF SHW Pipe	X	
9003	Manual lighting control	Y			Select Condition			Select Condition			Select Condition		ft2 floor area affected.	X	
9009	Automatic time switch control	Y			Select Condition			Select Condition			Select Condition		ft2 floor area affected	X	
9011	Occupancy sensor control	Y			Select Condition			Select Condition			Select Condition		ft2 floor area required to have occupancy sensors	X	
9014A	Daylighting control	Y			Select Condition			Select Condition			Select Condition		ft2 of floor area where DL controls req'd	X	

9014B	For large, high-bay spaces total daylight zone under skylights at least 1/2 of floor area	Y			(* ** + ++) Daylight zone w/; stepped dimming			Select Condition			Select Condition		ft2 of floor area where DL controls req'd	X	
9025	Display lighting control	Y			(^ * ** - + ++) Display lighting controlled separately			Select Condition			Select Condition		Display Watts (W)	X	
9029	Lighting for nonvisual applications shall be controlled separately	Y			(* ** - + ++) Accessible separate control device			Select Condition			Select Condition		Uncontrolled Watt	X	
9031	Exterior lighting control	Y			Select Condition			Select Condition			Select Condition		Exterior Watts Affected	X	
9037	Interior lighting power allowance	Y	Watts interior lighting except retail display									0	ft2 floor area	X	
9047	Additional retail lighting power allowance	Y	Watts retail display lighting											X	
9048	Exterior lighting power allowance	Y	Exterior Total Watts											X	
9054AS	Occupant based parking garage light control	Y			Select Condition			Select Condition			Select Condition		W Parking garage lighting	X	
9055pAS	Receptacle controls	Y			Select Condition			Select Condition			Select Condition		Floor area subject to control, sq ft	X	
9099p	Lighting Testing or Commissioning	Y			(^* ** + ++) Commissioned; Satisfactory Quality			Select Condition			Select Condition	0	ft2 floor area	X	
10001	Kitchen exhaust and makeup air control	Y			Select Condition			Select Condition			Select Condition		Exhaust CFM	X	
10002	Indoor pool cover	Y			Select Condition			Select Condition			Select Condition		Pool Water Surface Area	X	
15007	Optional onsite renewable	Y	Annual kWh											X	

Appendix B: Data collection protocol

See next page for data collection protocol.



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IMT Commercial Buildings Energy Code Field Study - Data Verification Protocol Version 1.0

Modified by Slipstream, November 2018

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November 2018

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Table of Contents

Introduction

This document was modified by Slipstream based on The Cadmus Group's original Data Collection Protocol, in support of the Minnesota Commercial Energy Baseline and Market Characterization Study. The data verification protocol provides guidance on generic code requirements and compliance checks for each energy code measure specified in the accompanying *Data Collection Form and Data Collection iAuditor App*, two tools used to capture all key information needed for the Minnesota code compliance analysis. The data verification protocol is intended for use with the 2012 IECC with Minnesota Amendments. It is the responsibility of the data collection team to be knowledgeable of the MN state energy code and its provisions.

The protocol details how key information should be entered into the data collection form for each measure, offers tips for completing plan reviews and making in-field observations, and provides photographs and illustrations for various measures.

Data Collection Process

For the Minnesota Commercial Energy Baseline and Market Characterization Study, data collection teams are expected to follow three important steps listed below:

The protocol is designed for the data collection team to first conduct the plan review portion of the data collection process prior to the walk through of the building. However, our team recognizes that data collection teams might need to conduct field inspection step first for a few site visits.

Plan Review

In this step, data collection teams will review the building plans, energy code compliance documents (COMCheck or performance approach), and any other supporting documentation to identify key information for each measure listed on the data collection form and within this protocol for the analysis. Data collection teams should:

- Request the following from the design team or project contact: mechanical and architectural plans and specifications and COMCheck reports.
- Print out or refer to sheet index, floor types, wall plans and elevation plans. Elevation plans will help you calculate window-to-wall ratio and get an idea of what the building looks like.
- Get the minimum base code requirements from the energy code compliance documents; if documentation is not available, the team will need to assume base prescriptive requirements for the applicable energy code. Minimum base code requirements should be documented for each measure in the data collection form.
- Note plan review findings for each measure as described in each of the data collection form sections. It is required to note factor units specified in the Code Requirements and Compliance Checks section along with the affected quantity (see data collection form for units) on the data collection form.

Building Department Visit

Data collection teams should reach out to building departments prior to the site visit to clarify the data request protocol that needs to be followed. If required by the building department, data collection teams are recommended to submit data request for the necessary documents for plan review ahead of time prior to the site visit.

Data Collection Form

The data collection form and app were developed to capture all pertinent information needed for each code measure. Data collection teams can choose to fill out the form electronically or use the iAuditor app. The data collection form has six main sections:

- Building Information
- Envelope
- Mechanical
- Lighting

- Other
- Renewables

Guidance for completing the various sections of the data collection form are provided in the Code Requirements and Compliance Checks of this data collection protocol. Data collection teams are required to fill out all the information applicable to the building, as requested in the data collection form. Please note that cells requiring input are coded in ivory and cells requiring unit selection are coded in orange. Where there are different code requirements, assemblies, equipment, or compliance levels in parts of the building, data collection teams are required to make copies of certain sections of the form as described in the data collection form instructions and input the different conditions separately. The data collectors for plan reviews and field inspections should provide their name and note the building identifier (as assigned by data collection teams) on the cover of the data collection form before the data collection process begins.

Field Inspection

In this step, data collection teams will walk through the building during their site visit and observe the as-found conditions to identify key information for each measure listed on the data collection form and within this protocol for the analysis.

Preparation for the Site Visit

Field inspectors are advised to gather the following items for their site visit:

1. **Tablet**– access to iAuditor.
2. **Drawings** – relevant sections can be printed out. It is a good idea to print out lighting plans and mechanical plans.
3. **Business cards and Identification**
4. **Camera** (cell phone camera is sufficient as a back-up to the tablet's camera)
5. **Safety tools** – Ladder, mask, goggles, flashlight
6. **Technical tools** – light level meter
7. **Measurement tools –** Architect's scale ruler for plan takeoffs, tape measure, laser measuring tool

Ideally, all the data that is collected during field inspection will be viewable out on the site. The Code Requirements and Compliance Checks section provides recommendations for data collection strategies when a feature for a specific measure is not viewable so that a similar level of confidence is achieved for data collection.

During Site Visit

Data collection teams are expected to walk through the building and note the as-found condition for each measure on the iAuditor app. Before you begin your walk through, please provide your name and note building identifier on the title page of the iAuditor app.

Data collection teams are also expected to take photos of products, labels, and observed conditions for each measure through the iAuditor app; photos should be taken using the app software. It is the researchers responsibility to ensure that all pictures taken through the app or on an external camera are clear and in focus.

Data Storage and Quality Control

Once a data collection activity is completed, the data collection teams shall perform quality control on all data collection forms to make sure there are no discrepancies or errors.

Slipstream has setup a cloud-based External Shared Site for data collection teams to upload their documents for their data collection activities. Site link and detailed descriptions on how to use the site will be provided during data collection training sessions to the data collection teams. A link to the Sharepoint Site is here.

Completed data collection forms, iAuditor exported files, site photos taken, and copies of relevant documents (e.g. energy code documentation) collected on site shall be uploaded to the specific site folders on the Slipstream External Shared Site.

Personally Identifiable Information

Personally identifiable information (PII) is sensitive personal information which can be used to distinguish or trace an individual's identity, such as their name, social security number, date and place of birth, or driver's license and state ID information. For this project, we do not expect the research team to collect any PII.

Ongoing Support:

Please reach out to the following Slipstream Point of Contacts if you have any data collection activity related questions.

Tianyao Zhang
tzhang@slipstreaminc.org
608-210-7158

Jeannette LeZaks
JLeZaks@slipstreaminc.org
608-210-7156

Scott Hackel
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608-210-7129

Code Requirements and Compliance Checks

Envelope Measures

Measure Name	Measure Number	Code Section
Roof Insulation	5012	2012 IECC: 402.1.2

Measure Description

Roofs shall be insulated to meet the minimum requirements defined in the applicable energy code. A minimum insulation U-factor is listed in the code based on the climate zone and assembly type.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the architectural drawings set and energy code compliance documentation to determine the proposed roof insulation U-factor. Check the roof assembly cross sections in drawings (Figure 1 below). Roof insulations are shown with different symbols based on the insulation type, such as loose fill, rigid, or spray foam (Figure 2). The symbols can be verified in the symbol legend, which is typically within the first few pages of a drawing set.
3) If this measure applies to your building, mark it in the *Roof* section of the data collection form and provide the required information:
   a) Fill out the *Envelope - Roof Assembly* section of the data collection form and provide a description, detail (such as product information), and effective R-value for each layer of the roof assembly. Calculate the Assembly U-factor once the information for all layers of the roof assembly is noted.
   b) Once the Assembly U-factor is calculated, fill out the *Roof* section of the data collection form.

Field Inspection

1) If roof insulation is in the construction stage and visible:
   a) Determine the roof insulation R-value for all layers of the roof assembly.
   b) Verify the Assembly U-factor matches the Assembly U-factor calculated during plan review. If there are any discrepancies and layers do not match the Assembly U-factor calculated in plan review stage, note it on the data collection form and recalculate the Assembly U-factor.
   c) Rate and record the installation quality of the insulation:
      - Good installation
      - Fair installation = gaps over 2.5% area
      - Poor installation = gaps over 5% area
2) If roof insulation is not visible:
   a) Request shop drawings for the roofing system from the onsite construction superintendent and product specifications from the insulation contractor.
   b) Verify the Assembly U-factor matches the Assembly U-factor calculated during plan review. If there are any discrepancies and layers do not match the Assembly U-factor calculated in plan review stage, please note it on the data collection form and recalculate the Assembly U-factor.

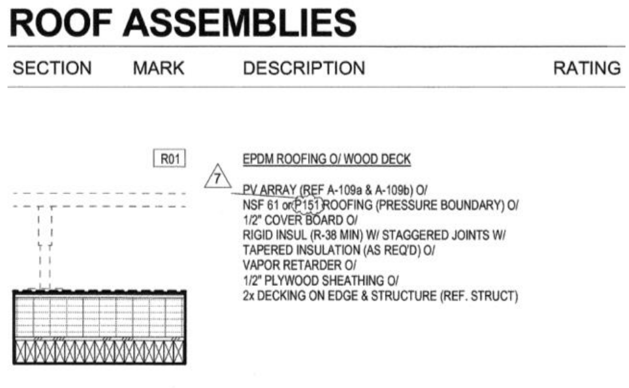


Figure 1 . Roof Assembly Cross Section

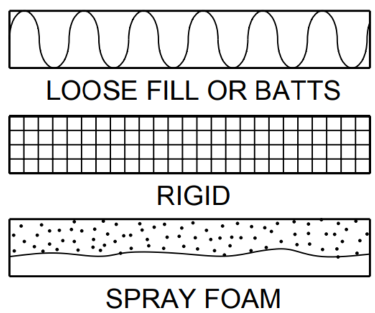


Figure 2. Insulation Types in Architectural Drawings

Figure 3. Attic Insulation and Insulation Entirely Above the Roof Deck[1]

Figure 4. Roof Insulation in Metal Buildings[2]

[1] Source: Britt/Makela Group and Ryan Meres. 2009 International Energy Conservation Code for Simple Commercial Buildings Compliance Guide. 2014

[2] Source: Department of Energy. Evaluating Commercial Buildings for Energy Code Compliance. September 2010.

Measure Name	Measure Number	Code Section
Above grade frame walls shall be insulated to meet climate zone requirements	5018A	2012 IECC: C402.2.3

Measure Description

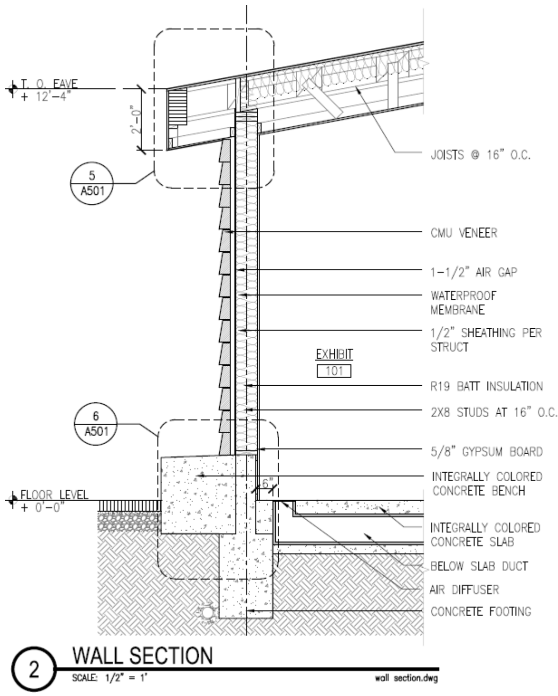
Above grade walls shall meet the minimum insulation requirements defined in the applicable energy code. A minimum insulation U-factor is listed in the code based on the climate zone and assembly type. Refer to the code for the specifics of what can and cannot be counted as the U-factor.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the architectural drawings set and energy code compliance documentation to determine the proposed wall U-factor. Check the wall assembly cross sections in drawings (see example below). Wall insulations are shown with different symbols based on the insulation type, such as loose fill, rigid or spray foam (see roof insulation example). The symbols can be verified in the symbol legend, which is typically within the first few pages of a drawing set.
3) If this measure applies to the building, mark it in the *Walls* section of the data collection form and provide the required information:
    a) Fill out the *Envelope* - *Wall* section of the data collection form and provide a description, detail (such as product info), and effective R-value for each layer of the wall assembly. Calculate the Assembly U-factor once the information for all layers of the wall assembly is noted using the handouts provided at the training or the ASHRAE Handbook – Fundamentals.
    b) Once the Assembly U-factor is calculated, fill out the *Walls* section of the data collection form.

Field Inspection

1) If wall insulation is in the construction stage and visible:
    a) Determine the wall insulation R-value for all layers of the wall assembly.
    b) Verify if the Assembly U-factor matches the Assembly U-factor calculated during plan review. If there are any discrepancies and layers do not match the Assembly U-factor calculated in plan review stage, note it on the data collection form and recalculate the Assembly U-factor
    c) Rate and record the installation quality of the insulation:
        i) Good installation
        ii) Fair installation = gaps over 2.5% area
        iii) Poor installation = gaps over 5% area
2) If wall insulation is not visible:
    a) Request shop drawings for the wall assembly from the onsite construction superintendent and product specifications from the insulation contractor.
    b) Check the inspection records from authority having jurisdiction (AHJ).
    c) Verify if the Assembly U-factor matches the Assembly U-factor calculated during plan review. If there are any discrepancies and layers do not match the Assembly U-factor calculated in plan review stage, please note it on the data collection form and recalculate the Assembly U-factor.



Example of Wall Assembly Cross Section


Examples of Cavity Insulation and Continuous Insulation respectively[3]

[3] Source: Britt/Makela Group and Ryan Meres. 2009 International Energy Conservation Code for Simple Commercial Buildings Compliance Guide. 2014

Measure Name	Measure Number	Code Section
Above grade mass walls shall be insulated to meet CZ and density requirements	5018B	2012 IECC: C402.2.3

Measure Description

Above grade walls shall meet the minimum insulation and weighing requirements defined on the statewide energy code. A minimum insulation U-factor is listed in the code based on the climate zone and assembly type. A minimum weighing requirement for mass walls is also defined in the code in terms of density of wall surface area.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the architectural drawings set and energy code documentation to determine the proposed wall assembly U-factor, framing type, and framing spacing or mass wall.
3) Check the wall assembly cross sections in drawings. Wall insulations are shown with different symbols based on the insulation type such as loose fill, rigid or spray foam (See roof insulation example). The symbols can be verified in the symbol legend, which is typically within the first few pages of a drawing set
4) If this measure applies to your building, mark it in the *Walls* section of the data collection form and provide the required information:
    a) Fill out the *Envelope - Wall* section of the data collection form and provide a description, detail (such as product info), and effective R-value for each layer for the wall assembly. Calculate the Assembly U-factor once the information for all layers of the wall assembly is noted using the handouts provided at the training or the ASHRAE Handbook – Fundamentals.
    b) Once the Assembly U-factor is calculated, fill out the *Walls* section of the data collection form.
    c) Verify mass wall densities and note any issues in the *Walls* section of the data collection form.

Field Inspection

1) If wall insulation is in the construction stage and visible:
    a) Determine the wall insulation R-value for all layers of the wall assembly.
    b) Rate and record the installation quality of the insulation:
        i) Good installation
        ii) Fair installation = gaps over 2.5% area
        iii) Poor installation = gaps over 5% area
    c) Verify if the Assembly U-factor matches the Assembly U-factor calculated during plan review. If there are any discrepancies and layers do not match the Assembly U-factor calculated in plan review stage, please note it on the data collection form and recalculate the Assembly U-factor. Fill out the *Envelope - Walls* section of the data collection form.
2) If wall insulation is not visible:
    a) Check the inspection records from the AHJ.
    b) Check wall thickness on site to determine if proposed insulation can fit into wall cavity.
    c) Verify insulation type from packaging found onsite in addition to viewing insulation through voids in the wall system, around windows and doors.
    d) Verify if the Assembly U-factor matches the Assembly U-factor calculated during plan review. If there are any discrepancies and layers do not match the Assembly U-factor calculated in plan review stage, please note it on the data collection form and recalculate the Assembly U-factor. Fill out the *Envelope - Walls* section of the data collection form.

Measure Name	Measure Number	Code Section
Exterior frame floors shall meet the insulation requirements	5023A	2012 IECC: 402.2.5

Measure Description

Exterior frame floors shall meet the minimum insulation requirements defined in the energy code. A maximum insulation U-factor is listed in the code based on the climate zone and framing type. Refer to the code for the specifics of what can and cannot be counted as R-value.
Plan Review
1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed. 2) Review the architectural drawings set and energy code compliance documentation to determine the proposed floor insulation U-factor. Check the floor assembly cross sections in drawings. Floor insulations are shown with different symbols based on the insulation type such as loose fill, rigid or spray foam (See roof insulation example). The symbols can be verified in the symbol legend, which is typically within the first few pages of a drawing set. 3) If this measure applies to your building, mark it in the *Floors* section of the data collection form and provide the required information: a) Fill out the *Envelope – Exposed Floor* section of the data collection form and provide a description, detail (such as product information), and effective R-value for each layer for the floor assembly. Calculate the Assembly U-factor once the information for all layers of the floor assembly is noted using the handouts provided at the training or the ASHRAE Handbook – Fundamentals. 4) Once the Assembly U-factor is calculated, fill out the *Floors* section of the data collection form
Field Inspection
1) If floor insulation is in the construction stage and visible: a) Determine the floor insulation R-value for all layers of the floor assembly. b) Rate and record the installation quality of the insulation, paying particular attention to cavity insulation: i) Good installation ii) Fair installation = gaps over 2.5% area iii) Poor installation = gaps over 5% area c) Verify if the Assembly U-factor matches the Assembly U-factor calculated during plan review. If there are any discrepancies and layers do not match the Assembly U-factor calculated in plan review stage, note it on the data collection form and recalculate the Assembly U-factor. 2) If floor insulation is not visible: a) Request information on the floor insulation system from the onsite construction superintendent and product information from the insulation contractor. b) Verify insulation type from packaging found onsite. c) Check the inspection records from AHJ. d) Verify if the Assembly U-factor matches the Assembly U-factor calculated during plan review. If there are any discrepancies and layers do not match the Assembly U-factor calculated in plan review stage, note it on the data collection form and recalculate the Assembly U-factor. 3) Record all findings in the *Envelope – Exposed Floor* section of the data collection form.

Measure Name	Measure Number	Code Section
Exterior mass floors shall meet the insulation requirements by assembly type	5023B	2012 IECC: 402.2.5
Measure Description		

Exterior mass floors shall meet the minimum insulation requirements defined in the energy code. A maximum U-factor is listed in the code based on climate zone and floor type.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the architectural drawings set and energy code compliance documentation to determine the proposed floor overall U-factor. Check the floor assembly cross sections in drawings. Floor insulations are shown with different symbols based on the insulation type such as loose fill, rigid or spray foam (See roof insulation example). The symbols can be verified in the symbol legend, which is typically within the first few pages of a drawing set.
3) If this measure applies to your building, mark it in the *Floors* section of the data collection form and provide the required information:
    a) Fill out the *Envelope – Exposed Floor* section of the data collection form and provide a description, detail (such as product information), and effective R-value for each layer for the floor assembly. Calculate the Assembly U-factor once the information for all layers of the floor assembly is noted using the handouts provided at the training or the ASHRAE Handbook – Fundamentals.
4) Once the Assembly U-factor is calculated, fill out the *Floors* section of the data collection form

Field Inspection

1) If floor insulation is in the construction stage and visible, determine the proposed floor insulation R-value of the insulation product and measure the thickness of the insulation. Verify insulation type from packaging found onsite in addition to viewing insulation through voids in the floor system.
2) Verify that the installed R-value meets the minimum R-value requirement shown on the drawings and energy code compliance documentation.
3) Verify that the thickness of the insulation is consistent across the floor assembly.
4) If applicable, verify mass floor densities.
5) Ensure the insulation is installed uncompressed and in permanent contact with the underside of the subfloor above. Rate and record the installation quality of the insulation:
    i) Good installation
    ii) Fair installation = gaps over 2.5% area
    iii) Poor installation = gaps over 5% area
6) Verify that the insulation is installed per manufacturer's instructions.
7) If floor insulation is not visible:
    a) Request information on the floor insulation system from the onsite construction superintendent and product information from the insulation contractor.
    b) Verify insulation type from packaging found onsite.
    c) Check the inspection records from AHJ.
8) Verify if the Assembly U-factor matches the Assembly U-factor calculated during plan review. If there are any discrepancies and layers do not match the Assembly U-factor calculated in plan review stage, note it on the data collection form and recalculate the Assembly U-factor.
9) If floor insulation is over outside air and covered up with soffit lining, check the inspection records from AHJ.
10) Record all findings in the *Envelope - Exposed Floor* section of the data collection form.

Measure Name	Measure Number	Code Section
Opaque rollup doors shall meet U-factor requirements	5029B	2012 IECC: C402.2.7

Measure Description

Opaque doors, or doors that have less than 50% glass area, shall meet the minimum insulation requirements defined in the energy code. A minimum insulation R-value or maximum U-factor is listed in the code based on the climate zone and assembly type.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the architectural drawing set and energy code compliance documentation to determine the proposed opaque roll up door U-factor. Verify, if possible, accurate NFRC 100 or ANSI/DASMA 105 certified U-factors, either on an NFRC label or certificate.
   a) Call NFRC to verify U-factor of the product if needed
3) If the door is unlabeled, use the values in ASHRAE 90.1 Section A7 Opaque Doors to determine U-factor.
4) Ensure that the U-factor shown on drawings and energy code compliance documentation has the proper value that will meet the maximum U-factor requirements of the energy code based on the assembly type and climate zone.
5) Record all findings in the *Rollup Doors* section of the data collection form.

Field Inspection

1) Verify make and model number of opaque roll up doors; get product specifications from the onsite construction superintendent, if available.
2) Record all findings in the *Rollup Doors* section of the data collection form.

Example of Opaque Rollup Doors[4]

[4] Source: Britt/Makela Group and Ryan Meres. 2009 International Energy Conservation Code for Simple Commercial Buildings Compliance Guide. 2014

Measure Name	Measure Number	Code Section
Window-to-Wall Ratio	5034	2012 IECC: C402.3.1

Measure Description

Window-to-wall ratio (WWR) shall not exceed maximum limits, as specified in the code.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Calculate percent (%) of the window area and note it in the data collection form.
3) Calculate ft^2 of gross wall area and note it in the data collection form.

Field Inspection

1) Spot check the window area in several spaces in the building where area take-offs were performed.
2) Photograph all orientations of the building.
3) Verify that daylighting controls meeting the requirements of IECC for WWR between 30% and 40% are present if WWR is greater than 30%, or that the building complied via the performance path or ASHRAE 90.1.
4) Record all findings in the data collection form.

Measure Name	Measure Number	Code Section
Skylight to Roof Ratio	5035	2012 IECC: C402.3.1
Measure Description		
Skylight to roof ratio shall not exceed the maximum limits as specified in the code.		
Plan Review		
1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed. 2) Determine SRR limit and designed SRR. 3) Perform area take-offs of skylights (one if all the same size) and determine total skylight area. 4) Determine gross roof area and calculate skylight to roof ratio. 5) Note all findings in the data collection form.		
Field Inspection		
1) Verify skylight size and confirm that the number of skylights and skylight area is consistent with what is shown on the plans. 2) Determine constructed SRR if different from plan take-off. 3) Note all findings in the data collection form.		

Measure Name	Measure Number	Code Section
Windows shall meet U-factor requirements	5042A	2012 IECC: C402.3.3

Measure Description

Windows shall not exceed the maximum rate of heat loss requirements per the energy code. A maximum heat loss rate is listed in the code based on the climate zone and fenestration type. Refer to the code for specific U-factor requirements.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the architectural drawings, specifications, and energy code compliance documentation to determine the fenestration U-factor for each window type.
3) Note affected quantity for each fenestration type.
4) Record all findings in the Envelope- Window U-factor section of the data collection form.

Field Inspection

1) Verify the U-factors for each window and determine the quantity for each type. Please note findings on the *Envelope – Window U-factor* section of the data collection form.
2) If the building envelope is in the construction stage and fenestration products are accessible, determine the product model and request product specifications.
3) Verify that the values on the National Fenestration Rating Council (NFRC) label (see example below) attached to the installed fenestration products match the U-factor values shown on the drawings and energy code compliance documentation.
4) Request copies of the NFRC certificates (if site-built windows, see example below) or product labels (if manufactured wood/vinyl/metal frame) from the construction manager or the authority having jurisdiction (AHJ). Only these three forms of NFRC certifications are acceptable:
   a) NFRC Label affixed to the fenestration product
   b) NFRC site-built procedure label certificate (either affixed to building or included in compliance documentation)
   c) NFRC Component Modeling Approach (CMA) label certificate (either affixed to building or included in compliance documentation).
5) If no information is available onsite, record window type, frame type, size, and number of panes.

WINDOW NO.	LOCATION	WINDOW OPENING			NO. OF PANELS	SILL HEIGHT AFF	MATERIAL/FINISH				DETAIL			
		WIDTH	HEIGHT	THICKNESS			WINDOW		FRAME		HEAD	JAMB	SILL	OTHER
1	EXHIBIT	6'–1"	11'–2"	1"	2	1'–4"	GL	LOW–E CLEAR	AL	–	SIM. 1/A603	SIM. 5/A603	SIM. 3/A603	SIM. 6/A603
2	EXHIBIT	12'–0"	14'–0"	1"	6	0'–0"	GL	LOW–E CLEAR	AL	–	SIM. 1/A603	SIM. 5/A603 8/A603	SIM. 3/A603	6/A603 4/A604
3	OFFICE	5'–5"	11'–0"	1"	1	3'–0"	GL	LOW–E CLEAR	AL	–	SIM. 1/A603	SIM. 5/A603	SIM. 4/A603	
4	OFFICE	5'–4 1/2"	8'–7 1/2"	1"	1	3'–0"	GL	LOW–E CLEAR	AL	–	SIM. 1/A603	SIM. 5/A603	SIM. 4/A603	
5	EXHIBIT	3'–0"	10'–0"	1"	2	0'–0"	GL	LOW–E CLEAR	AL	–	SIM. 1/A603	SIM. 5/A603	3/A603	SIM. 6/A603
6	EXHIBIT	5'–0"	10'–0"	1"	2	0'–0"	GL	LOW–E CLEAR	AL	–	SIM. 1/A603	SIM. 5/A603	3/A603	SIM. 6/A603
7	VESTIBULE	7'–8"	10'–0"	1"	3	0'–0"	GL	LOW–E CLEAR	AL	–	SIM. 1/A603	SIM. 5/A603 8/A603	3/A603	7/A603
8	CLASSROOM	2'–9 3/4"	10'–0"	1"	2	0'–0"	GL	LOW–E CLEAR	AL	–	SIM. 1/A603	SIM. 5/A603	3/A603	SIM. 6/A603
9	CLASSROOM	7'–11 3/8"	10'–0"	1"	2	0'–0"	GL	LOW–E CLEAR	AL	–	SIM. 1/A603	SIM. 5/A603 8/A603	3/A603	7/A603
10	EXHIBIT/VESTIBULE	6'–1"	10'–0"	1"	1	0'–0"	GL	LOW–E CLEAR	AL	–	1/A603	SIM. 5/A603 8/A603	3/A603	SIM. 6/A603 7/A603
11	EXHIBIT	24'–5 3/8"	3'–1 1/2"	1"	5	VARIES	GL	LOW–E CLEAR	AL	–	10/A603 1/A604	9/A603 3/A604	11/A603 2/A604	12/A603
12	EXHIBIT	20'–2"	3'–1"	1"	4	VARIES	GL	LOW–E CLEAR	AL	–	10/A603 1/A604	9/A603 3/A604	11/A603 2/A604	12/A603
13	CLASSROOM	45'–2"	5'–1 1/2"	1"	13	VARIES	GL	LOW–E CLEAR	AL	–	10/A603 1/A604	9/A603 3/A604	11/A603 2/A604	12/A603

05 WINDOW SCHEDULE

SCALE: –

Example of Window Schedule

Example of NFRC Label [5]

[5] Source: NFRC Website: http://nfrc.org/fenestrationfacts.aspx. Actual required values are determined by code requirements.

Measure Name	Measure Number	Code Section
Windows shall meet SHGC requirements	5042B	2012 IECC: C402.3.3

Measure Description

Windows shall not exceed the maximum Solar Heat Gain Coefficient (SHGC) requirements of the energy code. A required SHGC is listed in the code based on the climate zone; refer to the code for specific SHGC requirements.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the architectural drawings set windows schedule (provides the type of windows [aluminum, thermal break with low e, etc.] and dimensions; see example above) and energy code compliance documentation to determine the fenestration SHGC.
3) Ensure that the fenestration SHGC on the windows schedule on drawings match that the values shown in the energy code compliance documentation. Please note any discrepancies on the data collection form.
4) Ensure that the fenestration SHGC shown on drawings and the energy code compliance documentation has the proper values that will meet the requirements defined on the energy code based on the climate zone.
5) Record all findings in the data collection form.

Field Inspection

1) If the building envelope is in the construction stage and fenestration products are accessible, determine the product model and request product specifications.
2) Verify that the installed fenestration products match the SHGC values shown on the drawings and energy code compliance documentation.
3) Request copies of the National Fenestration Rating Council (NFRC) certificates (if site-built windows) or product labels (if manufactured wood/vinyl/metal frame) from the construction manager or the authority having jurisdiction (AHJ). Only these three forms of NFRC certifications are acceptable:
    a) NFRC Label affixed to the fenestration product
    b) NFRC site-built procedure label certificate (either affixed to building or included in compliance documentation)
    c) NFRC Component Modeling Approach (CMA) label certificate (either affixed to building or included in compliance documentation).
4) If no information is available onsite, record frame type, tint type, and number of panes.
5) Record all findings in the data collection form.

Measure Name	Measure Number	Code Section
Skylights shall meet U-factor Requirements	5043A	2012 IECC: C402.3.3

Measure Description

Skylights shall not exceed the maximum rate of heat loss requirements of the energy code. A maximum heat loss rate is listed in the code based on climate zone and fenestration type. Refer to the code for specific U-factor requirements.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the architectural drawings set glazing schedule (provides the type of skylights [aluminum, thermal break with low e, site built, manufactured, etc.] and dimensions) and energy code compliance documentation to determine the fenestration U-factor.
3) Ensure that the fenestration U-factor on the glazing schedule on drawings match that the values shown in the energy code compliance documentation. Please note any discrepancies on the data collection form.
4) Ensure that the fenestration U-factor shown on drawings and the energy code compliance documentation has the proper values that will meet the requirements defined on the energy code based on the climate zone.
5) Record all findings in *Skylight U-factor* section of data collection form.

Field Inspection

1) If the building envelope is in the construction stage and fenestration products are accessible, determine the product model and request product specifications.
2) Verify that the installed fenestration products meet the U-factor values shown on the drawings and energy code compliance documentation.
3) Request copy of the National Fenestration Rating Council (NFRC) certificates (if site-built windows) or product labels (if manufactured wood/vinyl/metal frame) from the construction manager or the authority having jurisdiction (AHJ). Only these three forms of NFRC certifications are acceptable:
   a) NFRC Label affixed to the fenestration product
   b) NFRC site-built procedure label certificate (either affixed to building or included in compliance documentation)
   c) NFRC Component Modeling Approach (CMA) label certificate (either affixed to building or included in compliance documentation).
4) If no information is available onsite, record frame type and number of panes.
5) Record all findings in *Skylight U-factor* section of data collection form.

Measure Name	Measure Number	Code Section
Skylights shall meet SHGC requirements	5043B	2012 IECC: C402.3.3

Measure Description

Skylights shall meet the maximum Solar Heat Gain Coefficient (SHGC) requirements of the energy code. A required SHGC is listed in the code based on climate zone. Refer to the code for the specifics of SHGC requirements.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the architectural drawings set glazing schedule (provides the type of skylight (aluminum, thermal break with low e, etc.) and dimensions) and energy code compliance documentation to determine the fenestration SHGC.
3) Ensure that the fenestration SHGC on the glazing schedule on drawings match that the values shown in the energy code compliance documentation. Please note any discrepancies on the data collection form.
4) Ensure that the fenestration SHGC shown on drawings and the energy code compliance documentation has the proper values that will meet the requirements defined on the energy code based on the climate zone.
5) Record all findings in the data collection form.

Field Inspection

1) If the building envelope is in the construction stage and fenestration products are accessible, determine the product model and request product specifications.
2) Verify that the installed fenestration products meet the SHGC values shown on the drawings and energy code compliance documentation.
3) Request copy of the National Fenestration Rating Council (NFRC) certificates (if site-built windows) or product labels (if manufactured wood/vinyl/metal frame) from the construction manager or the authority having jurisdiction (AHJ). Only these three forms of NFRC certifications are acceptable:
   a) NFRC Label affixed to the fenestration product
   b) NFRC site-built procedure label certificate (either affixed to building or included in compliance documentation)
   c) NFRC Component Modeling Approach (CMA) label certificate (either affixed to building or included in compliance documentation).
4) If no information is available onsite, record frame type, tint type, and number of panes.
5) Record all findings in the data collection form.

Measure Name	Measure Number	Code Section
Stair and shaft vent leakage	5077	IECC 2012: C402.4.4

Measure Description

Doors and other openings to shafts, chutes, stairways and elevator lobbies must be sealed. Shaft dampers shall be low leak and closed during normal building operations.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the plans to identify doors and other openings that must be sealed per code specifications. Record the number of shafts and stairwells in the *Envelope – Air Leakage* section of the data collection form.
3) Verify that doors and other openings to shafts, chutes, stairways, and elevator lobbies are specified to be sealed as required.
4) Verify stair and shaft vents have motorized low leak dampers as required and are specified to be closed during normal operation.
5) Record all findings in the *Air Leakage* section of the data collection form.

Field Inspection

1) Verify doors and other openings to shafts, chutes, stairways, and elevator lobbies are sealed as required. *Note: This may include gaskets, weatherstripping, and other sealing.*
2) Verify stair and shaft vents have motorized low leak dampers as required and are configured to be closed during normal operation.
   a) Visually inspect dampers to see if they are closed.
3) Record damper and door condition per the designations provided in the *Envelope– Air Leakage* section of the data collection form:
   a) Dampers normally closed; Good weather stripping and seals; Dampers meet leakage requirements
   b) Dampers normally closed; Poor weather stripping and seals; Dampers meet leakage requirements
   c) Dampers normally closed; Good weather stripping and seals; Dampers do not meet leakage requirements
   d) Dampers normally closed; Poor weather stripping and seals; Dampers do not meet leakage requirements
   e) Dampers normally open; Good weather stripping and seals
   f) Dampers normally open; Poor weather stripping and seals

2) Record all observations in the *Air Leakage* section of the data collection form.

Measure Name	Measure Number	Code Section
Continuous Air Barrier	5056	2012 IECC: C402.4.1

Measure Description

Building shall meet continuous air barrier requirements. See code for air barrier specifics.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review construction details for the roof, wall and floor assemblies to determine if compliant air barrier materials have been specified on the building plans.
3) Check to see if leakage testing is specified.
4) Check that materials and assemblies specified meet the code requirements.
5) Verify that plan notes are present that show intent to seal between each of the air barrier materials shown in the assembly details.
6) Verify the method of meeting the air barrier requirements is designated in the compliance documentation e.g. materials, assemblies or testing.
7) Perform area takeoff and calculate thermal envelope ft^2 (excluding slab floor/UG walls) and note it in the *Envelope - Air Barrier* section of the data collection form.

Field Inspection

1) Verify that the air barrier materials documented on the building plans are installed in the field. Look for evidence of air sealing between air barrier materials in areas that are exposed.
2) Verify that the air barrier is continuous between wall and roof assemblies and between wall and floor assemblies.
3) Review the inspection notes from the AHJ to determine if an air sealing inspection has been conducted.
4) Request documentation to determine if the air barrier has been commissioned.
5) Note leakage rate; review the air leakage testing results if the testing option was taken.

Additional Details

The insulation must be in contact with an “air barrier” that prevents air from passing through the insulation, such as would occur if installing the insulation directly under the roof deck or on top of a sheetrock ceiling. Ceilings with removable tile will not prevent air movement and are not considered air barriers.

Measure Name	Measure Number	Code Section
Vestibule	5083	2012 IECC: C402.4.7

Measure Description

Building entrances shall be protected with an enclosed vestibule. Vestibules are required in Climate Zones 3-8 on entrance doors opening into spaces > 3,000 ft^2.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Determine if vestibule or allowed alternative, such as revolving door or air curtain, is required based on the applicable code. Determine which is specified if required.
3) Determine if specified solution meets requirements for door closing or air curtain adjustments.
4) Determine # of entrances that require vestibules (or other) that are not included.

Field Inspection

1) Determine if installed solution meets requirements for door closing or air curtain adjustments.
2) Select discrete condition from the following:
   - Vestibule Installed; Interior/exterior doors open different times; Air Curtain with vestibule
   - Vestibule Installed; Interior/exterior doors open different times
   - Vestibule Installed; Interior/exterior doors open same time
   - Air Curtain Installed; Air Curtain adjusted properly
   - Air Curtain Installed; Air Curtain not adjusted properly
   - No vestibule or air curtain installed

Measure Name	Measure Number	Code Section
Fenestration Orientation	5089	ASHRAE 2010: 5.5.4.5

Measure Description

Windows must be oriented in accordance with ASHRAE specifications.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Determine if building is required to meet fenestration orientation requirements and note on the data collection form if it applies.
3) Verify the orientation of windows from the floor plans, elevations, and building site plans.
4) Determine area of fenestration on S, E, and W separately.
5) Determine area of fenestration on E > S plus area W > S.
6) Coordinate take-offs with measurements for Window-to-wall ratio (Measure Number: 5034).

Field Inspection

1) Verify number, location, and size of installed windows matches approved plans for each orientation.
2) Verify that the windows are installed on the correct orientation.
3) Verify site construction matches calculations done during plan review.

HVAC Measures

Measure Name	Measure Number	Code Section
Equipment sizing requirement for packaged air conditioners	6004A	IECC 2012: C403.2.2

Measure Description

Packaged air conditioners must meet the sizing requirements in Table C403.2.3(3) of the 2012 IECC when tested and rated in accordance with the applicable test procedure.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the total building equipment airside direct expansion (DX) cooling capacity from the HVAC system schedule (see diagram below) and the base guidelines for building type.
3) If sizing calculations are not available, use the HVAC equipment sizing estimation tool:
    a. Calculate the floor area of the building cooled by DX systems to calculate sf/ton.
        i. If <130% of base guideline, no further action - deemed to meet sizing requirements
        ii. If >175% of base guideline, deemed to be oversized unless sizing calculations are reviewed and found to support size is in alignment with referenced standard
        iii. If between 130% and 175% of sizing base guideline, review calculations (if available) or document unusual loads that would require an increase in sizing vs. base guideline
4) Record all findings in the data collection form and note equipment details in the *HVAC Log*.

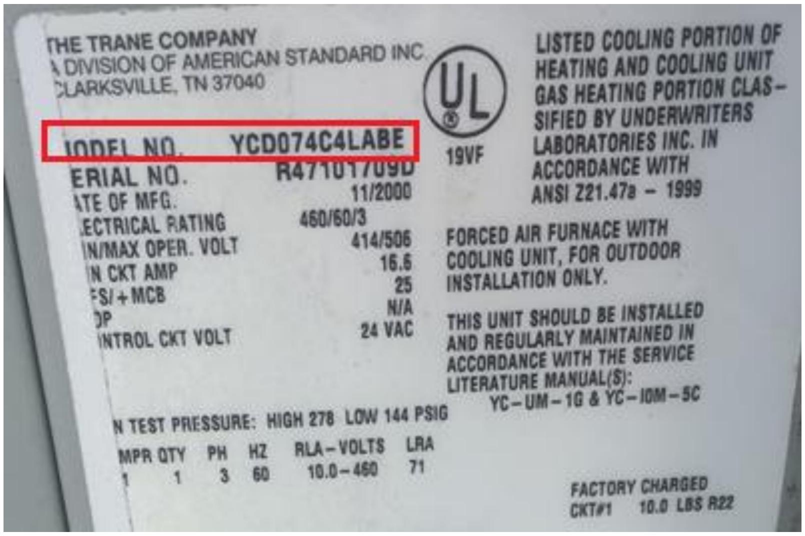
Field Inspection

1) Verify the total combined airside cooling capacity of installed packaged air conditioners in field matches plans within 10%. This is done by recording the cooling capacity of every packaged air conditioner, adding up all the values, and comparing with the total cooling capacity from the plans.
    a) Note the percent difference.
2) Record all observations in the data collection form and note equipment details in the *HVAC Log*.

PACKAGE – GAS / ELECT. UNIT SCHEDULE														
SYMBOL	MANUF.	MODEL NO.	EER	CFM	EXT. S.P. (IN)	TOTAL COOLING (BTUH)	INPUT HEATING (BTUH)	ELECTRICAL			HP	O.S.A	OPER. WT. (LBS.)	REMARKS
								MCA	MOCP	VOLTAGE				
AC 1, AC 3	YORK	ZJ037N0	12.20	1,200	.75	37,000	60,000	8.5	25	230–3–60	1.5	430/170	835	PROVIDE UNIT W/ECONOMIZER, MERV-13 FILTERS
AC 2	YORK	ZJ049N0	12.20	1,600	1.0	50,000	80,000	3.9	30	230–3–60	1.5	360	857	PROVIDE UNIT W/ECONOMIZER, MERV-13 FILTERS

Simple packaged air conditioner mechanical schedule

Typical packaged air conditioner



Nameplate data of a rooftop package unit

TRANE

Model Number Description

Y	S	C	036	A	3	R	L	A	**	C	0	0	0	C	1	0	0	0	1	A	1
1	2	3	4,5,6	7	8	9	10	11	12,13	14	15	16	17	18	19	20	21	22	23	24	25

DIGIT 1 - Unit Function

Y = DX Cooling, Gas Heat

DIGIT 2 - Efficiency

S = Standard Efficiency
H = High Efficiency

DIGIT 3 - Airflow

C = Convertible

DIGITS 4,5,6 - Nominal Gross Cooling Capacity (MBh)

036 = 3 Ton
048 = 4 Ton
060 = 5 Ton
072 = 6 Ton
090 = 7½ Ton, Single Compressor
092 = 7½ Ton, Dual Compressors
102 = 8½ Ton
120 = 10 Ton

DIGIT 7 - Major Design Sequence

A = First

DIGIT 8 - Unit Voltage

1 = 208-230/60/1
3 = 208-230/60/3
4 = 460/60/3

DIGIT 14 - Fresh Air Selection

0 = No Fresh Air
A = Manual Outside Air Damper 0-50%
B = Motorized Outside Air Damper 0-50%
C = Economizer, Dry Bulb 0-100% without Barometric Relief
D = Economizer, Dry Bulb 0-100% with Barometric Relief
E = Economizer, Reference Enthalpy 0-100% without Barometric Relief
F = Economizer, Reference Enthalpy 0-100% with Barometric Relief
G = Economizer, Comparative Enthalpy 0-100% without Barometric Relief
H = Economizer, Comparative Enthalpy 0-100% with Barometric Relief

DIGIT 15 - Supply Fan/Drive Type/Motor

0 = Standard Drive
1 = Oversized Motor
2 = Optional Belt Drive Motor

DIGIT 16 - Hinged Service AccessFilters

0 = Standard Panels/Standard Filters
A = Hinged Access Panels/Standard Filters
B = Standard Panels/2" Pleated Filters
C = Hinged Access Panels/2" Pleated Filters

DIGIT 17 - Condenser Coil Protection

0 = Standard Coil

DIGIT 20 - Convenience Outlet

0 = No Convenience Outlet
A = Unpowered Convenience Outlet
B = Powered Convenience Outlet (3 phase only)

DIGIT 21 - Communications Options

0 = No Communications Interface
1 = Trane Communications Interface
2 = LonTalk® Communications Interface
3 = Novar 2024 Controls
4 = Novar 3051 Controls

DIGIT 22 - Refrigeration System Option

0 = Standard Refrigeration System
A = Thermal Expansion Valve (TXV)
B = Dehumidification (Hot Gas Reheat Coil)

DIGIT 23 - Refrigeration Controls

0 = No Refrigeration Control
1 = High Pressure Control
2 = Frostat
3 = Crankcase Heater
4 = High Pressure Control and Frostat
5 = High Pressure Control and Crankcase Heater
6 = Frostat and Crankcase Heater
7 = High Pressure Control, Frostat and Crankcase Heater

Nameplate data description

Measure Name	Measure Number	Code Section
Equipment sizing requirement for packaged VAV	6004B	IECC 2012: C403.2.2

Measure Description

Packaged VAV systems must meet the sizing requirements in Table C403.2.3(3) of the 2012 IECC when tested and rated in accordance with the applicable test procedure.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the total building equipment airside cooling capacity from the HVAC system schedule and the base guidelines for building type.
    a) Calculate the floor area of the building cooled by DX systems to calculate sf/ton.
        i) If <150% of base guideline, no further action - deemed to meet sizing requirements
        ii) If > 200% of base guideline, deemed to be oversized unless sizing calculations are reviewed and found to support size is in alignment with referenced standard
        iii) If between 150% and 200% of sizing base guideline, review calculations (if available) or document unusual loads that would require an increase in sizing vs. base guideline
3) Record all findings in the data collection form and note equipment details in the *HVAC Log*.

Field Inspection

1) Verify the total combined airside cooling capacity of installed packaged VAV units in field matches plans within 10%. This is done by recording the cooling capacity of every packaged VAV unit, adding up the values of each, and comparing the total with the total cooling capacity from the plans.
2) Record all observations in the data collection form and note equipment details in the *HVAC Log*.

Typical packaged VAV unit

TRANE

Model Number Description

S	F	H	F	C	5	5	F	H	A	5	5	C	6	9	D	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0'
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38

DIGIT 1 — UNIT TYPE
S = Self-Contained (Packaged Rooftop)

DIGIT 2 — UNIT FUNCTION
A = DX Cooling, No Heat
E = DX Cooling, Electric Heat
F = DX Cooling, Natural Gas Heat
L = DX Cooling, Hot Water Heat
S = DX Cooling, Steam Heat
X = DX Cooling, No Heat, Extended Casing

DIGIT 3 — UNIT AIRFLOW
H = Single Zone

DIGIT 4 — DEVELOPMENT SEQUENCE
F = Sixth

DIGITS 5,6,7 — NOMINAL CAPACITY
C20 = 20 Tons
C25 = 25 Tons
C30 = 30 Tons
C40 = 40 Tons
C50 = 50 Tons
C55 = 55 Tons
C60 = 60 Tons
C70 = 70 Tons
C75 = 75 Tons

DIGIT 8 — POWER SUPPLY (See Notes)
4 = 460/60/3 XL
5 = 575/60/3 XL
E = 200/60/3 XL
F = 230/60/3 XL
Note: SEHF units (units with electric heat) utilizing 208V or 230V require dual power source.

DIGIT 9 — HEATING CAPACITY
Note: When the second digit calls for "F" (Gas Heat), the following values apply: Additionally, please note G and M available ONLY on 50 Ton models and above.
H = High Heat-2-Stage
L = Low Heat-2-Stage
0 = No Heat
J = High Heat-Limited Modulation
G = Low Heat-Limited Modulation
P = High Heat-Full Modulation
M = Low Heat-Full Modulation
Note: When the second digit calls for "E" (electric heat), the following values apply:
D = 30 KW
H = 50 KW
L = 70 KW
N = 90 KW
Q = 110 KW
R = 130 KW
U = 150 KW
V = 170 KW
W = 190 KW
Note: When the second digit calls for "L" (Hot Water) or "S" (Steam) Heat, one of the following valve size values must be in Digit 9:
High Heat Coil: 1 = .50", 2 = .75", 3 = 1", 4 = 1.25", 5 = 1.5", 6 = 2".
Low Heat Coil: A = .50", B = .75", C = 1", D = 1.25", E = 1.5", F = 2".

DIGIT 10 — DESIGN SEQUENCE
A = First (Factory Assigned)
Note: Sequence may be any letter A thru Z, or any digit 1 thru 9.

DIGIT 11 — EXHAUST OPTION
0 = None
1 = Barometric
2 = 100%, 1.5 HP W/Statitrac
3 = 100%, 3 HP W/Statitrac
4 = 100%, 5 HP W/Statitrac
5 = 100%, 7.5 HP W/Statitrac
6 = 100%, 10 HP W/Statitrac
7 = 100%, 15 HP W/Statitrac
8 = 100%, 20 HP W/Statitrac
A = 50%, 1.5 HP
B = 50%, 3 HP
C = 50%, 5 HP
D = 50%, 7.5 HP
E = 100%, 1.5 HP W/O Statitrac (CV Only)
F = 100%, 3 HP W/O Statitrac (CV Only)
G = 100%, 5 HP W/O Statitrac (CV Only)
H = 100%, 7.5 HP W/O Statitrac (CV Only)
J = 100%, 10 HP W/O Statitrac (CV Only)
K = 100%, 15 HP W/O Statitrac (CV Only)
L = 100%, 20 HP W/O Statitrac (CV Only)

DIGIT 12 — EXHAUST AIR FAN DRIVE
0 = None
4 = 400 RPM
5 = 500 RPM
6 = 600 RPM
7 = 700 RPM
8 = 800 RPM
9 = 900 RPM
A = 1000 RPM
B = 1100 RPM

DIGIT 13 — FILTER
A = Throwaway
B = Cleanable Wire Mesh
C = High-Efficiency Throwaway
D = Bag With Prefilter
E = Cartridge With Prefilter
F = Throwaway Filter Rack Less Filter Media
G = Bag Filter Rack Less Filter Media

DIGIT 14 — SUPPLY AIR FAN HP
1 = 3 HP
2 = 5 HP
3 = 7.5 HP
4 = 10 HP
5 = 15 HP
6 = 20 HP
7 = 25 HP
8 = 30 HP
9 = 40 HP[3]

DIGIT 15 — SUPPLY AIR FAN DRIVE
5 = 500 RPM
6 = 600 RPM
7 = 700 RPM
8 = 800 RPM
9 = 900 RPM
A = 1000 RPM
B = 1100 RPM
C = 1200 RPM
D = 1300 RPM
E = 1400 RPM
F = 1500 RPM
G = 1600 RPM

DIGIT 16 — FRESH AIR
A = No Fresh Air
B = 0-25% Manual
D = 0-100% Economizer

DIGIT 17 — SYSTEM CONTROL
1 = Constant Volume Control
2 = VAV Supply Air Temperature Control w/o Inlet Guide Vanes
3 = VAV Supply Air Temperature Control w/ Inlet Guide Vanes
4 = Space Pressure Control with Exhaust VFD w/o Bypass
5 = Space Pressure Control with Exhaust VFD and Bypass
6 = VAV Supply Air Temperature Control with VFD w/o Bypass
7 = VAV Supply Air Temperature Control with VFD and Bypass
8 = Supply and Exhaust Fan with VFD w/o Bypass
9 = Supply and Exhaust Fan with VFD and Bypass

DIGIT 18 — ACCESSORY PANEL
0 = None
A = BAYSENS008*
B = BAYSENS010*
C = BAYSENS013*
D = BAYSENS014*
E = BAYSENS019*
F = BAYSENS020*
G = BAYSENS021*
*Note: *Asterisk indicates current model number digit A, B, C, etc. These sensors can be ordered to ship with the unit.*

DIGIT 19 — AMBIENT CONTROL
0 = Standard
1 = 0° Fahrenheit

DIGIT 20 — AGENCY APPROVAL
0 = None (UL Gas Heater, see note)
1 = UL
2 = CSA
Note: Includes UL classified gas heating section only when second digit of Model No. is a "F."

DIGITS 21 - 38 — MISCELLANEOUS
21 A = Unit Disconnect Switch
22 B = Hot Gas Bypass
23 0 = Without Economizer
C = Economizer Control w/ Comparative Enthalpy
23 Z = Economizer Control w/ Reference Enthalpy
23 W = Economizer Control w/Dry Bulb
24 E = Low Leak Fresh Air Dampers
25 F = High Duct Temperature Thermostat
26 G = High Capacity Evap. Coil
27 H = Copper Fins (Cond. Only)
28 K = Generic B.A.S. Module
29 L = High-Efficiency Motors (Supply and Exhaust)
30 M = Remote Human Interface
31 N = Ventilation Override Module
32 R = Extended Grease Lines
33 T = Access Doors
34 V = Inter-Processor Communication Bridge
35 Y = Trane Communication Interface (TCI) Module
35 7 = LonTalk Communication Interface (LCI) Module
36 8 = Spring Isolators
37 6 = Factory-Powered 15A GFI Convenience Outlet
38 5 = VFD Line Reactor

Nameplate data showing VAV control and cooling capacity

Measure Name	Measure Number	Code Section
Packaged air conditioner efficiency	6005A	IECC 2012: C403.2.3

Measure Description

Packaged air conditioners must meet the minimum efficiency requirements in Table C403.2.3(1) of the 2012 IECC when tested and rated in accordance with the applicable test procedure. Alternately, efficiency may be determined by other codes, tradeoffs, or optional efficiency measures.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the HVAC equipment schedule on the mechanical plans (see example below) to identify any packaged air conditioners.
3) If this measure applies to the building, record the following information per the building plans in the *Mechanical – Efficiency* section of the data collection form:
    a. Make and model number of the equipment
    b. Equipment efficiency (EER and SEER)
    c. Cooling capacity
4) If efficiency data is not available on the plans:
    a. Record the make and model number of the equipment in the data collection form
    b. Look up the corresponding efficiency in the directory linked in the Additional Details section below and record in the data collection form
5) Record all findings in the *Mechanical – Efficiency* section of the data collection form and note equipment details in the *HVAC Log*

Field Inspection

1) Record the make and model number of the installed packaged air conditioners in the *Mechanical – Efficiency* tab of the data collection form.
2) Verify that the make and model number of the installed units match the numbers recorded during plan review.
    a) If the make or model number does not match the plans:
        i) Record the make and model numbers of the actual installed equipment in the data collection form
        ii) Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below and record in the data collection form.
3) Record all findings in the *Mechanical – Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Additional Details

To look up equipment efficiency using the make and model number of the unit, use the manufacturer's website or the AHRI product directory: https://www.ahridirectory.org/ahridirectory/pages/home.aspx.

PACKAGE – GAS / ELECT. UNIT SCHEDULE

SYMBOL	MANUF.	MODEL NO.	EER	CFM	EXT. S.P. (IN)	TOTAL COOLING (BTUH)	INPUT HEATING (BTUH)	ELECTRICAL			HP	O.S.A	OPER. WT. (LBS.)	REMARKS
								MCA	MOCP	VOLTAGE				
AC 1, AC 3	YORK	ZJ037NC	12.20	1,200	.75	37,000	60,000	18.5	25	230–3–60	1.5	430/170	835	PROVIDE UNIT W/ECONOMIZER, MERV-13 FILTERS
AC 2	YORK	ZJ049NC	12.20	1,600	1.0	50,000	80,000	23.9	30	230–3–60	1.5	360	857	PROVIDE UNIT W/ECONOMIZER, MERV-13 FILTERS

Mechanical schedule showing packaged unit efficiency

General Data

(3 - 4 Tons) Standard Efficiency

Table GD-1 — General Data

	3 Ton Convertible Units						4 Ton Convertible Units					
	YSC036A1			YSC036A3, A4, AW			YSC048A1			YSC048A3, A4, AW		
Cooling Performance[1]												
Gross Cooling Capacity		37,400			37,400			50,300			49,200	
SEER[2]		10.5			10.7			10.1			10.0	
Nominal CFM / ARI Rated CFM		1,200/1,200			1,200/1,200			1,600/1,600			1,600/1,600	
ARI Net Cooling Capacity		36,000			36,000			48,000			47,000	
System Power (KW)		3.91			3.79			5.28			5.40	
Heating Performance[4]												
Heating Models	Low	Medium	High	Low	Medium	High	Low	Medium	High	Low	Medium	High
Heating Input (Btu)	60,000	80,000	120,000	60,000	80,000	120,000	60,000	80,000	120,000	60,000	80,000	120,000
Heating Output (Btu)	47,000	63,000	95,000	48,000	64,000	96,000	47,000	63,000	95,000	48,000	64,000	96,000
AFUE %[5]	80	80	80	81	81	81	80	80	80	81	81	81
Steady State Efficiency (%)	80	80	80	81	81	81	80	80	80	81	81	81
No. Burners	2	2	3	2	2	3	2	2	3	2	2	3
No. Stages	1	1	1	1	1	1	1	1	1	1	1	1
Gas Supply Line Pressure												
Natural (minimum/maximum)		4.5/14.0			4.5/14.0			4.5/14.0			4.5/14.0	
LP (minimum/maximum)		10.0/14.0			10.0/14.0			10.0/14.0			10.0/14.0	
Gas Connection Pipe Size (in.)	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2	1/2
Compressor												
No./Type		1/Hermetic			1/Hermetic			1/Scroll			1/Scroll	

Equipment specifications showing cooling efficiency based on unit model number

Measure Name	Measure Number	Code Section
Packaged heat pump efficiency	6005B	IECC 2012: C403.2.3

Measure Description

Packaged heat pumps must meet the minimum efficiency requirements in Table C403.2.3(2) of the 2012 IECC when tested and rated in accordance with the applicable test procedure. Alternately, efficiency may be determined by other codes, tradeoffs, or optional efficiency measures.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed. Requirements will vary if high efficiency HVAC additional efficiency option is selected for compliance.
2) Use the HVAC equipment schedule on the mechanical plans (see example below) to identify any packaged heat pumps.
3) If this measure applies to the building, record the following information per the building plans in the *Mechanical – Efficiency* section of the data collection form:
    a. Make and model number of the equipment
    b. Equipment efficiency (COP)
    c. Cooling capacity
4) If efficiency data is not available on the plans:
    a. Record the make and model number in the data collection form
    b. Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below and record in the data collection form.
5) Record all findings in the *Mechanical – Heat Pump & Gas Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Field Inspection

1) Record the make and model number of the installed packaged heat pumps in the *Mechanical – Efficiency* tab of the data collection form.
2) Verify that the make and model number of the installed units match the numbers recorded during plan review.
    a) If the make or model number does not match the plans:
        i) Record the make and model numbers of the actual installed equipment in the data collection form
        ii) Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below and record in the data collection form
3) Record all findings in the *Mechanical – Heat Pump & Gas Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Additional Details

To look up equipment efficiency using the make and model number of the unit, use the manufacturer's website or the AHRI product directory: https://www.ahridirectory.org/ahridirectory/pages/home.aspx.

Measure Name	Measure Number	Code Section
Gas furnace efficiency	6005C	IECC 2012: C403.2.3

Measure Description

Gas furnaces must meet the minimum efficiency requirements of Table C403.2.3(4) of the 2012 IECC when tested and rated in accordance with the applicable test procedure. Alternately, efficiency may be determined by other codes, tradeoffs, or optional efficiency measures.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the HVAC equipment schedule on the mechanical plans to identify any gas furnaces (see example in 6005A Additional Details).
3) If this measure applies to the building, record the following information per the building plans in the *Mechanical –Heat Pump & Gas Efficiency* section of the data collection form:
    a. Make and model number of the equipment
    b. Equipment efficiency (thermal efficiency or AFUE)
    c. Output capacity (Btu/h)
4) If efficiency data is not available on the plans:
    a. Record the make and model number of the equipment in the data collection form
    b. Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below and record in the data collection form.
5) Record all findings in the *Mechanical – Heat Pump & Gas Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Field Inspection

1) Record the make and model number of the installed gas furnaces in the *Mechanical – Efficiency* tab of the data collection form.
2) Verify that the make and model number of the installed units match the numbers recorded during plan review.
    a) If the make or model number does not match the plans:
        i) Record the make and model numbers of the actual installed equipment in the data collection form
        ii) Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below and record in the data collection form.
3) Record all findings in the *Mechanical – Heat Pump & Gas Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Additional Details

To look up equipment efficiency using the make and model number of the unit, use the manufacturer's website or the AHRI product directory: https://www.ahridirectory.org/ahridirectory/pages/home.aspx.

Typical gas fired furnace

Measure Name	Measure Number	Code Section
Boiler efficiency	6005D	IECC 2012: C403.2.3

Measure Description

Boilers must meet the minimum efficiency requirements in Table C403.2.3(5) of the 2012 IECC when tested and rated in accordance with the applicable test procedure. Alternately, efficiency may be determined by other codes, tradeoffs, or optional efficiency measures.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the HVAC equipment schedule on the mechanical plans (see example below) to identify any boilers (see example below).
3) If this measure applies to the building, record the following information per the building plans in the *Mechanical – Boiler & WSHP Efficiency* section of the data collection form:
    a. Make and model number of the equipment
    b. Equipment efficiency (thermal efficiency or AFUE)
    c. Input capacity of the equipment
    d. Output capacity (Btu/h) of the equipment
4) If efficiency data is not available on the plans:
    a. Record the make and model number of the equipment in the data collection form
    b. Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below.
5) Determine the required efficiency based on code, tradeoffs, or optional efficiency measures.
6) Record all findings in the *Mechanical – Boiler & WSHP Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Field Inspection

1) Record the make and model number of the installed boilers in the *Mechanical – Boiler & WSHP Efficiency* tab of the data collection form.
2) Verify that the make and model number of the installed units match the numbers recorded during plan review.
    a) If the make or model number does not match the plans:
        i) Record the make and model numbers of the actual installed equipment in the data collection form.
        ii) Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below and record in the data collection form.
3) Record all findings in the *Mechanical – Boiler & WSHP Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Additional Details

To look up equipment efficiency using the make and model number of the unit, use the manufacturer's website or the AHRI product directory: https://www.ahridirectory.org/ahridirectory/pages/home.aspx.

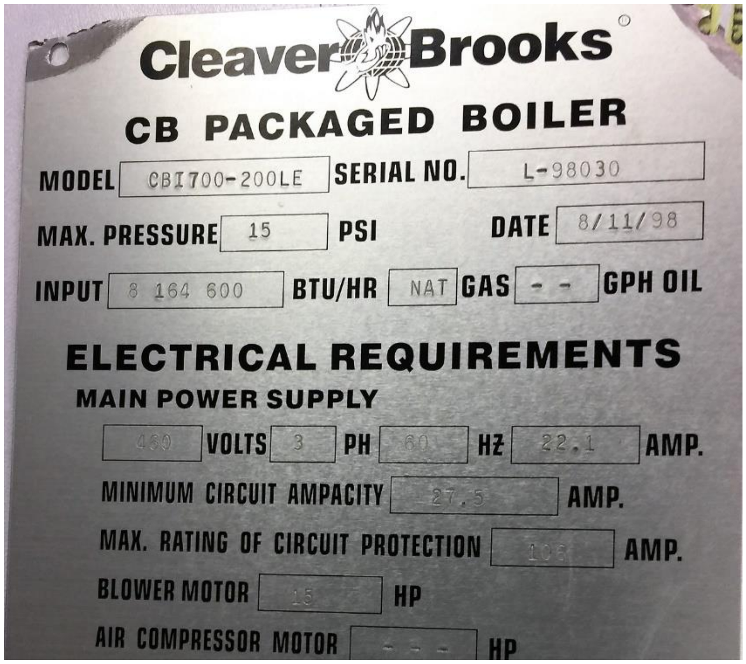
BOILER SCHEDULE

SYMBOL	MAKE	MODEL	TYPE	LOCATION	SERVICE	CAPACITY (MBH)		EFF (%)	GPM	EWT (°F)	LWT (°F)	△ P (PSI)	PRESS. RELIEF (PSI)	FUEL	MIN-MAX FUEL PRESSURE (W.C.")	ELECTRICAL		OPERATIONG WGT. (LBS)	REMARKS
						INPUT	OUTPUT									AMPS	VOLTAGE		
B-1	AERCO	BMK-195LN GLB	CONDENSING BOILER	BASEMENT MECH. ROOM	HEATING HOT WATER	1,950	1677	96	85	105	140	0.6	100	NAT. GAS	8-14	11	460/3/60	1,750	1, 2, 3, 4, 5
B-2	AERCO	BMK-195LN GLB	CONDENSING BOILER	BASEMENT MECH. ROOM	HEATING HOT WATER	1,950	1677	96	85	105	140	0.6	100	NAT. GAS	8-14	11	460/3/60	1,750	1, 2, 3, 4, 5

Boiler mechanical schedule showing boiler input capacity, output capacity, and efficiency

Typical condensing boiler

Typical steam boiler



Boiler nameplate data

Measure Name	Measure Number	Code Section
Water source heat pump efficiency	6005E	IECC 2012: C403.2.3

Measure Description

Water source heat pumps must meet the minimum efficiency requirements in Table C403.2.3(2) of the 2012 IECC when tested and rated in accordance with the applicable test procedure. Alternately, efficiency may be determined by other codes, tradeoffs, or optional efficiency measures.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the HVAC equipment schedule on the mechanical plans to identify any water source heat pumps (see example in 6005A Additional Details).
3) If this measure applies to the building, record the following information per the building plans in the *Mechanical – Boiler & WSHP Efficiency* section of the data collection form:
    a. Make and model number of the equipment
    b. Equipment efficiency (COP)
    c. Cooling capacity (Btu/h)
4) If efficiency data is not available on the plans:
    a. Record the make and model number of the equipment in the data collection form
    b. Look up the corresponding efficiency the AHRI product directory linked in the Additional Details section below and record in the data collection form.
5) Record all findings in the *Mechanical – Boiler & WSHP Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Field Inspection

1) Record the make and model number of the installed water source heat pumps in the *Mechanical – Efficiency* tab of the data collection form.
2) Verify that the make and model number of the installed units match the numbers recorded during plan review.
    a) If the make or model number does not match the plans:
        i) Record the make and model numbers of the actual installed equipment in the data collection form.
        ii) Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below and record in the data collection form.
3) Record all findings in the *Mechanical – Boiler & WSHP Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Additional Details

To look up equipment efficiency using the make and model number of the unit, use the manufacturer's website or the AHRI product directory: https://www.ahridirectory.org/ahridirectory/pages/home.aspx.

Measure Name	Measure Number	Code Section
Air-cooled chiller efficiency	6007A	IECC 2012: C403.2.3

Measure Description

Air-cooled chillers must meet the minimum efficiency requirements in Table C403.2.3(7) of the 2012 IECC when tested and rated in accordance with the applicable test procedure. Alternately, efficiency may be determined by other codes, tradeoffs, or optional efficiency measures.

Plan Review

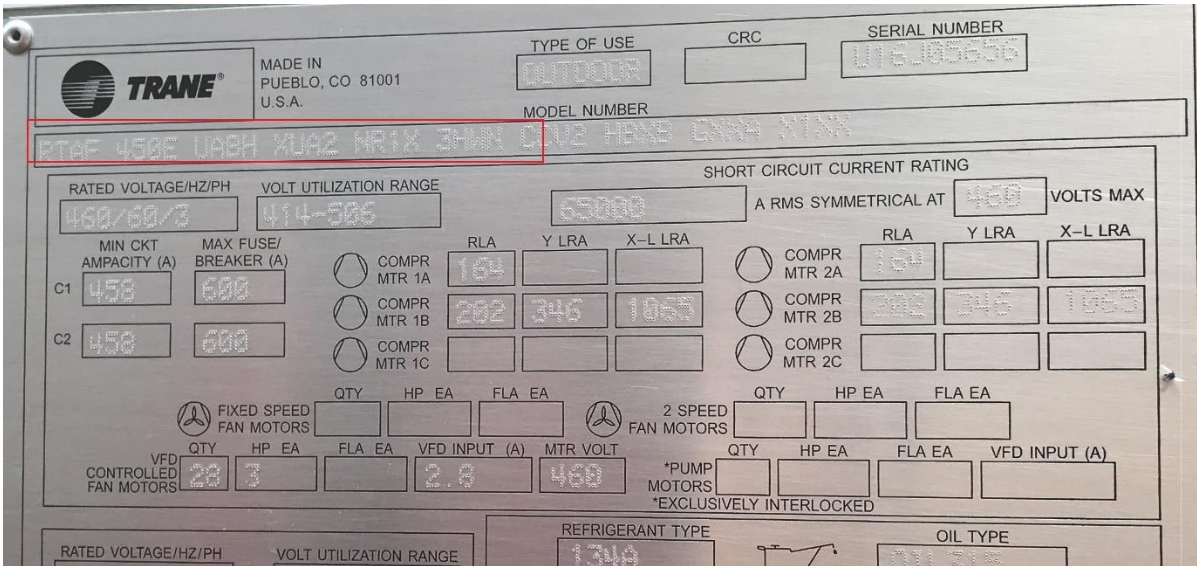
1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the HVAC equipment schedule on the mechanical plans to identify any air-cooled chillers (see example below).
3) If this measure applies to the building, record the following information per the building plans in the *Mechanical – Chiller Efficiency* section of the data collection form:
    a) Make and model number of the equipment
    b) Equipment efficiency (EER, IEER, COP, or kW/ton)
    c) Cooling capacity
4) If efficiency data is not available on the plans:
    a) Record the make and model number of the equipment in the data collection form
    b) Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below and record in the data collection form
5) Record all findings in the *Mechanical – Chiller Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Field Inspection

1) Record the make and model number of the installed air-cooled chillers in the *Mechanical – Chiller Efficiency* tab of the data collection form.
2) Verify that the make and model number of the installed units match the numbers recorded during plan review.
    a) If the make or model number does not match the plans:
        i) Record the make and model number of the actual installed equipment in the data collection form
        ii) Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below and record in the data collection form
3) Record all findings in the *Mechanical – Chiller Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Additional Details

To look up equipment efficiency using the make and model number of the unit, use the manufacturer's website or the AHRI product directory: https://www.ahridirectory.org/ahridirectory/pages/home.aspx.



Air-cooled chiller nameplate

Typical air-cooled chiller

Measure Name	Measure Number	Code Section
Water-cooled chiller efficiency	6007B	IECC 2012: C403.2.3

Measure Description

Water-cooled chillers must meet the minimum efficiency requirements in Table C403.2.3(7) of the 2012 IECC when tested and rated in accordance with the applicable test procedure. Alternately, efficiency may be determined by other codes, tradeoffs, or optional efficiency measures.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the HVAC equipment schedule on the mechanical plans to identify any water-cooled chillers (see example below).
3) If this measure applies to the building, record the following information per the building plans in the *Mechanical – Chiller Efficiency* section of the data collection form:
    a. Make and model number of the equipment
    b. Equipment efficiency (kW/ton / COP)
    c. Cooling capacity
4) If efficiency data is not available on the plans:
    a. Record the make and model number of the equipment in the data collection form
    b. Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below and record in the data collection form
5) Record all findings in the *Mechanical – Chiller Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Field Inspection

1) Record the make and model number of the installed water-cooled chillers in the *Mechanical – Chiller Efficiency* tab of the data collection form.
2) Verify that the make and model number of the installed units match the numbers recorded during plan review.
    a) If the make or model number does not match the plans:
        i) Record the make and model numbers of the actual installed equipment in the data collection form
        ii) Look up the corresponding efficiency in the AHRI product directory linked in the Additional Details section below and record in the data collection form.
3) Record all findings in the *Mechanical – Chiller Efficiency* section of the data collection form and note equipment details in the *HVAC Log*.

Additional Details

To look up equipment efficiency using the make and model number of the unit, use the manufacturer's website or the AHRI product directory: https://www.ahridirectory.org/ahridirectory/pages/home.aspx.

WATER COOLED CHILLER SCHEDULE

UNIT NO.	LOCATION	CAPACITY (TON)	EVAPORATOR						CONDENSER						EFFICIENCY KW/TON	NPLV KW/TON
			EWT (°F)	LWT (°F)	FLOW GPM	ΔP (FT.)	NO. OF PASSES	FOULING FACTOR	EWT (°F)	LWT (°F)	FLOW GPM	ΔP (FT.)	NO. OF PASSES	FOULING FACTOR		
CH-1	MECH. SERVICE YARD	350	58	44	600	14.8	2	0.0001	72	82	940	18.9	2	0.00025	0.411	0.313
CH-2	MECH. SERVICE YARD	104	58	44	178.3	25.1	2	0.0001	72	82	287.5	11.6	2	0.00025	0.567	0.478

REFRIGERENT TYPE	ELECTRICAL					MANUFACTURER / MODEL NO.	OPERATING WEIGHT	REMARKS
	VOLT/ø/Hz	UNIT POWER (KW)	MOP	MCA	LRA			
R134A	460/3/60	144	500	279	–	CARRIER / 23XRV3637NRVR351	21,000	1,2,3,4,5,7
R134A	460/3/60	58.9	175	126	–	CARRIER / 30HXC096	5,855	1,2,3,4,5,8,9

Water-cooled chiller mechanical schedule

Measure Name	Measure Number	Code Section
Heat pump supplementary heat control	6017	IECC 2012: C403.2.4.1.1

Measure Description

Heat pumps with supplementary heat must have controls that lock out electric resistance heat when the heat pump can meet the heating load. Examples include an outside air lockout at 40°F or warmer or a ramped startup setpoint.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical schedule to identify electric resistance backup heat.
3) Use the mechanical plans to identify any advanced heat pump thermostat or outside air lockout temperatures.
    a) Indicate which of the options from the data collection form best describes the system:
        i) Lock out supplementary heat OA≤30F; Comp Lock Out OA=0F; or special heat pump thermostat
        ii) Lock out supplementary heat OA≤40F; Comp Lock Out OA≤10F; or special heat pump thermostat
        iii) Lock out supplementary heat OA=50F; or Comp Lock Out OA≥20F
        iv) No lock out supplementary heat or set OA=70F; or Comp Lock Out OA≥35F
4) Check heat pump SOO or heat pump specifications.
5) Record all findings in the data collection form and note thermostat details in the *Thermostat Log*.

Field Inspection

1) Record the make and model of the thermostat in the *Mechanical – Heat Pump Controls* section of the data collection form.
2) Test the thermostat by increasing the space temperature setpoint and measuring the supply air temperature (SAT). If the outside air temperature (OAT) is above 40°F and the SAT is warmer than 95°F, the system does not comply with code.
3) If the system uses a BAS instead of a thermostat:
    a) Raise the space temperature setpoint to test the system
    b) Measure the SAT
    c) If the OAT is above 40°F and the SAT is warmer than 95°F, the system does not comply with code.
4) Record all findings in the data collection form and note thermostat details in the *Thermostat Log*.

Additional Details

To look up equipment efficiency using the make and model number of the unit, use the manufacturer's website or the AHRI product directory: https://www.ahridirectory.org/ahridirectory/pages/home.aspx.

Measure Name	Measure Number	Code Section
Thermostat deadband requirement	6018	IECC 2012: C403.2.4.2

Measure Description

Zone thermostatic controls must have at least a 5°F deadband.
Exception: Thermostats requiring manual changeover between heating and cooling modes.

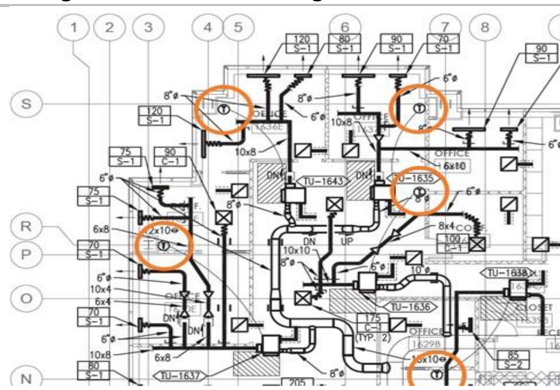
Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical floor plans to identify any thermostats (see image below).
3) If this measure applies to the building, record the following information per the building plans in the *Thermostat Log* located in the *Mechanical* section of the data collection form for each thermostat:
    a. Zone and corresponding square footage of the location of the thermostat
        i. Note where in the field to look for different thermostats (e.g., standalone thermostat, DDC)
    b. Make and model of the thermostat
4) Evaluate sequence of operations (SOO) to check if a deadband is specified and record findings in the data collection form.

Field Inspection

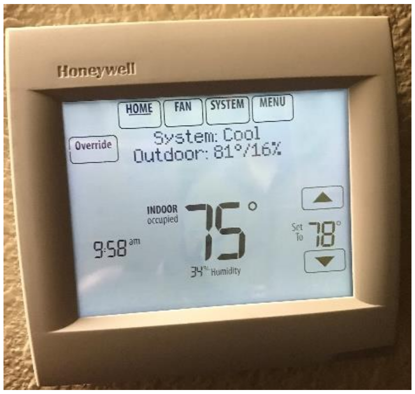
If data is easily accessible in the BAS, the following information should be collected for all thermostats. If no BAS is present or data is not observable, data should be gathered from at least 3 thermostats or 20% of the total number of thermostats installed, whichever is greater. Thermostats should be located in different occupancy within the building if possible (e.g. conference, open office, etc.)

1) Record the setpoints observed at the thermostats or from the BAS, as shown in the photos below, in the *Thermostat Log.*
2) Determine the deadband in degrees and record findings in the data collection form.



Mechanical floor plan showing thermostats in multiple locations[6]

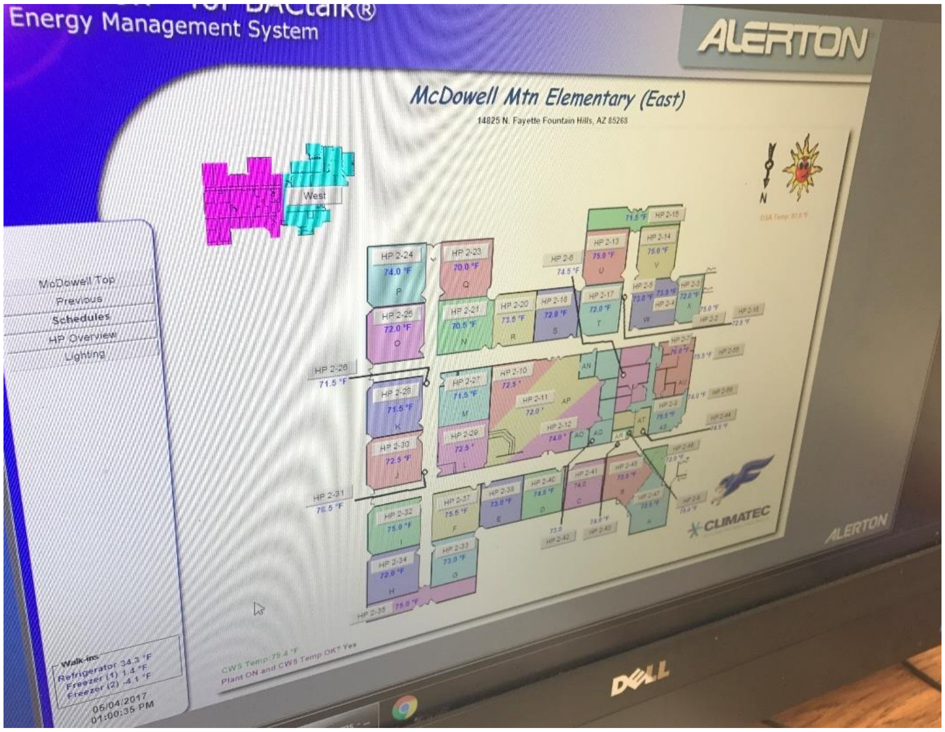
[6] PECI HVAC controls protocol



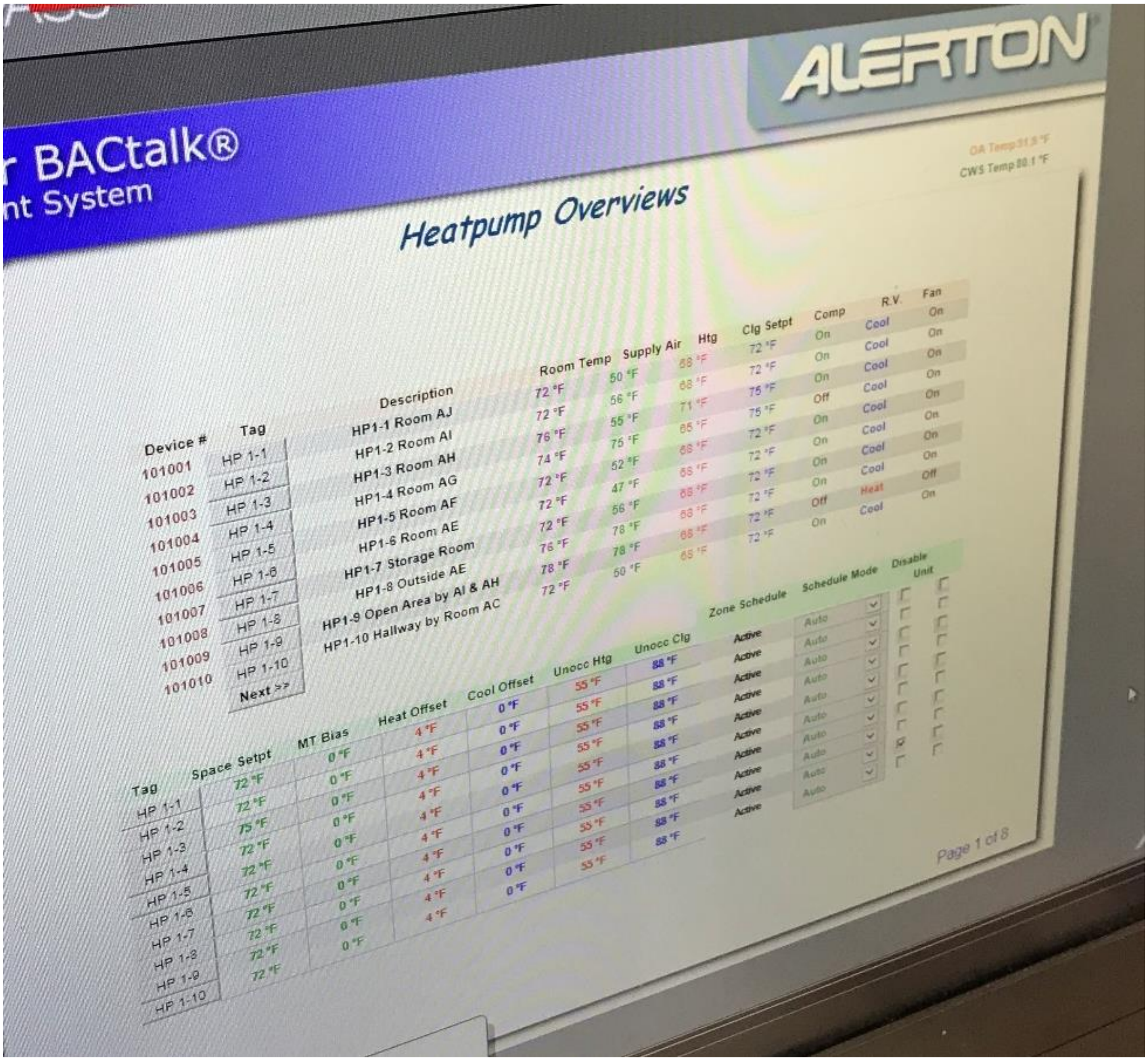
Programmable thermostat showing cooling setpoint

Temperature sensor[7]

[7] PECI HVAC controls protocol



Building automation system (BAS) screenshot showing temperature sensors measuring zone temperatures



BAS screenshot showing temperature setpoints for each HVAC unit

Measure Name	Measure Number	Code Section
Thermostat setback	6019A	IECC 2012: C403.2.4.3

Measure Description

Each zone must have thermostatic setback controls that are controlled by either an automatic time clock or programmable control system. Thermostatic controls must have the capability to set back or temporarily operate the system to maintain zone temperatures between 55°F and 85°F.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical floor plans to identify any thermostats (see image for 6018).
3) If this measure applies to the building, record the following information per the building plans in the *Thermostat Log* located in the *Mechanical* section of the data collection form for each thermostat:
    a) Zone and corresponding square footage of the location of the thermostat
        i. Note where in the field to look for different thermostats (e.g., standalone thermostat, DDC)
    b) Make and model of the thermostat
4) Check SOO to see if unoccupied setback is specified and record findings in the data collection form.

Field Inspection

If data is easily accessible in the BAS, the following information should be collected for all thermostats. If no BAS is present or data is not observable, data should be gathered from at least 3 thermostats or 20% of the total number of thermostats installed, whichever is greater. Thermostats should be located in different occupancy within the building if possible (e.g. conference, open office, etc.)

1) Record the setpoints observed at the thermostats or from the BAS, as shown in the photos for measure 6018, in the *Thermostat Log.*
2) Determine the setback, in degrees, for heating and cooling and record findings in the data collection form.
3) Record all observations in the data collection form.

Measure Name	Measure Number	Code Section
Night fan control	6019C	IECC 2012: C403.2.4.3

Measure Description

Fans shall be scheduled off during unoccupied periods.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical floor plans to identify any thermostats (see image for measure 6018).
3) If this measure applies to the building, record the following information per the building plans in the *Thermostat Log* in the data collection form:
    a. Zone and corresponding square footage of the location of the thermostat
        i. Note where in the field to look for different thermostats (e.g., standalone thermostat, DDC)
    b. Make and model of the thermostat
4) Use the SOO to determine if any fans are scheduled off during unoccupied periods and record findings in the data collection form.
5) Determine the airflow (cfm) that is affected by this measure and record all findings on the data collection form.

Field Inspection

If data is easily accessible in the BAS, the following information should be collected for all thermostats. If no BAS is present or data is not observable, data should be gathered from at least 3 thermostats or 20% of the total number of thermostats installed, whichever is greater. Thermostats should be located in different occupancy within the building if possible (e.g. conference, open office, etc.)

1) Record the fan schedule settings observed at the thermostats or from the BAS.
2) Select which description best describes measure:
    - Fan cycles during unoccupied period and warmup by schedule or sensor; or DOAS with fan always cycling
    - Fan cycles during unoccupied period by Schedule, but fan "ON" during warmup
    - Fan ON during unoccupied period or ON/AUTO switch only
3) Record all observations in the data collection form.

Measure Name	Measure Number	Code Section
Automatic (Optimal) start controls	6023	IECC 2012: 403.2.4.3.3

Measure Description

HVAC systems shall have optimal start controls.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Verify an outdoor air temperature sensor is specified on the plans.
3) Determine the floor area (sf) that is affected by this measure.
4) Check SOO to determine where in field to look, e.g. standalone T-stat vs. DDC (direct digital controls).
   a) Select which description best describes measure:
      - Optimum start; OA sensor
      - Optimum start; no OA sensor
      - No optimum start

5) Record all findings in the data collection form and note thermostat details in the *Thermostat Log*.

Field Inspection

1) Verify an outdoor air temperature sensor is installed.
2) Verify the installed thermostat is capable of optimum start and is activated.
   Note: To accomplish this, it may be necessary to access the contractor settings in the thermostat. Look up the instructions on how to access these settings using the thermostat manufacturer's website.
3) Check BAS activation through trends, programming verification, or inclusion of sequence on control drawings.
   Note: It may be necessary to get support from a controls contractor to accomplish this, otherwise a building operator with access to the controls can assist.
4) Record all findings in the data collection form and note thermostat details in the *Thermostat Log*.

Measure Name	Measure Number	Code Section
Snow and ice-melting system control	6026p	IECC 2012: 403.2.4.5

Measure Description

Snow and ice-melting systems are not required; however, if they are installed, such systems must have automatic controls that shut off the system when the pavement temperature is above 50°F temperature, no precipitation is falling, and the outdoor air temperature is above 40°F.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical plans or specifications section to identify any snow and ice-melting systems.
3) If this measure applies to the building, use the SOO to determine if the system has sensors for the following:
    a. Pavement temperature
    b. Outside air temperature
    c. Precipitation

    Record findings in the *Mechanical – Snow & Ice Controls* section of the data collection form.
4) Indicate in the data collection form which of the following best describes the system:
    a. Snow Melt only if OA <35F; pavement <40F; and precipitation sensor.
    b. Snow Melt automatic only if OA <40F; pavement <50F; and precipitation sensor.
    c. Snow Melt only if OA <40F or readily accessible manual; pavement <50F; and precipitation sensor.
    d. Snow Melt manual only; no automatic control.
5) Determine the floor area (sf) of heated surface for this measure and record findings in the data collection form.

Field Inspection

1) Verify a snow and ice-melting system controller exists.
2) Verify all three sensors are installed: pavement temperature, outside air temperature, and precipitation.
    a) If the system relies on a BAS, verify the three sensors are included in the BAS.
3) If possible, check the sensor setpoints on the controller or BAS and record all findings in the *Mechanical – Snow & Ice Controls* section of the data collection form.

Measure Name	Measure Number	Code Section
Demand control ventilation	6029	IECC 2012: 403.2.5.1

Measure Description (requirements vary by code version)

Demand control ventilation (DCV) must be provided for spaces larger than 500 ft^2 and with an average occupant load of 25 people per 1000 ft^2 of floor area (as established in Table 403.3 of the International Mechanical Code) and served by systems with one or more of the following:

1. An air-side economizer
2. Automatic modulating control of the outdoor air damper
3. A design outdoor airflow greater than 3,000 cfm.

Demand control ventilation is not required for the following systems and spaces:

1. Systems with energy recovery complying with Section C403.2.6 of the 2012 IECC.
2. Multiple-zone systems without direct digital control of individual zones communicating with a central control panel.
3. System with a design outdoor airflow less than 1,200 cfm (600 L/s).
4. Spaces where the supply airflow rate minus any makeup or outgoing transfer air requirement is less than 1,200 cfm (600 L/s).
5. Ventilation provided for process loads only.

Determine the floor area (sf) of the spaces qualifying for DCV.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Review the mechanical plans and identify any spaces where DCV is required based on the floor area and occupant load.
   Note: The occupant load is often found in the ventilation calculations section of the mechanical plans.
3) If this measure applies to the building, determine the floor area (sf) of the spaces qualifying for DCV and record findings in the *Mechanical – DCV* section of the data collection form.
4) Check for and verify that DCV is mentioned in the SOO.
5) Check the location of the sensors (typically CO_2 sensors) and verify at least one sensor is located in each space (or return air for single zone system) where DCV is required. Record all findings on the data collection form.

Field Inspection

1) Record the floor area of the spaces qualifying for DCV in the *Mechanical – DCV* section of the data collection form and note whether a DCV system is installed.
2) Verify that a sensor (typically CO_2 sensor) is located in each space where DCV is required.
3) Access the BAS and check and record the DCV related setpoints:
   a) CO_2 level
   b) Airflow
4) For a sample of zones, breathe on the sensor and verify the outdoor air damper responds. Alternately, modify the CO_2 setpoint at the BAS to see if damper opens. Record all observations in the data collection form.

Measure Name	Measure Number	Code Section
Energy recovery ventilation system	6030	IECC 2012: C403.2.6

Measure Description

Fan systems with large supply airflow and outdoor airflow rates that exceed the values specified in Table C403.2.6 of the 2012 IECC must include an energy recovery system.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Determine the outdoor airflow (cfm) for which the energy recovery ventilation (ERV) system is required.
3) Review the mechanical plans and appropriate codes to identify any spaces where ERV is required.
4) If this measure applies to the building, verify and record the following information per the plans in the *Mechanical – ERV* section of the data collection form:
    - An ERV system is included in the plans
    - Make and model number of the equipment
    - Equipment Efficiency
    - Specified and code required effectiveness

Note: *ERV effectiveness is defined as "the change in the enthalpy of the outdoor air supply divided by the difference between the outdoor air and return air enthalpies at design conditions."*
This is different from the typical "efficiency" in product literature. For an engineered system, the required data is typically provided with submittals.

5) Verify the fan system includes provisions to bypass or otherwise control the economizer so that energy is not recovered during economizer operation. This may be accomplished by one of the following:
    a. A physical bypass with dampers and ducting that avoids the ERV during economizer
    b. The physical rotation of an ERV wheel in the airstream so that it is not functioning
    c. The stopping of the rotation of the ERV wheel.
6) Record all findings in the *Mechanical – ERV* section of the data collection form and note equipment details in the *HVAC Log*.

Field Inspection

1) Verify the ERV equipment is installed in the field.
2) Record the make and model number from the equipment nameplate in the *Mechanical – ERV* section of the data collection form and verify it matches the plans. Record any discrepancies.
3) Verify economizer bypass or control by completing the following:
    a) Check for a physical bypass.
    b) Use the BAS (if available) to exercise the ERV to see if there is a strategy to control or bypass during economizer operation.
    c) If there is no BAS, trigger the economizer sequence to verify the ERV is controlled or bypassed.
4) Record the presence and efficiency of the system using one of the following descriptors from the data collection form:
    - ERV installed; Energy Recovery Ratio ≥ 60%; Full bypass OA & EA when in Econo
    - ERV installed; Energy Recovery Ratio ≥ 60%; Bypass OA or control in Econo.
    - ERV installed; Energy Recovery Ratio ≥ 50%; Bypass OA or control in Econo.
    - ERV installed; Energy Recovery ≥ 50%; No bypass or control in Econo.
    - ERV installed; Energy Recovery Ratio > 35% but < 50%; Bypass OA or control in Econo.
    - ERV installed; Energy Recovery Ratio > 35% but < 50%; No bypass or control in Econo.
    - ERV Not Used; or Egy Recvy Ratio <35%
1) Record all findings in the *Mechanical – ERV* section of the data collection form and note equipment details in the *HVAC Log*.

Measure Name	Measure Number	Code Section
Duct insulation requirement	6033p	IECC 2012: C403.2.7

Measure Description

Supply and return air ducts and plenums must be insulated with a minimum of R-6 insulation where located in unconditioned spaces and a minimum of R-8 insulation where located outside the building.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical plans or specifications to verify proper insulation where required by code. *Note: This measure is only being verified for ducts located outside the building or in unconditioned space (e.g., vented attic, crawlspace, etc.).*
3) Record the following information per the building plans in the *Mechanical – Insulation* section of the data collection form:
    a. Insulation R-value
    b. Insulation thickness in inches
    c. Insulation type
4) Record the required R-value so the percent required can be determined. *Note: The percent required will always be based on code as duct insulation is not available for tradeoff.*
5) Determine and record the surface area (sf) of the exterior duct surface.
6) Record all findings in the *Mechanical – Duct & Piping Insulation* section of the data collection form.

Field Inspection

1) Verify applicable ducts are insulated.
2) Record the following information for insulation, as installed, in the *Mechanical – Insulation* section of the data collection form:
    a) Insulation R-value
    b) Insulation thickness in inches
    c) Insulation type
    d) Insulation condition
3) Record all findings in the data collection form.

Field Tip: Inspection of insulation should occur during duct insulation installation for best results.

Measure Name	Measure Number	Code Section
Duct leakage requirement	6035	IECC 2012: 403.2.7.1

Measure Description

Duct joints, seams, and connections must be fastened and sealed. Joints and seams must comply with Section 603.9 of the International Mechanical Code.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical plans or specifications to determine the type of sealant proposed for the ductwork. Record this information in the *Mechanical – Leakage* section of the data collection form.
   Note: This measure is only being verified for ducts located outside the building or in unconditioned space (e.g., vented attic, crawlspace, etc.). Additionally, duct sealing information may not be available on the plans or specifications.
3) Determine the airflow (cfm) delivered by the specified ducts and note it in the data collection form.

Field Inspection

1) Verify proper support and sealant has been used
   a) If Underwriters Laboratory (UL) listed and labeled tape or mastic is used, ensure tape is permitted by code.
2) Check the flex duct to boot attachment is complete with screws and zip ties.
3) Evaluate the quality of sealing using the designations provided in the data collection form:
   a) Tested when not required
   b) Sealed as required
   c) Poorly sealed
   d) Multiple branch disconnections
4) Record all observations in the *Mechanical – Leakage* section of the data collection form.

Field Tip: For any duct sections that are hard to access, consider using a small mirror on a stick to help with inspection.

Measure Name	Measure Number	Code Section
Hydronic Heating Piping Insulation	6042B	IECC 2012: 403.2.8

Measure Description

Piping in a heating system must be insulated in accordance with Table C403.4.8 of the 2012 IECC.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical plans to identify any hydronic heating equipment and piping.
3) Verify the applicability of this measure based on the fluid temperature.
   Note: Pipe insulation is not available for tradeoff.
4) If this measure applies to the building, check the mechanical plans or specifications for proper insulation of both the heating water supply and return piping as required by code. Record the following information in the *Mechanical – Duct & Piping Insulation* section of the data collection form:
   a) Insulation R-value
   b) Insulation thickness
   c) Insulation type
5) Determine the length (ft) of the HW supply and return piping for each condition (100% insulation, 50%, 0%, etc.) and record findings in the data collection form.

Field Inspection

1) Verify applicable piping is insulated.
2) Record the following information for insulation, as installed, in the *Mechanical – Duct & Piping Insulation* section of the data collection form:
   a) Insulation R-value
   b) Insulation thickness
   c) Insulation type
3) Record all findings in the data collection form.

Field Tip: Inspection of insulation should occur during insulation installation for best results.

Measure Name	Measure Number	Code Section
Mechanical Commissioning	6045p	IECC 2012: C403.2.9

Measure Description

Mechanical systems must be commissioned in accordance with Section C408.2 of the 2012 IECC.

The following systems are exempt from the commissioning requirements:

1. Mechanical systems in buildings where the total mechanical equipment capacity is less than 480,000 Btu/h cooling capacity and 600,000 Btu/h heating capacity.
2. Systems included in Section C403.3 that serve dwelling units and sleeping units in hotels, motels, boarding houses or similar units.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical specifications to determine any commissioning (Cx) requirements for the building.
3) If this measure applies to the building, verify that a Cx plan has been submitted with the plans and specifications.
    a. Verify the required equipment and controls are specified as part of the Cx plan.
4) Verify that a preliminary Cx report has been submitted to demonstrate Cx has occurred on the project and indicates the status of each piece of equipment that has been commissioned.
    a. If a Cx report is not available, inquire about Cx and a Cx report with building contact.
5) Assess the quality of the Cx and rate in accordance with the designations provided in the data collection form:
    a. Commissioned: High Quality
    b. Commissioned: Satisfactory Quality
    c. Commissioned: Poor Quality
    d. Not Commissioned.
6) Record all findings in the data collection form.

Field Inspection

1) Using the Cx report and/or Cx plan as a data verification tool, verify that commissioning has been documented for the required equipment and controls.
2) Record all findings in the data collection form.

Field Tip: Contact the person responsible for commissioning the building if no Cx report or plan is present onsite.

Additional Details

The following list includes examples of mechanical systems required to be commissioned:

1) Air systems balancing
2) Hydronic systems balancing
3) Functional performance testing of HVAC controls and economizers

Measure Name	Measure Number	Code Section
Fan power limit requirement for packaged air conditioners	6046A	IECC 2012: C403.2.10

Measure Description

HVAC systems with total fan system motor nameplate horsepower (hp) greater than 5 hp must be properly sized. Total fan system motor nameplate horsepower (hp) exceeding 5 horsepower (hp) must meet the provisions of Sections C403.2.10.1 through C403.2.10.2 of the 2012 IECC.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical plans to determine the maximum horsepower allowed based on the supply airflow for each system.
3) Check the mechanical schedule for compliance with the motor nameplate hp limit and record findings in the *Mechanical – Airside* section of the data collection form.
    a. If the system is not compliant, check the mechanical schedule and code compliance forms for brake horsepower (bhp) allowance and compliance. Limits include supply, return, exhaust, and series fan power terminal units (FPTU) fans. Include any "device" credits available to system when using the bhp approach.

Note: While this requirement applies to any system with a total nameplate hp exceeding 5 hp (sum of supply, return, and exhaust fan motors), typically it is easily met by systems less than 15 tons. Relief fan motors that operate only during economizer operation are not counted against the limit.

Field Inspection

1) For each system, verify the nameplate hp for each fan matches those shown in the plans.
2) For all fans, verify that the fan motors installed in the field match the nameplate hp that was indicated on the plans.
    a) If the installed equipment does not match what was called for on the plans:
        i) Record the make and model number off the unit nameplate on each piece of equipment
        ii) Record the fan nameplate motor hp after the completion of the onsite data collection effort.
3) If brake hp approach for compliance was used, verify that any devices claimed for pressure drop credit in the calculations (e.g., fully ducted return, filtration greater than MERV 8, ERV, etc.,) are installed.
4) Record all findings in the data collection form.

Measure Name	Measure Number	Code Section
Fan power limit requirement for VAV	6046B	IECC 2012: C403.2.10

Measure Description

HVAC systems with total fan system motor nameplate horsepower (hp) greater than 5 hp must be properly sized.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical plans to determine the maximum horsepower allowed based on the supply and return airflow for each system.
3) Check the mechanical schedule for compliance with the motor nameplate hp limit and record findings in the data collection form.
    a. If the system is not compliant, check the mechanical schedule and code compliance forms for brake horsepower (bhp) allowance and compliance. Limits include supply, return, exhaust, and series fan power terminal units (FPTU) fans. Include any "device" credits available to system when using the bhp approach.

Note: While this requirement applies to any system with a total nameplate hp exceeding 5 hp (sum of supply, return, exhaust, and FPTU fan motors), typically it is easily met by systems less than 15 tons. Relief fan motors that operate only during economizer operation are not counted against the limit.

Field Inspection

1) For each system, verify the nameplate hp for each fan matches those shown in the plans.
2) For all fans, verify that the fan motors installed in the field match the nameplate hp that was indicated on the plans.
    a) If the installed equipment does not match what was called for on the plans:
        i) Record the make and model number off the unit nameplate on each piece of equipment
        ii) Record the fan nameplate motor hp after the completion of the onsite data collection effort.
3) If brake hp approach for compliance was used, verify that any devices claimed for pressure drop credit in the calculations (e.g., fully ducted return, filtration greater than MERV 8, ERV, etc.,) are installed.
4) Record all findings in the *Mechanical – Fan Power VAV* section of the data collection form.

Measure Name	Measure Number	Code Section
Outdoor heating shall be radiant and controlled with occupancy sensor	6051	IECC 2012: C403.2.11

Measure Description

Outdoor heating systems are not required; however, systems installed to provide heat outside of a building must be radiant systems.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical plans to identify any outside or covered exterior areas with heating.
3) If this measure applies to the building:
   a) Verify that an occupancy sensor or timer is provided to control the heating system
   b) Verify that the heating source is a radiant system.
2) Select the proper designation for the system from those provided in the data collection form:
   a) Radiant heat; Occupancy sensor or timer
   b) Radiant heat; Schedule control
   c) Radiant heat; No automatic controls
   d) Other than radiant heat
3) Record heating capacity in MBh
4) Record all findings in the data collection form.

Field Inspection

1) Look for outside heating, particularly at exterior entries or check-out counters.
2) Verify presence of occupancy sensor or timer and confirm heating is radiant rather than fan unit heater or other type.
3) Select the proper designation for the system from those provided in the data collection form:
   a) Radiant heat; Occupancy sensor or timer
   b) Radiant heat; Schedule control
   c) Radiant heat; No automatic controls
   d) Other than radiant heat
4) Verify recorded heating capacity
5) Record all findings in the data collection form.

Measure Name	Measure Number	Code Section
Economizer supplies 100% design supply air	6056	IECC 2012: C403.3.1.1.1

Measure Description

Cooling systems with fans must include an air or water economizer. Air economizer systems must be capable of modulating outdoor air and return air dampers to provide up to 100 percent of the design supply air quantity as outdoor air for cooling.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use plans to identify cooling systems with fans.
3) If this measure applies to the building, verify outside air ductwork on plans is sized the same as the main return or supply, the unit is rooftop, or the unit has direct access to outside.
4) Verify that an economizer has been specified for the applicable pieces of cooling equipment based on cooling capacity.
    a. Note exceptions where an economizer is not required
5) Record all findings in the *Mechanical – Economizer* section of the data collection form and note equipment details in the *HVAC Log*.

Field Inspection

1) Verify outside air ductwork matches the ductwork indicated in the plans.
2) Confirm the cooling capacity for the economizer unit matches the plans.
3) Verify return air damper is fully closed during economizer operation.
4) Look for and note the results of any reports that show a functional performance test has been conducted on the economizer(s).
6) Record all findings in the *Mechanical – Economizer* section of the data collection form and note equipment details in the *HVAC Log*.

Outside air ductwork for air economizer – Source U.S. DOE

Measure Name	Measure Number	Code Section
Water economizer capacity meets requirements	6066P	IECC 2012: C403.4.1.1

Measure Description

Water economizers must provide 100% of the cooling load at specified temperature and humidity.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical plans to identify and review the cooling tower, fluid cooler, and heat exchanger sizing related to the water economizer.
3) Verify heat rejection capacity at water economizer design conditions matches required capacity.
4) If a waterside economizer is specified on the plans and specs, check mechanical schedule for waterside economizer capacity at design outdoor air temperature is specified (varies by code).
5) Record all findings in the *Mechanical – Economizer* section of the data collection form and note equipment details in the *HVAC Log*.

Field Inspection

1) Verify that the installed equipment matches that specified in the HVAC plans.
2) If installed equipment is different than was specified in the plans, verify with the HVAC designer that the installed system meets the energy code requirements for water side economizer capacity.
3) Look for and note the results of any reports that show a functional performance test has been conducted on the economizer(s).
4) Record all findings in the *Mechanical – Economizer* section of the data collection form and note equipment details in the *HVAC Log*.

Measure Name	Measure Number	Code Section
Multi-zone reheat systems shall be VAV and fans with motors ≥7.5 hp shall have variable speed, variable pitch axial, or fan demand reduction	6070	IECC 2012: C403.4.2

Measure Description

VAV fans with motors 7.5 hp or larger must have variable speed, variable pitch axial, or fan demand reduction. Zone dampers must reduce airflow before reheating.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the plans to identify any multi-zone reheat systems.
3) If this measure applies to the building, verify that multi-zone fan systems with simultaneous heating and cooling systems, at a minimum, have dampers in place and specified to reduce individual zone airflow as required by code (varies by code).
4) Verify that the VAV system is specified with either a variable speed drive (VSD), variable pitch axial fan, or fan demand reduction.
    a. Fans with hp greater than or equal to the code requirement must have a VSD.
5) Check the HVAC equipment schedule or equipment specifications to determine which option has been selected.
6) Zone air for reheat systems shall be limited to 30% or 20% with dual max, or have a documented ventilation exception.
7) Identify and record the speed control and fan nameplate hp in accordance with the designations provided in the data collection form:
    a) Variable flow fan with ~33% turndown; VSD
    b) Variable flow fan with ≤50% turndown; VSD
    c) Variable flow fan with ~66% turndown; VSD or two-speed
    d) Variable air flow; Outlet damper; no VSD
    e) Constant volume fan; Constant airflow
8) Record all findings in the *Mechanical – MZ VAV* section of the data collection form.

Field Inspection

1) Verify that the test and balance (TAB) or Cx report shows that box minimums have been properly set to match plan documents.
2) Verify that VSD is in place if required and that the fan is operating at reduced speed.
3) Confirm speed control and fan nameplate hp and record in accordance with the designations provided in the data collection form:
    a) Variable flow fan with ~33% turndown; VSD
    b) Variable flow fan with ≤50% turndown; VSD
    c) Variable flow fan with ~66% turndown; VSD or two-speed
    d) Variable air flow; Outlet damper; no VSD
    e) Constant volume fan; Constant airflow
4) Record all observations in the *Mechanical – MZ VAV* section of the data collection form.

Measure Name	Measure Number	Code Section
Static pressure sensors	6071	IECC 2012: C403.4.2.1

Measure Description

Static pressure sensors used to control VAV fans must be placed in a position such that the controller setpoint is no greater than one-third of the total design fan static pressure (or 1.2 inches w.c.), except for systems with zone static reset control complying with Section C403.4.2.2 of the 2012 IECC.

Note: ASHRAE 90.1-2013 and the 2015 IECC require both when direct digital controls (DDC) are present.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use specifications, plans, or control drawings to identify static pressure (SP) sensor placement.
    a. For buildings with DDC controls, check SOO to verify setpoint is being reduced (reset) based on zone cooling demand.
3) Note sensor location and total fan CFM per the data collection form:
    - Static pressure reset with max setpoint 1/3 of design pressure or 1.2" w.c.; and reset is at least 0.5" w.c.
    - Static pressure reset at least 0.5" w.c; or the max setpoint ≤1/3 of design pressure
    - No static pressure reset; or the max setpoint >1/3 of design pressure
4) Record all findings in the data collection form.

Field Inspection

1) Confirm static pressure placement matches plan review findings.
2) If pressure sensor cannot be located, verify location on control drawings or contact the HVAC contractor to determine the location of the SP sensor.
3) Observe setpoint and reset in BAS, if possible.
4) Record all observations in the data collection form.

Measure Name	Measure Number	Code Section
Each water source heat pump in a system exceeding 10 hp pump shall have a two-position valve	6089	IECC 2012: C403.4.3.3.3

Measure Description

Each hydronic heat pump on the hydronic system having a total pump system power exceeding 10 hp shall have a two-position valve and VSD on circulation pump.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Document heat pump nameplate horsepower.
3) Use the plans or specifications to verify water source heat pump (WSHP) loop pump size
    a. Verify that when total pump system power >10 hp, each WSHP has a two-position valve.
4) Verify VSD control of pump.
5) Indicate in the *Mechanical – Plant* section of the data collection form which of the following options pertains to the system:
    - Individual WSHP valves; VSD on pumps
    - Individual WSHP valves; pump rides pump curve
    - No individual WSHP valves; pump is constant flow.
6) Record all findings in the data collection form.

Field Inspection

1) Confirm for at least 3 and at least 10% of the WSHP units that there is a 2-position water loop shutoff valve if required (total of all hydronic heat pump units >10 hp).
   Note: A small number of units may have no valve to avoid pump deadheading.
2) Verify VSD is installed on the pump.
3) Verify pump nameplate hp matches design.
4) If the system is operational, check that the pump is operating at reduced speed.
5) Record all observations in the data collection form.

Measure Name	Measure Number	Code Section
Multiple chiller shall reduce flow when a chiller is shut down	6091P	IECC 2012: C403.4.3.5

Measure Description

Chilled water plants with more than one chiller must reduce flow through the chiller plant when a chiller is shut down.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the plans to identify chillers.
3) If this measure applies to the building, verify each chiller has an isolation valve or a check valve combined with a dedicated primary pump.
4) Review the mechanical plans showing the hydronic piping layout and the pump schedule to verify that a VSD motor(s) has been installed.
5) Note the appropriate designation for the system per the *Mechanical – Plant* section of the data collection form:
    a) VSD primary chiller pump with variable flow chiller.
    b) Individual chiller valves and separate pumps for each chiller or VSD on common pump.
    c) Individual chiller valves, but not separate pumps for each chiller or VSD.
    d) No individual chiller valves and primary pumps are constant flow.
6) Check SOO for flow through chiller only when chiller is operational.
7) Record all findings in the *Mechanical – Chiller* section of the data collection form

Field Inspection

1) Verify that installed equipment matches plan review findings.
2) Verify each chiller has an isolation valve or a check valve combined with a dedicated primary pump.
3) Verify VSD is installed on all the chiller pumps.
4) If the system is operational, verify that each pump can operate at reduced speed and that the flow valve to non-operational chillers is closed.
5) Record all observations in the *Mechanical – Chiller* section of the data collection form.

Measure Name	Measure Number	Code Section
Multiple zone HVAC systems shall have supply-air temperature reset controls	6101	IECC 2012: C403.4.5.4

Measure Description

Multiple zone HVAC systems must include controls that automatically reset the supply air temperature in response to representative building loads or to outdoor air temperature. Temperature shall be reset at least 25% of the difference between design supply air temperature and cooling design room air temperature.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Verify SOO or specifications have SAT reset controls meeting code requirements.
3) Note design SAT and reset SAT per the designations provided in the *Mechanical – Controls* section of the data collection form:
    - SAT is reset; ≥ 25% des SA to space reset
    - SAT is reset; < 25% des SA to space reset; or core zones not sized for reset
    - No SAT reset
4) Record all findings in the *Mechanical – MZ Reset Controls* section of the data collection form.

Field Inspection

1) Observe SAT reset in operation, trends of the SAT setpoint, or programming in field.
   Note: This will likely require assistance from a controls contractor or building operator; the system must be operational.
2) Alternatively, verify SAT reset sequence on control drawings.
3) Record all observations in the *Mechanical – MZ Reset Controls* section of the data collection form.

Measure Name	Measure Number	Code Section
VAV Ventilation Optimization	6106AS	ASHRAE 90.1-2010: 6.5.3.3

Measure Description

Multi-zone VAV systems with DDC-to-zone (Direct Digital Control) must dynamically reset outside air intake in response to ventilation system efficiency. They must automatically reduce outdoor air intake flow below design rates in response to changes in system ventilation efficiency.

Note: This requirement does not apply when an energy model has been submitted for compliance.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Verify SOO or specifications have a dynamic ventilation reset for Multi-Zone systems.
3) Record flow of outside air (cfm)
4) Select best description of system:
    - VAV ventilation optimization; with zone DCV (Apx B, 62.1-2010 UM)
    - VAV ventilation optimization
    - No VAV ventilation optimization
5) Record all findings in the *Mechanical – VAV Ventilation Controls* section of the data collection form.

Field Inspection

1) Observe dynamic ventilation reset in operation, trends of outside air setpoint, or programming in field. *Note: This will likely require assistance from a controls contractor and the system be operational*.
2) Alternatively, verify dynamic ventilation reset sequence on control drawings.
3) Record observations in the *Mechanical – VAV Ventilation Control*s section of the data collection form.

Measure Name	Measure Number	Code Section
Single zone VAV	6108AS	ASHRAE 90.1-2010: 6.4.3.10

Measure Description

Single zone AHUs (air handling units) and FCUs (fan coil units) with fan motors 5 hp or larger and chilled water coils must be 2-speed or VAV with VSD (variable speed drives). Fan speed is limited at 50% cooling to the greater of 50% flow or minimum OA (outside air) requirements. Single zone systems with dx cooling, 110,000 Btuh or greater, must also be 2-speed or Variable Frequency Drive (VFD) with fan speed limited to 2/3 full speed at 50% cooling demand.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the HVAC equipment schedule or equipment specifications to verify that AHUs and FCUs are specified with variable or multi-speed fans if they have fan motors 5 hp or greater and chilled water coils.
    a. Note minimum speed and verify system is controlled to run at minimum speed at low or no load.
3) Record all findings in the *Mechanical – Single Zone VAV* section of the data collection form and note equipment details in the *HVAC Log*.

Field Inspection

1) Verify that the installed equipment matches what is specified on the plans and/ or in the specifications and the code requirements.
2) If the installed equipment is different than what is shown in the mechanical plans, check the fan motor nameplate for the horse power rating and for the presence of a VFD control or two speed motor.
3) Verify that the installed equipment model number is for equipment with variable or multi-speed fan capability.
4) Alternatively, contact the HVAC contractor to determine the specifications for the installed system.
5) Verify that fan is running at low speed during low or no load conditions.
6) Record all observations in the *Mechanical – Single Zone VAV* section of the data collection form and note equipment details in the *HVAC Log*.

Measure Name	Measure Number	Code Section
Parking garage fan controls	6109PAS	ASHRAE 90.1-2010: 6.4.3.4.5

Measure Description

Enclosed parking garage ventilation systems shall automatically detect contaminant levels and stage fans or modulate fan airflow rates to 50% or less of design capacity provided acceptable contaminant levels are maintained (see figure in Additional Details section below).

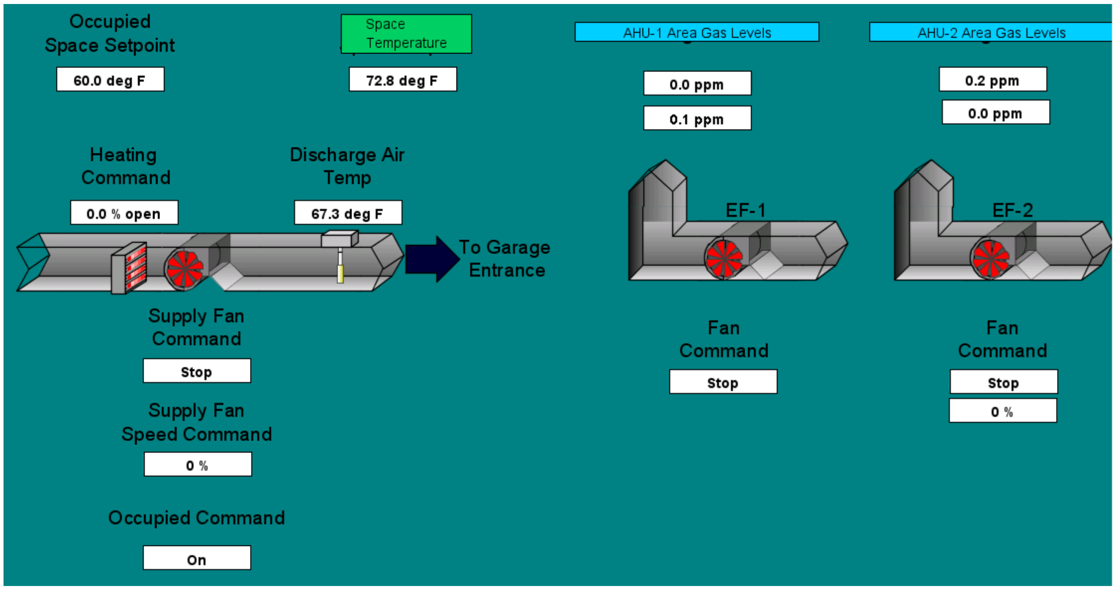
Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the plans to determine if parking garage fan controls are required.
3) If this measure applies to the building, verify SOO or specifications include CO sensors and ventilation flow controls, if required.
4) Indicate which of the following designations best describes the controls per the data collection form:
    - Parking garage exhaust reduction; VSD turn down to ~33%; automatic CO sensors
    - Parking garage exhaust reduction; with turn down ≤50%; automatic CO sensors.
    - Parking garage exhaust reduction; with turn down ≤50%; schedule/no contaminant sensors.
    - Constant volume parking garage exhaust.
5) Record the fan nameplate hp and other applicable information in the *Mechanical – Parking Garage Fan Controls* section of the data collection form.

Field Inspection

1) Verify that installed equipment matches plan review findings, including:
    a) VSD exists
    b) CO sensors are in place
    c) Fans are operating at reduced speed based on contaminate level.
2) Indicate which of the following designations best describes the controls per the data collection form:
    a) Parking garage exhaust reduction; with turn down ≤50%; automatic CO sensors
    b) Parking garage exhaust reduction; with turn down ≤50%; schedule/no contaminant sensors
    c) Constant volume parking garage exhaust
3) Record all observations in the *Mechanical – Parking Garage Fan Controls* section of the data collection form.

Field Tip: System will need to be observed in operation to determine that the fans operate at reduced levels and that they increase when contaminant levels reach threshold.



EMS screenshot showing garage fan control based on contaminant level

Garage exhaust fans

Garage fan VFD

Measure Name	Measure Number	Code Section GG
Zone Isolation	6110PAS	ASHRAE 90.1-2010: 6.4.3.5

Measure Description

HVAC systems serving zones that are not intended to operate or be occupied at the same time must be able to automatically shut off the supply of conditioned air, outdoor air, and exhaust air to any zone that is not occupied. Zones that do operate and are occupied simultaneously can be grouped into a single isolation zone ≤25,000 sf and not more than one floor.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the mechanical plans or specifications to verify that isolation devices, such as dampers, are present where zones are required to be isolated and that isolation areas are below required area thresholds.
3) Verify that the SOO in the mechanical plans or specifications have required zone isolation controls for spaces that operate for extended hours.
4) Record all findings in the *Mechanical – Zone Isolation section* of the data collection form.

Field Inspection

1) For multiple zones on a single fan system with various occupied times, confirm the schedules are programmed for each zone and isolation devices (dampers) shut off airflow to spaces that are not occupied.
2) Verify with the HVAC contractor or building operator that the controls are set up correctly.
   a) Alternatively, control functionality may be verified by exercising the BAS.
3) Record all observations in the *Mechanical – Zone Isolation section* of the data collection form.

Measure Name	Measure Number	Code Section
SWH Pipe Insulation – Recirculated	7006	IECC 2012: C404.5

Measure Description

For automatic circulating hot water and heat-traced systems, piping shall be insulated with not less than 1 inch of insulation having a conductivity not exceeding 0.27 Btu per inch/h × sf × °F, which is equivalent to an R-value of 3.7.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Use the plans to verify that insulation is specified for piping in recirculating HW systems.
3) Verify the R-value of the insulation, the type of insulation, and insulation thickness.
4) Determine the linear feet of the HW piping.
5) Record all findings in the *Mechanical – Insulation* section of the data collection tool.

Field Inspection

1) Verify piping is insulated as required in the plans.
2) Document pipe insulation type and thickness.
3) Record all observations in the *Mechanical – Insulation section* of the data collection form.

Lighting Measures

Measure Name	Measure Number	Code Section
Manual Lighting Control	9003	IECC 2012: C405.2.1

Measure Description

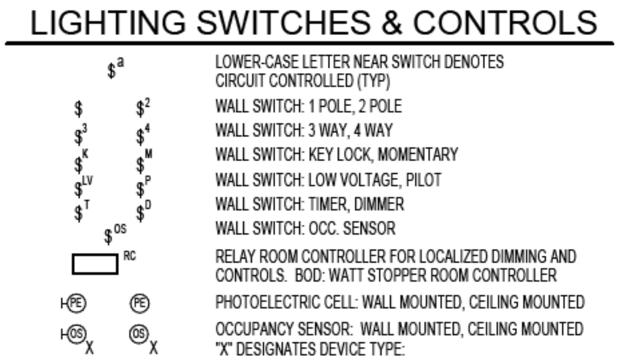
Each enclosed area (space) shall have at least one manual control for the lighting in that area, as well as controls allowing reasonably uniform lighting reduction between 30% and 70% (varies by code). The controls shall be located within the area or be a remote switch that identifies the lights served and indicates their status.

Plan Review

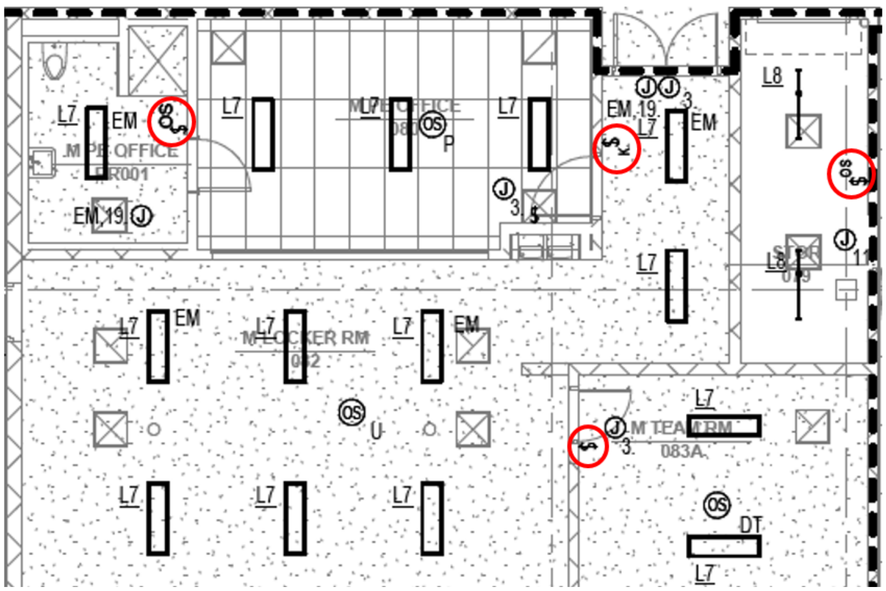
1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Verify the design for each space includes a switch for manual control. This can typically be found on the lighting floor plan with the switch indicated by a $ symbol. The symbol can be verified in the symbol legend, which is typically within the first few pages of a drawing set. Examples of a legend and a lighting floor plan are below. The space should be no larger than allowed by code. Exceptions to this requirement should be confirmed in the code.
3) Note any spaces not requiring manual controls.
4) Document spaces that do not have a switch on the plans for onsite verification, these may be controlled by a remote switch.
5) Verify the design includes lighting reduction controls per code in each space, unless not required, based on number of luminaries in the space, rated power of lighting within the space, space type, or alternate lighting controls in the space as required by code.
6) Approved lighting reduction controls include strategies such as dimming ($^D or similar on plans), dual switching lamps or luminaires ($$ - multiple switches on plans), or others. These strategies may be called out in a note on the plans as well.
7) Record all findings in the *Lighting – Manual Controls* section of the data collection form. Note any spaces not requiring lighting reduction controls.

Field Inspection

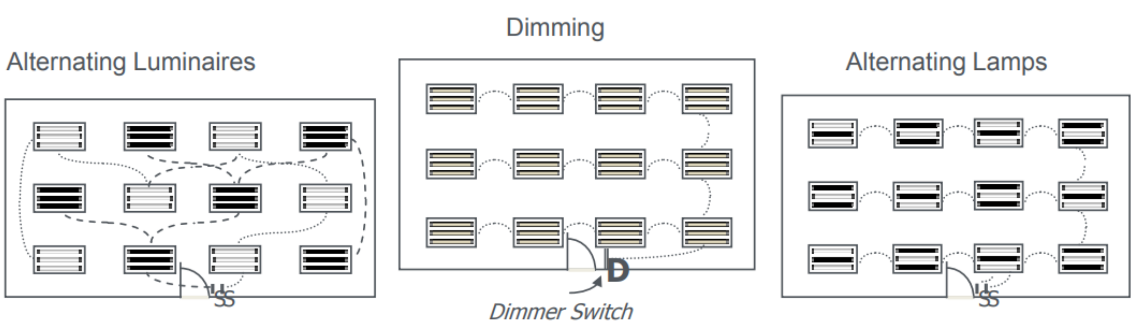
1) Verify each space includes a manual control unless noted during the plan review that one is not required.
2) If the control is remote, verify it identifies the lights served and indicates their status.
3) Verify required lighting reduction controls are present for each space by observing a second switch, button, or a dimmer that uniformly reduces the lighting by at least 50% (unless noted during the plan review that they are not required).
4) Verify maximum controlled area for each manual control as required by the specific code.
5) If any aspect of the onsite lighting does not match the plan design for a space, determine which exceptions may apply for the as-constructed space.
6) Record all findings in the data collection form.



* *Example Lighting Symbol Legend*



* *Example Lighting Floor Plan Switch Identification*



* *Example Uniform Lighting Reduction Strategies*[8]

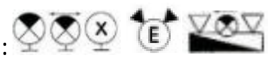
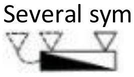
[8] *Source: https://www.energycodes.gov/sites/default/files/becu/2012iecc_commercial_lighting_BECU.pdf*

Measure Name	Measure Number	Code Section
Automatic Time Switch Control	9009	IECC 2012: C405.2.2.1

Measure Description

Lighting within all areas of a building must have automatic time switch controls unless it is controlled by an occupancy sensor. A means for override also must be provided. Emergency egress lighting may be exempt, depending on code.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Verify the design for each space includes an automatic time switch control, if required. Code may not require time switch control of emergency or egress lighting or lighting controlled by occupancy sensors.
    a) Emergency lighting may be indicated on plans by a diagonal fill in fixture or letter indicator and the circuit may be labeled 'E' or 'EM' .
    b) Several symbols are used to indicate exit or egress lighting, examples include:  
    c) Lighting controlled by an occupancy sensor is typically indicated by 
    d) The automatic time switch control is often within a lighting control system panel for all the building lights. If details of system settings (including automatic time switching) are not included on the plans, note to verify controls on site.
3) Verify each space is provided with an override switching device that meets code requirements. Override switching devices may be the same switch or device that is utilized to provide the manual lighting control and lighting level reduction control. Again, these control details may be found in drawing set floor plans, one-line controls diagram, specifications, or not at all. Code requirements may be dependent on whether a captive-key control is used, an example of this is shown below.
4) Record all findings in the *Lighting – Time Switch Controls* section of the data collection form.

Field Inspection

1) Ask the facility contact person what controls the automatic time switch and where the device is located. If this is unknown, check mechanical rooms, electrical rooms, and other facilities closets.
2) For a stand-alone time-clock, verify there are times set for on and off operation and confirm it controls the lighting circuits as expected from plans.
3) For a control system, ask to be shown the schedules for the automatic on/off. Confirm the spaces controlled align with those required and determined during the plan review.
4) Note the square footage of any spaces not meeting the code requirement for automatic time switch controls.
5) Record all findings in the data collection form.

Lighting Control Panels [9]

Digital/Electronic Programmable Clock [10]

Captive Key Switch[11]

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[9] Sources: http://www.nexlight.com/nexlight/products.asp?mc=18, http://ali-and-co.com/Lighting%20Control%20Panels.html, and https://www.legrand.us/wattstopper/lighting-control-panel-systems/contractor-panels/lp8.aspx

[10] Source: https://www.intermatic.com/en/timer-controls/electronic-controls/et90215c

[11] Source: http://www.acuitybrands.com/products/detail/336774/Lighting-Controls-and-Design/Key-Enabled-DigitalSwitch/Key-Enabled-DigitalSwitch

Measure Name	Measure Number	Code Section
Occupancy Sensor Control	9011	IECC 2012: C405.2.2.2

Measure Description

Occupancy sensors are required in certain specific space types, varying by code. Occupancy sensors must turn lights off automatically within a certain time period of occupants leaving the space. In some cases, the lights must be turned on automatically to no more than 50% power or turned on manually. Specific requirements and exceptions are included in the applicable code.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Verify the design for each space type required by the code includes an occupancy sensor control - typically indicated by 

.
3) Identify the intended control method and the delay off time in the plans, specifications, or control diagrams, as available.
4) Record all findings in the *Lighting – Occupancy Controls* section of the data collection form.

Field Inspection

1) Locate occupancy sensors in each space as required. Examples of sensors are shown below.
2) If the lights are on before you enter the space, be sure the space is unoccupied and wait for the lights to turn off. Wait at least an additional 30 seconds before entering the space and note whether they come on automatically or require manual switching. If they come on automatically, note whether they came on to 50% power or less and whether there is a method to turn them to 100%. Determine approximate percentages using a light level meter.
3) Verify how long the occupancy sensors are set to wait before switching off the lights. If the sensors do not have an adjustable control that the time can be determined from, document the make and model to look up the default settings later.
4) If the lighting is controlled by a lighting control system or panel, ask to see the settings to verify the wait time.
5) Verify that the lights are not turned on by movement in adjacent spaces.
6) Record all findings in the data collection form.

Ceiling Mount and Wall Switch Occupancy Sensors[12]

[12] *Sources:* http://www.mcwonginc.com/c11599/c12300.asp *and* http://www.homecontrols.com/Leviton-Occupancy-Sensor-Wall-Switch-with-LED-Nightlight-LVOSSNLIDx

Measure Name	Measure Number	Code Section
Daylight Zone Control	9014A	IECC 2012: C405.2.2.3

Measure Description

For enclosed spaces with more than two fixtures, lighting in daylight zones must be controlled independently (either manually or automatically) of general lighting. Each daylight control zone may not exceed 2,500 ft^2. Contiguous daylight zones along vertical fenestrations may be controlled together provided they do not contain zones facing more than two adjacent cardinal directions. Daylight zones under skylights more than 15 ft from the perimeter must be controlled separately from the perimeter daylight zones. In certain cases, daylight zones are required to be controlled automatically. Those requirements are specific to each code and, in the case of the IECC, specific to window-to-wall ratio. Automatic daylighting controls requirements can either be "stepped" dimming or continuous, depending on code and application.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Identify daylight zones using floor plans, if available, or code requirements.
3) Draw the daylight zones out for use during the site visit.
4) Determine whether fixtures in each daylight zone are required to be controlled manually, by automatic stepped dimming, or by continuous dimming.
5) Determine whether fixtures in each daylight zone (either partially or completely) are on a separate circuit from the other general lighting and controlled manually, or if the daylight controls are automated. Automated controls will include a photocell which is often indicated by a Ⓟ symbol on the plans. Note: Fixtures in the daylight zone may be on the same electrical circuit; if this is the case, the fixtures must operate on an independently switched or controlled branch of that circuit.
6) If automated controls details are on the plans, determine if requirements are met by:
    a. Continuous dimming that must reduce power continuously down to less than 35% the rated value, or
    b. Stepped dimming requires at least two steps, one to 50%-70% of rated power, and one to 35% or less.
7) Daylight zones in spaces where multi-level lighting controls are required must be controlled separately. Lighting must be capable of being reduced to 35% or less of rated power.
8) Record all findings in the *Lighting – Daylight Controls* section of the data collection form.

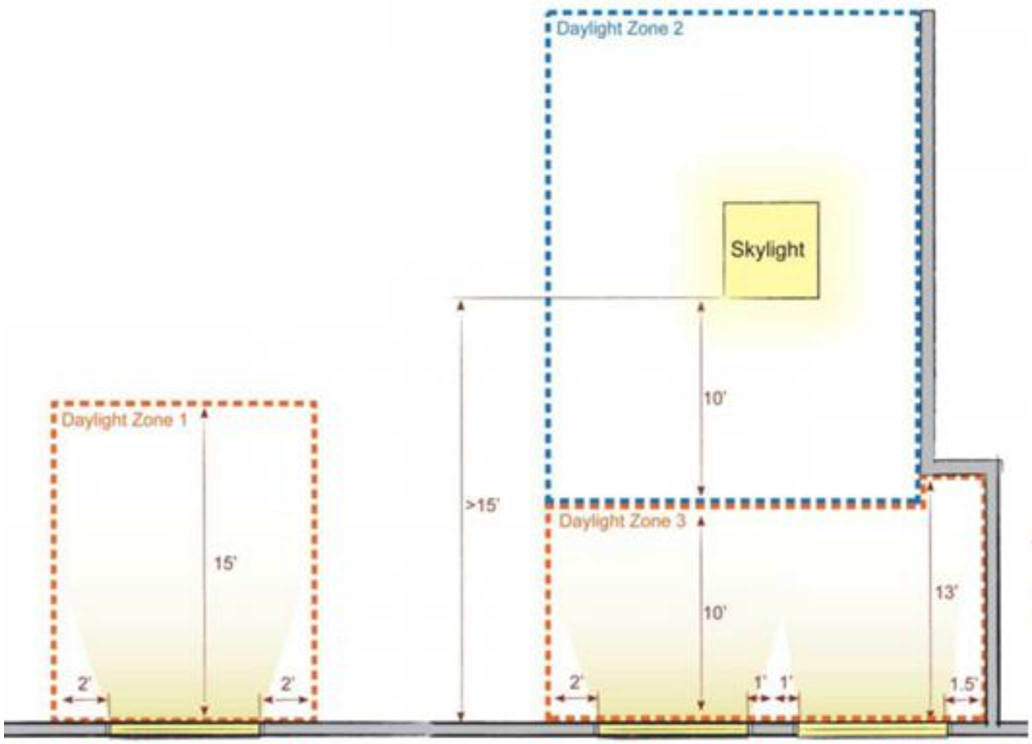
Field Inspection

1) Locate fixtures within each daylight zone identified during plan review.
    a) For manually controlled fixtures, determine if these fixtures are switched separately from the other general lighting.
    b) For automatically controlled fixtures, locate the photocell and, if possible, cover it or shine a flashlight on it (depending on current conditions). Wait a few minutes and note whether lights automatically adjust.
        i. Note whether control is stepped or continuous.
        ii. Verify that calibration and setpoint controls are readily accessible and separate from the light sensor.
2) Record all findings in the data collection form.

Additional Details
Daylight zones can be determined as follows (see diagram below): • Under skylights: The area under skylights whose horizontal dimension, in each direction, is equal to the skylight dimension in that direction plus either the floor-to-ceiling height or the dimension to a ceiling height opaque partition, or one-half the distance to adjacent skylights or vertical fenestration, whichever is least. For the 2015 IECC this is equal to the skylight dimension in that direction plus either 0.7 X the floor-to-ceiling height or the dimension to an opaque partition equal to 0.7 X the ceiling height, or one-half the distance to adjacent skylights or vertical fenestration, whichever is least. • Adjacent to vertical fenestration: The area adjacent to the vertical fenestration with a depth of 15 ft or to the nearest ceiling height opaque partition, whichever is less. For the 2015 IECC, the area adjacent to the vertical fenestration with a depth of height of the top of the window or to the nearest ceiling height opaque partition, whichever is less. The zone width is assumed to be the window width plus: 2 ft on each side, the distance to an opaque partition, or one half the distance to adjacent skylight or vertical fenestration, whichever is least. If more detailed analysis was conducted, the daylight zone definitions may not match those defined above. Examples of some daylight zone calculations are shown below.

Photocell Sensors[13]

[13] Sources: https://www.legrand.us/wattstopper/daylighting-controls/daylighting-controls/lmls-400.aspx and https://www.legrand.us/wattstopper/legacy-products/commercial-products-legacy/daylighting-controls-legacy/ls-101.aspx



Daylight Zone Calculation Examples for the 2012 IECC[14]

[14] *Source:* http://kenergy.us/files/6613/6370/9460/2012_IECC_commercial_lighting_BECU.pdf

Measure Name	Measure Number	Code Section
Daylighting for large, high-bay spaces total daylight zone under skylights at least 1/2 of floor area	9014B	IECC 2012: C402.3.2

Measure Description

An enclosed space greater than 10,000 ft^2 (varies by code) with a ceiling height greater than 15 ft and designated for certain uses specified by code, must have a total daylight zone under skylights of at least half the floor area. Exceptions and specifications for skylight area to daylight zone requirements are detailed in the code.

Lighting in the daylight zone must meet multi-level lighting control requirements:

1. Controlled separately from other lighting in the space.
2. Automatic multi-level control that reduces lighting power to 35% of rated power or less when daylight illuminance is greater than design illuminance values.
3. Calibration and setpoint controls must be accessible and separate from the photocell.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Identify high-bay spaces for which this requirement is applicable and note the total area of that space.
3) Calculate and draw out the daylight zones as defined by the applicable code; note the total area.
4) Determine if a photocell has been indicated on the plans (often by a symbol such as Ⓟ) for automated control.
5) Determine if circuiting for the daylight zone is separate from other lighting in the space.
Note: Fixtures in the daylight zone may be on the same electrical circuit; if this is the case, the fixtures must operate on an independently switched or controlled branch of that circuit.
6) Determine automatic daylighting control approach: on/off, stepped, or continuous dimming
7) Determine the design illuminance level for the space. If this is not indicated on the plans, consult the Footcandle Lighting Guide[15] or similar source to estimate a design illuminance level.
8) Record all findings in the data collection form.

Field Inspection

1) Verify daylighting zone matches that calculated during plan review.
2) Verify lighting in daylight zones is controlled separately from other lighting.
3) Using a light meter, verify illuminance meets design levels. If possible, cover or shine a flashlight (depending on current conditions) on the photocell for a couple minutes to verify lighting responds to a change in conditions.
4) Verify automatic daylighting control approach: on/off, stepped, or continuous dimming.
5) Verify that calibration and setpoint controls are readily accessible and separate from the light sensor.
6) Record all findings in the data collection sheet.

[15] https://www.lightingdesignlab.com/sites/default/files/pdf/Footcandle_Lighting%20Guide_Rev.072013.pdf

Photocell Sensors[16]

[16] *Sources:* https://www.legrand.us/wattstopper/daylighting-controls/daylighting-controls/lmls-400.aspx and https://www.legrand.us/wattstopper/legacy-products/commercial-products-legacy/daylighting-controls-legacy/ls-101.aspx

Measure Name	Measure Number	Code Section
Display Lighting Control	9025	IECC 2012: C405.2.3

Measure Description

Display lighting falls under the specific application controls code which states that dedicated controls, or those independent from controls for other lighting in the space, are required for:

1. Display and accent lighting
2. Lighting in display cases
3. Lighting installed to highlight retail merchandise or art exhibits

Display lighting is installed to highlight specific merchandise in addition to lighting equipment and is not considered as part of the general overhead lighting.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Identify display lighting in the lighting plans that show lighting controls. If more lighting is needed than allowed using the Allowed Interior Lighting Power calculation, display lighting is often identified in the compliance documentation.
3) Verify any lighting dedicated for display purposes is controlled independently from other lighting; it should have a dedicated circuit and record findings in the *Lighting – Display Controls* section of the data collection form.

Field Inspection

1) Identify the switch locations for display lighting using the lighting controls plans, if available. Lighting controls are often located at the display cases or switched from a circuit breaker box.
2) Switch off/on display lighting to verify it is controlled independently from other lighting and record findings in the data collection form.

Display and Accent Lighting and Display Case Lighting Examples[17]

[17] *Sources: http://usaledsolutions.com/applications/accent-lighting/, http://www.gelighting.com/LightingWeb/la_en/north/products/industry/retail/overview/, and http://www.showcases-smart.com/wp-content/uploads/2010/04/black-museum-showcase-display-case-lights-bktr411.jpg*

Measure Name	Measure Number	Code Section
Non-Visual Application Lighting Control	9029	IECC 2012: C405.2.3

Measure Description

Lighting for non-visual applications falls under the specific application controls code which states this type of lighting shall be controlled independently of other lighting in the space. Examples of non-visual applications include plant growth, food warming, or lighting for sale.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Identify any non-visual lighting on the lighting plans and energy code compliance documentation.
3) Verify lighting dedicated for non-visual purposes is controlled independently from other lighting; it should have a dedicated circuit on the plans.
4) Record all findings in the *Lighting – Display Controls* section of the data collection form.

Field Inspection

1) Use the lighting control plans, if available, to help locate the lighting controls for non-visual lighting.
2) Switch off/on non-visual lighting to verify it is controlled independently from other lighting and record findings in the data collection form.

Non-Visual Application Lighting Examples[18]

[18] *Sources:* http://thegreatestgarden.com/2014/12/the-grow-lights-for-indoor-plants.html *and* http://commercialkitchendesign.net/category/food-warming/

Measure Name	Measure Number	Code Section
Exterior Lighting Control	9031	IECC 2012: C405.2.4

Measure Description

Exterior lighting designated for dusk-to-dawn operation shall be controlled by an astronomical time switch[19] or a photocell. Exterior lighting not designated for dusk-to-dawn operation shall be controlled by an astronomical time switch or a combination of a photocell and a time switch. When required, a portion of exterior lighting (either 30% or 50% of non-façade and landscape lighting) shall be deenergized by schedule or controlled by occupancy sensor during nighttime after business hours.

All time switches must retain their programming during power loss for a minimum time period, specified by code.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Identify any exterior lighting controls on the plans. Exterior lighting controls may be indicated either in a note or showing the sensor and/or timeclock on the floor plans.
   a) A photocell is often shown as a Ⓟ symbol.
   b) The time switch or time clock may also be denoted on the plans using a symbol; check the electrical legend to determine if so.
3) Check lighting controls or SOO for after-hours reduction of exterior lighting as required.
4) Check circuiting to determine if required portion of lights to be deenergized is separately circuited.
5) Record all findings in the *Lighting – Exterior Controls* section of the data collection form.

Field Inspection

1) Verify from the facility contact person if the exterior lighting is scheduled for dusk-to-dawn operation or not.
   a) If dusk-to-dawn operation is in use, request to see the astronomical time switch or photocell.
   b) If dusk-to-dawn operation is not in use, request to see the astronomical time switch or both the photocell and time switch.
2) Verify the following for each device on site:
   - Astronomical Time Switch – Appropriate location must be input. Current time indicated by switch must match actual time.
   - Time Switch – Current time indicated by switch must match actual time.
   - Photocell – Must be outdoors with access to receive sunlight (direct sunlight not necessary). Should not be covered or blocked. It may be possible to temporarily block the device and wait to see if the lighting turns on. However, if the photocell is used in conjunction with a time clock, no change may occur.
3) If required, check lighting controller or BAS to see if a portion of exterior lighting is deenergized after hours or if occupancy sensors are present as required. Record all findings in the data collection form.

[19] An astronomical time switch will calculate the rise of the sun and set times based on location. It will also automatically adjust for daylight savings. Look for a zip code or other location input.

Exterior Photocell and Time Switch Examples[20]

Astronomical Time Switch Examples[21]

[20] Sources: http://www.superiorlighting.com/70_Watt_LED_Dusk_to_Dawn_Yard_Lights_p/7101caal068.htm, https://www.grainger.com/product/6P008&AL!2966!3!166591460085!!!s!81032115957, and https://www.1000bulbs.com/product/3419/ELEC-T101.html

[21] Sources: https://www.zoro.com/tork-electronic-timer-astro-365-days-spdt-dzs200bp/i/G2802371/ and http://www.directindustry.com/prod/general-industrial-controls-p-ltd/product-61204-556346.html

Measure Name	Measure Number	Code Section
Interior Lighting Power Allowance	9037	IECC 2012: C405.5

Measure Description

Total connected lighting power (the sum of all interior lighting equipment power not including exempt lighting) must be not greater than the allowed interior lighting power.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
   Note: Lighting power requirements will not be typical prescriptive requirements if the high efficiency lighting additional efficiency package option is selected.
2) While checking counts or calculations during the plan review, keep in mind they will also need to be verified during an onsite visit. Use the *Lighting – Interior Lgt Pwr* section of the data collection form for easy reference during the onsite data collection process.
3) Determine if the COMcheck, or other code approved software, documentation already reports the interior lighting allowed and connected load calculations.
   a. If so, verify fixture counts match the number of fixtures shown on the floor plans, verify fixture wattages match those in the lighting fixture schedule, and confirm space types and floor areas.
      i. For low voltage lighting the supplying transformer wattage must be used to determine load.
      ii. For line voltage track lighting, load is based on wattage of connected fixtures with a minimum of 30W/lf of track the length of track, or the wattage of the systems circuit breaker, or an installed current limiting device.
   b. Fixture wattages shown in design documents often do not match what was bid on and ultimately gets installed. If available, check product submittals or O&M manuals to verify fixture wattage matches what is on the plans. If there are differences, assume submittals or O&M manual is correct.
   c. Verify the correct energy code was input into the COMcheck, or other code approved software; it should be listed near the top.
4) If there is no COMcheck or other code approved software documentation available, use the fixture counts, wattages, floor areas, and building or space types shown on the plans to calculate the design connected load and allowed load.
   a. Start with the building-area method first since it is much simpler. When using the building area method retail display lighting is included. If the connected load is not in compliance with the allowed lighting power using the building-area method, it may still comply using the space-by-space method. Allowed lighting power should then be calculated using the space-by-space method and the data collection form workbook. (See the *Lighting – Spaces* section of the data collection form). If using the space-by-space method, retail display lighting is not included here if it is separately circuited, but in separate retail display lighting measure (9047).
5) If the site is larger than 150,000 ft^2, select about 10% of rooms of each space type to verify while onsite.
6) Record all findings in the *Lighting – Interior Lgt Pwr* section of the data collection form.

Field Inspection

1) Before walking the site, ask to see where the spare bulbs and ballasts are stored. This is the easiest way to confirm wattages on different fixture and lamp types. Take photos of the lamps to reference later and confirm wattage on each lamp type listed in the fixture schedule or on the data collection form provided.
2) Using the data collection form, conduct a fixture count of each space (or those sampled during the plan review) and record the results. If a full fixture count was conducted during plan review, verify the installed lighting in 10% of the spaces for each space type (e.g. private office, bathroom, etc.). Be sure to confirm the fixture types match the plans and make a note if they do not. Number of lamps per fixture should also be verified and noted. If available, collect make and model of the fixtures to confirm specifications after the

visit; this is especially helpful with LEDs since they do not fit into standard wattage categories. Remember to review code for special cases before the visit; for example, screw-base fixtures must be recorded as the maximum labeled wattage rather than the rated wattage of the bulb. For low voltage or track lighting, confirm length of track, circuit breaker wattage, transformer wattage, or circuit breaker wattage as necessary.

3) If some lighting is not counted here because it is considered retail display lighting verify that it is separately controlled from general lighting and highlighting retail displays.
4) If site-verified data varies more than 10% from the design and plan reviewed information, verify another 10% of spaces.
5) Record all findings in the data collection form.

Additional Details

Helpful Hints:
It may be easiest to calculate space-by-space allowed and designed connected lighting powers using the provided data collection form excel workbook or COMcheck or other code approved software. COMcheck is free and can be downloaded at this link: https://www.energycodes.gov/comcheck

Measure Name	Measure Number	Code Section
Additional Retail Lighting Power Allowance	9047	IECC 2012: Table C405.5.2(2) footnote

Measure Description

Sales area space types qualify for an additional interior lighting power allowance for display lighting beyond the value listed in the space-by-space table, depending on the type of goods for sale. This additional lighting power is only available if the project has demonstrated compliance via the space-by-space method and if the display lighting is:

- highlighting merchandise
- in addition to and switched separately from the space general lighting

The additional allowance is determined by the retail area type which is based on the type of merchandise highlighted by the display lighting. If the building complied using the building area method including all retail display lighting, there is no need to consider this measure.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) While checking counts or calculations during the plan review, keep in mind they will also need verified during an onsite visit. Use the data collection form for easy reference during the onsite data collection process.
3) Identify any sales areas on the plans and determine the square footage of each retail area type in the space.
4) Using these values and the equation provided in the code, calculate the retail display lighting power allowed. In addition to the calculated retail display lighting allowance, any excess general lighting not used based on the calculation done for Interior Lighting Power Measure 9037 should be added to the calculation to come up with the total allowed retail display allowance.
5) The COMcheck documentation may already report the retail display lighting allowed and connected load calculations.
    a. If so, verify fixture counts match the number of fixtures shown on the floor plans, verify fixture wattages match those in the lighting fixture schedule, and confirm retail area types and floor areas.
        i. For low voltage lighting, the supplying transformer wattage must be used to determine load.
        ii. For line voltage track lighting, load is based on wattage of connected fixtures with a minimum of 30W/lf of track the length of track, or the wattage of the systems circuit breaker, or and installed current limiting device.
    b. Fixture wattages shown in design documents often do not match what was bid on and ultimately gets installed. If available, check product submittals or O&M manuals to verify fixture wattage matches what is on the plans. If there are differences, assume submittals or O&M manual is correct.
    c. Verify the correct energy code was input into the COMcheck, or other code approved software; it should be listed near the top.
6) Using fixture counts and wattages, calculate the design connected retail display lighting (which should be less than the allowed lighting power calculated above).
7) Verify retail display lighting is separately controlled from general lighting.
8) Record all findings in the *Lighting– Retail Ltg Pwr* section of the data collection form.

Field Inspection

1) Before walking the site, ask to see where the spare bulbs and ballasts are stored. This is the easiest way to confirm wattages on different fixture and lamp types. Take photos of the lamps to reference later and confirm wattage on each lamp type listed in the fixture schedule or on the data collection form. If low voltage or track lighting is included, confirm length of track, transformer wattage, or circuit breaker wattage as necessary.
2) Using the data collection form, conduct a fixture count of retail display lighting in each space and record the results. Be sure to confirm the fixture types match the plans and make a note if they do not. Number of lamps per fixture should also be verified and noted. If available, collect make and model of the fixtures to confirm specifications after the visit, this is especially helpful with LEDs since they do not fit into standard wattage categories. Verify that retail display lighting is separately controlled from general lighting and highlighting retail displays.
3) Remember to review the code for special cases before the visit; for example, screw-base fixtures must be recorded as the maximum labeled wattage rather than the rated wattage of the bulb and track and low voltage lighting as described above.
4) Record all findings in the data collection form.

Additional Details

Helpful Hints:
It may be easiest to calculate space-by-space allowed and designed connected lighting powers using a spreadsheet software such as excel or the COMcheck software. COMcheck is free and can be downloaded at this link: https://www.energycodes.gov/comcheck

If a spreadsheet is developed, leave blanks for onsite verification values as well and take the printout to the site.

Measure Name	Measure Number	Code Section
Exterior Lighting Power Allowance	9048	IECC 2012: C405.6

Measure Description

Exterior lighting power for fixtures supplied through the building energy service must be less than the allowance specified by code. Exterior luminaires with input wattage values above code-specified limits must meet efficacy (lumens /Watt) requirements.

Exceptions may include low voltage landscape lighting and those approved for historical, safety, signage, or emergency considerations but are specific to each code. Certain exterior lighting applications are also exempt from the exterior lighting power allowance requirements. Depending on the code, these may include sports fields, monuments, marinas, temporary lighting, and more.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) While checking counts or calculations during the plan review, keep in mind they will also need verified during an onsite visit. Use the data collection form for easy reference during the onsite data collection process.
3) Exterior lighting power allowances and design may be summarized in provided COMcheck documentation. If so, verify counts and wattage match the fixture schedule, and confirm other calculations, such as dimensions used.
4) If no COMcheck documentation is provided:
    a) Calculate the design connect exterior lighting power by multiplying fixture counts by wattage values.
    b) Determine the appropriate exterior lighting zone type for the site (1-4) using the table and descriptions from code. Verify with code official if possible.
    c) Determine if the design includes lighting for any of the non-tradable surfaces called out in code. If so, for each surface, calculate the lighting power allowance using the value specified in code and the site dimensions. Calculate the total design power for the surface by multiplying counts and wattages of each fixture to determine if it is less than the allowance.
    d) When calculating the area of surface to apply the power density allowance to for both tradeable and non-tradeable surfaces, consider only the area of the surface that is illuminated to an industry standard, such as the IESNA Handbook. If the design documents do not identify the illuminated area, some judgement may be necessary.
    e) Sum the base site and tradable surfaces allowances using the values specified in code for the appropriate zone and the site dimensions from the plans.
    f) Calculate the total design power for the tradable surfaces by multiplying counts and wattages of each fixture not included in the non-tradable surfaces and not exempt. This should be less than the sum of the base site and tradable surfaces allowance.
    g) If fixture details such as make and model are provided, confirm wattages on product documentation. Also, collect images of each fixture to reference while on site. Fixture wattages shown in design documents often do not match what was bid on and ultimately gets installed. If available, check product submittals or O&M manuals to verify fixture wattage matches what is on the plans. If there are differences, assume submittals or O&M manual is correct.
5) Record findings in the *Lighting – Exterior Lgt Pwr* section of the data collection form.

Field Inspection

1) Verify fixture counts and wattages match those called out in design documents, submittals, or O&M documents. If possible, visit the bulb and spare fixture storage location to confirm make and model details as well as bulb wattages.
2) Make note if any fixtures do not appear to match those expected from the plans or the images collected during plan review.
3) Verify illuminated surface areas matched that calculated in accordance with the plans. Record all findings in the data collection form.

Additional Details

Helpful Hints:
It may be easiest to calculate the exterior lighting power allowance and designed connected lighting powers using a spreadsheet software such as excel or the COMcheck software. COMcheck is free and can be downloaded at: https://www.energycodes.gov/comcheck.

If a spreadsheet is developed, leave blanks for onsite verification values as well and take the printout to the site.

Measure Name	Measure Number	Code Section
Parking Garage Lighting Controls	9054AS	ASHRAE 90.1-2013: 9.4.1.2

Measure Description

Parking garage lighting shall be scheduled to automatically shut off during unoccupied times.

Lighting power must be reduced by at least 30% when there is no activity detected within 20 minutes in the lighting zone no larger than 3,600 feet.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Identify any parking garage areas and determine if they have scheduled automatic shutoff controls, such as a programmed time switch or lighting control system shutoff. This may be shown on the plans or indicated in a note.
3) Determine whether the design includes motion sensors for the lighting zones, these may be indicated as occupancy sensors (

or similar) or using another symbol. The sensors also may be called out on the lighting fixture schedule as integral to the fixtures. If the zones are indicated on the plans, verify they are no larger than what is allowed by code (3,600 ft. – ASHRAE 90.1-2013).
4) Select best description of controls:
    - Occupancy sensor light control; zones ≤ 3.6 ksf; @ fixt off ≥30%; and off in ≤ 30 min
    - Occupancy sensor light control; overall reduction <30%; or off in > 30 min
    - Schedule based lighting controls
    - No automatic lighting controls
5) Record findings in the *Lighting – Parking Controls* section of the data collection form.

Field Inspection

1) Verify schedule for automated shutoff within a lighting control system or time switch. This should match the hours of operation or occupied times of the garage. Size limits on controlled areas and override requirements should be verified with code.
2) Verify lighting power is reduced when no activity is detected. Lighting levels should increase as someone enters the zone after it has been vacant for a period. Wait-period and zone sizing requirements should be verified with code.
3) Look for occupancy sensors throughout the lighting zones. Record all findings in the data collection form.

Note: Parking garage lighting may be easiest to inspect during darker hours.

Motion Sensor, Photocells, Time Switch, and Lighting Control System Examples[22]

[22] Sources: http://www.mcwonginc.com/c11599/c12300.asp, https://www.wholesalecontractorsupply.com/Photocells-Photocontrols-Locking-s/224.htm, https://www.1000bulbs.com/product/3419/ELEC-T101.html, and http://ali-and-co.com/Lighting%20Control%20Panels.html

Measure Name	Measure Number	Code Section
Automatic Receptacle Controls	9055pAS	ASHRAE 90.1-2010 and 90.1-2013: 8.4.2

Measure Description

A percentage of receptacles in certain space types and for modular furniture, as specified by the standard used, shall be automatically controlled to turn off. This may be based on a programmed schedule or, when no activity is detected in the area, by using an occupancy sensor or other device.

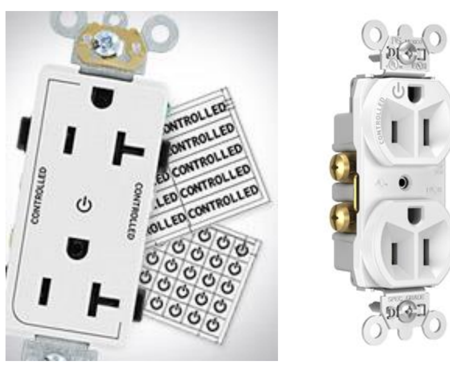
Additionally, 25% of branch circuit feeders that are installed for future modular furniture (those not shown on the construction documents) must also have automatic controls. (ASHRAE 90.1 – 2013 only)

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Verify receptacles in the specified space and use types have overlapping circuitry since a percentage of them must be connected to automated controls.
   a) The controlled receptacles should be indicated by a different symbol than uncontrolled receptacles; verify with legend on plans.
   b) Occupancy sensors (OS or similar) or a time switch may be shown on the plans.
3) Record findings in the *Lighting – Receptacle Controls* section of the data collection form.

Field Inspection

1) Verify controlled receptacles are permanently marked to visually differentiate them from the uncontrolled ones. (ASHRAE 90.1 – 2013 only)
2) Count the marked and unmarked receptacles to determine the correct percentage were installed.
3) Inspect the time switch to ensure it is programmed correctly, or verify occupancy sensors or another system is in place for the automatic shutoff. Record all findings in the data collection form.



Marked Controlled Receptacle Examples[23]

[23] Sources: http://www.leviton.com/en/solutions/leviton/energy-management/ashrae-901/receptacle-control-solutions and http://www.legrand.us/passandseymour/receptacles/commercial-grade/hard-use-spec-grade/plug-load/half-controlled/15a/5262chw.aspx

Measure Name	Measure Number	Code Section
Lighting Commissioning or Functional Testing	9099p	IECC 2012: C408.3
Measure Description		
Testing of the lighting controls hardware and software must be conducted to ensure they are operating as designed. Documentation must be issued certifying that installation meets code requirements. All occupant sensors, time switches, programmable schedule controls, and photo-sensors or daylighting controls installations shall be verified for appropriate placement, sensitivity, and programming, as applicable.		
Plan Review		
1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed. 2) Determine which lighting controls need to be commissioned or functionally tested based on the code requirement. 3) Verify construction documents require the commissioning or testing and locate reports documenting such tests were conducted. a) The construction documents should state which party did the testing. Documentation certifying the lighting controls or a commissioning report, if issued, would confirm the requirement was met. 4) Assess quality of commissioning or testing: • Commissioned: High Quality • Commissioned: Satisfactory Quality • Commissioned: Poor Quality • Commissioning not completed or specified 5) Record findings in the *Lighting– Cx* section of the data collection form.		
Field Inspection		
1) Request to see the commissioning report or certification for the lighting controls system. 2) Ask a facilities team member about the commissioning process and if they have had many issues with the system since it was commissioned. 3) Determine if commissioning is high quality, satisfactory quality, poor quality, or not completed and note all findings in the data collection form.		

Other Measures

Measure Name	Measure Number	Code Section
Optional Onsite Renewables	15007	IECC 2012: C406.4

Measure Description

Renewable energy systems shall provide enough energy to meet code requirements based on peak rated output per square foot of building area or total sum basis, or as a percent of mechanical, water heating, and lighting annual consumption.

Plan Review

1) Determine and record the minimum code requirement based on energy code documentation. If there is no documentation or the documentation does not specify the selected compliance path for the project, assume prescriptive requirements are followed.
2) Identify any renewable energy systems and determine their peak rated output.
3) If compliance is based on a percent of mechanical, water heating, and lighting annual consumption, there should be energy model results and generation calculations provided to determine expected annual energy use of these systems.
4) If compliance is based on rated capacity in kW, annual output of the renewable energy system can be estimated as a check on generation calculations provided by the designer.
5) Record all findings in the *Renewables* section of the data collection form.

Field Inspection

1) Verify rated capacity of the renewable system matched design documents and calculations.
2) Verify it is in operation. Ask the facilities team member if the renewable system has been operating as expected and if they have any records of the production from the system.
3) Ask if the building is meeting energy goals set during the design process and record all findings in the data collection form.

Appendix C: Beyond code modeling assumptions

The following assumptions were applied to the typical building models for beyond code savings analysis. Modeling assumptions were based on findings from the data.

Table 15: Beyond code typical building model assumptions for each segment

Building type	Conditioned area (square feet)	Number of stories	Window-to-wall ratio	HVAC system type
High-rise multifamily	100,000	5	23%	Split system AC with gas furnace
Office	50,000	2	23%	Packaged VAV with HW Heat
Food service/ retail	12,000	1	15%	Split System w/ Gas Furnace

Table 16: Beyond code best-case conditions for each building segment[7]

Code elements	High-rise multifamily	Office	Food service/retail
Roof U-value	0.016	0.021	0.032
Frame wall U-value	0.043	0.032	-
Mass wall U-value	0.034	0.045	0.069
Window U-value	0.27	0.30	0.34
Window SHGC	0.28	0.27	0.30
Building shall meet continuous air barrier requirements	Tested at ≤0.25 cfm/ft2	Tested at ≤0.4 cfm/ft2 (>0.3)	Not tested; Mtls or assemb DO comply; CAB sealed and intact
Fenestration assemblies shall meet air leakage requirements	Labeled with leakage less than requirements	Labeled with leakage less than requirements	Windows and doors labeled as meeting
Packaged air conditioner efficiency	14 SEER (units < 65 MBH)	10.8 EER (units ≥ 135 MBH, < 240 MBH)	13.2 EER (units ≥ 65 MBH, < 135 MBH)
Gas furnace efficiency	96.70%	-	92%
Boiler efficiency	-	97.5%	-
Energy recovery requirement	ERV installed; Egy Recvy Ratio =>60%; Bypass OA or control in Econo	ERV installed; Egy Recvy Ratio =>60%; Bypass OA or control in Econo	ERV installed; Egy Recvy Ratio =>60%; Bypass OA or control in Econo

[7] For all other code elements not listed in table, best-case conditions match baseline.

Fan power limit requirement	60% Reduction for CAV systems from baseline	60% Reduction for VAV systems from baseline	62% Reduction for CAV systems from baseline
Parking garage fan controls	Parking garage exhaust reduction; VSD turn down to ~33%; automatic CO sensors	Parking garage exhaust reduction; VSD turn down to ~33%; automatic CO sensors	Parking garage exhaust reduction; VSD turn down to ~33%; automatic CO sensors
Water heater efficiency, Gas	96%	97%	95%
Interior lighting power	0.40 LPD	0.40 LPD	0.40 LPD
Exterior lighting power	60% Reduction from baseline	60% Reduction from baseline	60% Reduction from baseline

Appendix D: Phase-Specific Project Checklist

Design Checklist for Design Teams and Plan Reviewers

- ☐ Ensure the energy code compliance pathway is clearly indicated in drawings and/or specifications, including the following:
  - ☐ ASHRAE or IECC
  - ☐ Prescriptive or performance path
    - ☐ If IECC prescriptive path is chosen, document additional efficiency package under Section C406
    - ☐ If performance path is chosen, provide all necessary energy modeling files and supplemental documentation
- ☐ Ensure that the commonly non-compliant, high-impact elements below are designed to comply with energy code:

  Envelope Code Elements
  - ☐ Fenestration orientation
  - ☐ Window SHGC
  - ☐ Window U-value
  - ☐ Window-to-wall ratio

  Electrical Code Elements
  - ☐ Receptacle control
  - ☐ Exterior lighting control
  - ☐ Daylighting control
  - ☐ Manual lighting control
  - ☐ Garage lighting control

  Mechanical Code Elements
  - ☐ Thermostat deadband
  - ☐ Thermostat heating setback
  - ☐ Fan power – VAV
  - ☐ VAV ventilation optimization
  - ☐ Demand control ventilation
  - ☐ Economizer high limit shutoff
  - ☐ Energy recovery requirement
  - ☐ Optimal start controls

- ☐ Ensure complete architectural, mechanical, electrical, and plumbing documentation is provided through drawings, specifications, and COMcheck or energy modeling files (if being used to demonstrate compliance). Confirm that the following commonly-missed code elements are included:

  Envelope Code Elements
  - ☐ U-value for window assemblies (not just center-of-glass). This is especially important for custom-built glazing such as storefront and curtainwall.
  - ☐ SHGC for windows

  Electrical Code Elements
  - ☐ Receptacle controls
  - ☐ Lighting commissioning plan

  Mechanical Code Elements
  - ☐ Thermostat deadband
  - ☐ Thermostat heating setback
  - ☐ Optimal start controls
  - ☐ Economizer high limit shutoff
  - ☐ Mechanical commissioning and/or testing and balancing plan and schedule
  - ☐ Sequence of Operations

- ☐ Provide the following supplemental calculations with design documentation:
  - ☐ Interior lighting power calculations
  - ☐ Exterior lighting power calculations
  - ☐ Envelope area takeoffs demonstrating fenestration orientation and window-to-wall ratio
  - ☐ Fan power calculations

Construction Checklist for Contractors and Building Inspectors

- ☐ Ensure that the Sequence of Operations is available and used to implement system setpoints and control strategies.
- ☐ Ensure that the following elements that have the highest lost savings are constructed to meet energy code requirements:
  - ☐ Window U-factor and SHGC
  - ☐ Receptacle controls
  - ☐ Manual lighting controls
  - ☐ Exterior lighting control
  - ☐ VAV ventilation optimization
  - ☐ Fan power – VAV
  - ☐ Thermostat heating setback
  - ☐ Economizer high limit shut off
  - ☐ Thermostat deadband
  - ☐ Optimal start controls
- ☐ Ensure additional documentation (e.g. product data sheets, testing reports) is provided for code elements that were not observable during site inspections.

Commissioning Checklist for Commissioning Agents and Code Officials

- ☐ Ensure that all <u>HVAC control</u> code elements listed below are built to code:
  - ☐ Measure name
  - ☐ HP supplement heat control
  - ☐ Thermostat deadband
  - ☐ Thermostat heating setback
  - ☐ Thermostat cooling setback
  - ☐ Night fan control
  - ☐ Optimal start controls
  - ☐ Freeze protection control
  - ☐ Demand control ventilation
  - ☐ Energy recovery requirement
  - ☐ Outdoor heating control
  - ☐ Multi-zone reheat systems - VAV
  - ☐ Static pressure reset
  - ☐ WSHP - two position valve
  - ☐ Supply water temp reset
  - ☐ Multi-chiller reduce flow
  - ☐ Supply air temp reset
  - ☐ VAV ventilation optimization
  - ☐ Single zone VAV
  - ☐ Parking garage fan controls
  - ☐ Zone Isolation
- ☐ Ensure that all <u>lighting control</u> code elements listed below are built to code:
  - ☐ Manual lighting control
  - ☐ Automatic time switch control
  - ☐ Occupancy sensor control
  - ☐ Daylighting control
  - ☐ High bay daylighting
  - ☐ Display lighting control
  - ☐ Nonvisual lighting controls
  - ☐ Exterior lighting control
  - ☐ Garage light control
- ☐ Once items above have been verified to be built to code, provide commissioning checklist to building owner and code official

Appendix E: Guidance for Program Development

To complement the findings of the Minnesota Commercial Energy Baseline and Market Characterization Study, we researched local and national programs and energy codes to help provide context and guidance for program development in Minnesota. To demonstrate the breadth of opportunities, examples include programs that contribute to energy code compliance as well as programs and code pathways that are pushing energy savings beyond current code baselines. The information below is organized to correspond with the topics presented in the report's Opportunities and Discussion section.

Supporting Code Officials

The program examples below offer ways to move beyond general education programs for code officials toward technical support programs.

Circuit Rider Programs

A circuit rider is an in-field expert that supports specific code compliance and enforcement needs on a project-by-project basis. Circuit riders travel to various jurisdictions to provide resources and technical assistance across a state. These programs are designed to provide tailored technical assistance and training for code officials to support plan review and on-site verification efforts. In addition to increasing energy savings in the projects they support, circuit rider programs provide applied learning opportunities for code officials, which enables better concept retention than classroom learning (McCowan et al. 2014). The circuit rider model has had great success in increasing energy savings in various states across the country. Some examples of notable programs are below.

Example 1: Massachusetts Code Compliance Support Initiative (CCSI)

Implemented in 2014 and funded by Massachusetts Program Administrators, the CCSI aims to improve energy code compliance rates for non-residential and residential construction in Massachusetts. The program offers technical training and support services to code officials and building professionals via in-field and classroom training as well as a circuit rider. The circuit rider offers consultations on project compliance verification through plan and specification review, on-site observations, as well as phone and email support for energy code questions and interpretations (NMR Group, Inc. and Cadmus 2018). This program is predicted to contribute to roughly a 5% increase in energy code compliance rates by 2021 (NMR Group, Inc. and Cadmus 2018, 2).

Example 2: Florida's Energy Code Circuit Rider Program

The first energy code circuit rider program in the southeast, Florida's program was launched by Southeast Energy Efficiency Alliance (SEEA) in 2014. The program was developed to gain a better understanding of jurisdictional enforcement practices across the state and to subsequently provide targeted technical assistance to Florida's code officials for both commercial and residential construction (Westmoreland and Stewart 2016). Support from this program includes assistance with energy code plan reviews, tailored technical assistance, educational resources and training, and sharing best practices between code officials across the state (Kelley, Bryan, and Stewart 2019). The State of Florida, SEEA, and DOE provide the funding for these efforts. The program is deemed to have created a "large impact at the state level for code education, information dissemination, and awareness of energy efficiency across Florida" (Kelley, Bryan, and Stewart 2019, 9). Although Florida's energy code compliance rates are currently unknown,8 SEEA estimates this program is contributing to higher energy code compliance rates in both the commercial and residential sectors (Kelley, Bryan, and Stewart 2019).

Example 3: Minnesota's 2018 Commercial Energy Code Compliance Enhancement Pilot

Although not specified as a circuit rider program, in a recent pilot program study conducted for Minnesota by the Center for Energy and Environment (CEE), code officials were provided with various forms of technical support, including assistance with plan reviews, commissioning report reviews, and on-site inspections. To ensure that all applicable code items were accounted for during the on-site inspection process, code officials were also provided with an inspection checklist. The pilot program demonstrated that providing project-specific technical assistance for electrical, mechanical and envelope code elements resulted in a per-building savings range of 22,066 to 74,931 kWh and 433 to 1,301 therms for the 17 participating projects (Landry, Hoye, and Su 2018, 49). The estimated per-building cost for a full-scale program is $4,520, resulting in a projected utility program cost-benefit ratio ranging from 9.0 to 15.6 for electric utilities and 2.81 to 9.4 for gas utilities (Landry, Hoye, and Su 2018, 51, 53). Through a series of program surveys, participating code officials "expressed significant value in the program" and that they would participate in program services like this in the future (Landry, Hoye, and Su 2018, 63).

Third-Party Support Programs

Jurisdictions using third-party support programs outsource energy code plan review, on-site inspections, and/or performance testing to third-party experts, helping to rapidly increase energy code compliance while reducing city staff workload. As energy codes continue to increase in complexity and require more specialized knowledge, third-party programs offer a way for states to ensure that their energy goals are being met. These types of programs have been implemented across various states and local jurisdictions and have been found to have higher levels of quality assurance and cost savings, and quicker processing times than traditional enforcement and verification models (Meres and Krukowski 2013; Meres et al. 2012; Williams and Price 2014). In 2014, The American Council for an Energy-Efficient Economy (ACEEE) conducted a thorough literature review and survey study that showed the cost of outsourcing plan review and on-site inspections to a third-party would be less than or equal to the traditional review and inspection processes (Williams and Price 2014).

[8] In 2016, the Institute for Market Transformation launched a commercial energy code field study that focus on commercial energy code compliance for retail and office buildings in Florida, Iowa, and Nebraska. The project report has not been published. https://www.imt.org/how-we-drive-demand/building-energy-codes/

It has been noted that the effectiveness of such a program "lies in the availability of quality third-party companies and the government's ability to administer and oversee the program" (Meres et al. 2012), making it critical to establish strong criteria for evaluating and approving third-party entities as well as staff qualifications. Third-party programs can differ in organizational structures, funding sources, level of complexity, enforcement mechanisms, and employee certification requirements (Energy Futures Group 2011) to cater directly to a jurisdiction's needs. As an example, a comprehensive third-party program would include plan review and on-site inspection activities for all areas within the energy code while a targeted third-party program might focus on a specific energy code measure, building type, or compliance path – such as reviewing simulation documentation for projects pursuing a performance-based pathway. Two examples of third-party programs that focus on commercial energy codes are included below.

Example 1: Dallas' Third-Party Green Building Program

As a result of Dallas' Green Building Program established in 2011, the city requires registered third parties to conduct plan reviews and on-site inspections for all commercial construction to verify compliance (ACEEE 2020). To register as a commercial Third-Party Green Provider, the city requires individuals to 1) obtain an ICC Green Building or USGBC LEED AP certification, 2) have 2 years of experience in green building design/construction, 3) complete a mandatory training program by the City of Dallas, and 3) pass the Dallas Green Building Code exam. Third-Party Green Providers work directly with project teams to verify code compliance path, review and verify submitted data, and prepare affidavits of compliance. Once complete, the Third-Party Green Provider is required to submit an Inspection Compliance Affidavit to the City of Dallas prior to the final building inspection (Chauk and Small 2018).

Example 2: District of Columbia's Third-Party Program

The third-party program for the District of Columbia is administered by the Department of Consumer and Regulatory Affairs (DCRA) Green Building Division and allows plan reviews and on-site inspections to be conducted by a third-party agency for commercial and residential construction. Third-party agencies are required to obtain an ICC Certification and attend training hosted by DCRA. The program also includes green plan reviewers and green inspectors to ensure compliance with DC's Green Construction Code for projects 10,000 square feet and larger. During plan reviews, applicable DC Energy Conservation Code elements are identified on an Energy Verification Sheet which later serves as an inspection checklist during final energy inspections. Once complete, the DCRA Green Building Division reviews the application before issuing a Certificate of Occupancy (District of Columbia Department of Consumer and Regulatory Affairs 2019).

Supporting Design Teams

Example 1: Minnesota's 2018 Commercial Energy Code Compliance Enhancement Pilot

For this pilot program study, design teams were provided with an early kick-off meeting, quick reference tools to support energy code efforts, on-call technical support, and design review services. Early kick-off meetings were conducted with the entire design team to discuss energy code requirements, compliance paths, and potential challenges for the project, and introduced design teams to the quick reference tool. The tools included an applicability guide to help design teams determine which key code elements apply to their projects and a documentation checklist to track compliance throughout the design process. Additionally, the documentation checklist informed design teams of best practices to ensure code information was clearly documented within plans and specifications (Landry, Hoye, and Su 2018).

These services resulted in average per-building savings of 24,843 kWh and 545 therms for the 15 participating projects. The estimated per-building cost for a full-scale program is $4,220, resulting in a projected utility program cost-benefit ratio ranging from 2.7 to 6.5 for electric utilities and 0.86 to 3.28 for gas utilities. In a post-participation survey, design teams indicated that the early kick-off meeting was the most valuable of the services offered, leading to a recommendation to prioritize early design-phase meetings and quick reference tools rather than plan review efforts. Since the study showed higher recruitment costs and lower savings than the simultaneous code official pilot program, the authors recommend future CIPs offer design team education through code officials rather than directly to design teams (Landry, Hoye, and Su 2018, 74).

Promote High-Impact Prescriptive Strategies

Other states have implemented aggressive prescriptive-based approaches through programs and code pathways. The examples below elaborate on a handful of these examples to demonstrate how jurisdictions could capture beyond-code savings through a prescriptive based approach.

Example 1: New Building Institute's Advanced Buildings® New Construction Guide

In 2014, New Building Institute (NBI) developed the Advanced Buildings® New Construction Guide to help commercial buildings less than 100,000 square feet achieve high energy savings through a prescriptive path. The prescriptive design guide offers pre-assembled design packages that can deliver 15-35 percent energy savings over ASHRAE 90.1-2010 and IECC 2012. The U.S. Green Building Council approved the Advanced Buildings New Construction Guide as an alternative compliance path for LEED Version 4 that can earn projects up to 10 points. The Guide has also been endorsed by Architecture 2030 and initially served as the basis for the prescriptive path in the City of Boulder, Colorado (Architecture 2030 2015).

The guide includes four tiers that increase in stringency and energy savings, enabling design teams to choose the strategies that best suit the needs of their project while still offering energy savings that go beyond code. For instance, Tier 2 offers 15-25 percent savings compared to ASHRAE 90.1-2010 and Tier 3 offers 25-35 percent savings. Each Tier addresses an array of building features including thermal envelope, lighting efficiency, controls, and HVAC components (Edelson and Frankel 2014). Within each tier, pre-assembled prescriptive packages are offered for different building use types, including office, warehouse, retail, school and multifamily. These prescriptive packages are based on an accumulation of building energy simulation data (Architecture 2030 2015).

Example 2: Xcel Energy's Energy Efficient Buildings Program (EEB)

Xcel Energy offers a prescriptive program that incentivizes customers to incorporate energy-efficient strategies into new construction and renovation projects that include a minimum of two system changes, such as lighting and cooling. This program is geared toward projects that are smaller than 20,000 square feet or that missed the deadline to apply to the performance-based Energy Design Assistance program. The EEB program draws from Xcel's existing prescriptive and custom rebates to provide projects with a customized rebate package. Prescriptive rebates include items such as HVAC equipment upgrades, daylight sensors, and occupancy sensors while custom rebates give incentives for lighting power density reduction, window, roof and wall insulation upgrades. Plan review services help determine which rebates a project qualifies for and on-site verification ensures that the chosen strategies are installed properly. The program is available at no cost for Xcel Energy customers (Xcel Energy 2020b). Other utilities serving Minnesota offer similar prescriptive programs for new construction.

Example 3: New York's Energy Conservation Construction Code

The State of New York is currently following the 2020 Energy Conservation Construction Code of New York State (ECCCNYS) which is based on the 2018 IECC and ASHRAE Standard 90.1-2016 (New York State Energy Research and Development Authority 2020). As part of this code, a voluntary pathway can be adopted by local jurisdictions who are seeking to accelerate their energy savings. The code option promotes a set number of prescriptive strategies to go beyond the minimum requirements of the 2020 ECCCNYS. Through a cost and savings analysis, New York has demonstrated that this voluntary code path is roughly 11% more efficient than projects built to the 2020 ECCNYS standard, with a 10-year net present value savings of $0.30 per square foot and a 30-year net present value savings of $1.38 per square foot for buildings in climate zone 6A (Vidaris, Inc. 2019). The energy efficiency strategies include architectural, mechanical, and electrical code elements such as enhanced insulation for roofs and walls, reduced interior and exterior lighting power, and reduced fan power allowances (Vidaris, Inc. 2019).

Example 4: Boulder's Energy Conservation Code

In Colorado, the City of Boulder has recently implemented the 2020 City of Boulder Energy Conservation Code (COBECC), a locally developed code that improves the energy performance requirements of the prescriptive strategies outlined in the 2018 IECC. New commercial buildings with a construction valuation less than $500,000 are required to follow a prescriptive path, while the other commercial buildings are required to follow performance-based paths. To develop the code, the city eliminated code elements that do not apply to Boulder, incorporated local amendments such as requirements for solar ready zones, and integrated Boulder's local energy conservation requirements. The code is estimated to be 20% more efficient than the 2018 International Energy Conservation Code ("City of Boulder Energy Conservation Code" 2020).

Promote Energy Modeling

Performance-based approaches have the potential to offer energy savings that are more cost-effective than their prescriptive counterparts. Energy modeling is a key component of this approach and promotion can come in the form of existing voluntary programs and/or future performance code pathways that are more attractive for design teams. Some examples of this are outlined below.

Example 1: Energy Design Assistance for Commercial New Construction in Minnesota

Xcel Energy, CenterPoint Energy, Otter Tail Power Company, and Bright Energy Solutions offer CIPs that provide free energy consulting services to qualifying new construction and renovations projects in Minnesota. Xcel's program, Energy Design Assistance (EDA), offers two services tracks, Standard and Enhanced, each providing customized energy modeling to demonstrate options to reduce energy costs, assistance with identifying and evaluating energy saving strategies, on-site verification of installed strategies, and analysis of energy costs and project paybacks (Xcel Energy 2020a). To qualify for either track, projects must be receiving service from one of the participating utilities, be a new construction or a renovation project with HVAC and lighting upgrades, and be in a schematic or early design development stage. Projects must also meet the minimum square footage requirements defined by the utility. A minimum of 20,000 square feet is required by Xcel Energy and CenterPoint Energy and minimum of 5,000 square feet is required by Otter Tail Power Company and Bright Energy Solutions (The Weidt Group n.d.). The program guarantees a minimum of 5% electric demand savings (30% for Enhanced track), 5% electric consumption savings, and 5% natural gas savings (The Weidt Group n.d.), and offers rebates based on the energy savings achieved above current code standards (Xcel Energy 2020a). For Xcel customers looking to pursue higher energy savings through the Enhanced track, projects must be at least 50,000 square feet and register for a third-party green building program, such as LEED or Minnesota Sustainable Buildings 2030.

Example 2: Energy Modeling Guidance through ASHRAE Standard 209 – 2018

ASHRAE offers a framework that provides guidance for designers, engineers, and owners who are looking to incorporate energy modeling into their projects. Standard 209-2018 emphasizes early design stage modeling for projects to effectively and efficiently incorporate cost-effective energy saving strategies. The 20-page framework uses common language to support communication across disciplines and provides a useful starting point for contract scopes. Energy modeling concepts are presented in the form of eleven “cycles” to demonstrate the various energy simulations that can occur during all stages of a project, including construction and post-occupancy. It is not necessary for all eleven “cycles” to be used in order for owners and design teams to see the benefits of energy modeling (Shinn and Anderson 2018).

Example 3: California’s Performance Path

California’s 2019 Building Energy Efficiency Standards (Title 24) includes a performance approach, known as the Alternative Calculation Method, that uses an approved software program to determine compliance. In the state, over 70 percent of projects follow the performance path as it gives building designers more flexibility in choosing alternative energy efficiency features and helps find the most cost-effective solution for projects. The other 30 percent are either small or low-energy projects that use the prescriptive path to simplify compliance documentation (Karpman 2016; California Energy Commission 2018). To comply with the standard, design teams must demonstrate that the energy budget of the proposed design is less than or equal to a standard design.

Example 4: Green Building Programs

Beyond-code programs can improve energy efficiency in the commercial building marketplace and help jurisdictions reach their energy saving goals. Programs such as Leadership in Energy and Environmental Design (LEED) and Architecture 2030 are pushing projects to achieve higher energy savings than current code baselines. Although these programs do not require energy modeling, they do recognize that higher savings can be achieved for projects that do use energy modeling. Due to the high energy savings potential that these programs offer, some jurisdictions have elected to incorporate them into their performance standards. For example, Arizona; Indiana; Miami, FL; Oakland, San Francisco, and San Jose, CA; Denver CO; Portland, OR; and Washington D.C. require certain building types to be LEED-certified. In Baltimore, Maryland, achieving LEED Silver certification is a pathway for energy code compliance (American Council for an Energy-Efficient Economy 2020).

Jurisdictions can also promote voluntary use of green building programs by offering incentives such as expedited permitting processes, reimbursements for certification fees, property tax relief, income tax credits, or utility rate reductions. Over time, voluntary actions can become typical practice and eventually transition to new mandatory requirements. To ensure mandatory or voluntary green building program participation is successful, jurisdictions should establish clear goals with specific and measurable objectives and involve all stakeholders in the program’s development (U.S. Department of Energy 2011).

Address Operational Performance

Emerging programs and code pathways are tracking operational performance in order to ensure predicted savings are being achieved. Below are examples of outcome-based code pathways and voluntary programs that are capitalizing on measured energy use to confirm energy savings.

Example 1: Seattle's Target Performance Path

The Seattle Energy Code offers three compliance pathways including prescriptive, performance, and outcome based. The outcome-based code pathway, known as the Target Performance Path, was introduced in 2012 and was the first outcome-based energy code path in the nation (Pinch et al. 2014). This pathway is often used for projects when the prescriptive path becomes impractical, which includes instances such as: buildings with window-to-wall ratios higher than 40%, buildings without a dedicated outdoor air system (DOAS), and buildings with no air economizer (Seattle Department of Construction and Inspections 2018).

The compliance path requires an energy model of the proposed design in addition to 12 consecutive months of utility bills in order to show that actual building performance has met its energy use intensity (EUI) target after adjusting for changes in occupancy, weather, and operating hours (Seattle Department of Construction and Inspections 2018). If the project fails to meet the EUI target, the owner must pay a penalty up to $4 per square foot, depending on the degree to which energy use exceeds the target (Pinch et al. 2014). Half of this fine is allocated to the owner in order to implement strategies that will bring the building up to performance standards – which must be completed within one year – while the rest is paid to the jurisdiction (Seattle Department of Construction & Inspections 2018).

The development of the Target Performance Path began with a voluntary pilot program in 2008, which tested the energy and financial impacts of the proposed outcome-based path and provided lessons learned to inform its incorporation into the 2012 Seattle Energy Code. The City of Seattle Department of Planning and Development partnered with the Preservation Green Lab of the National Trust for Historic Preservation to coordinate the project. Seattle City Light, the City's publicly-owned electric utility, was also involved and provided incentives based on verified energy use after the post-occupancy period (Pinch et al. 2014).

Example 2: The City of Boulder

The 2020 City of Boulder Energy Conservation Code allows commercial buildings to demonstrate compliance by following the Measured Performance Outcome pathway. This requires building owners to report metered energy data to the local code official for 12 consecutive months through Energy Star Portfolio Manager. Predicted performance targets are established using the energy modeling procedures outlined in Appendix G of ASHRAE Standard 90.1-2016. For projects that follow this pathway, building owners must deposit an amount equal to $2 per square foot into an escrow account. If the project does not meet its energy target, the funds must be used to bring the building up to compliance. Otherwise, the funds are returned to the building owner ("City of Boulder Energy Conservation Code" 2020).

In addition, Boulder adopted a performance ordinance in 2015 that requires owners of commercial and industrial buildings to report energy use annually, conduct recommissioning every 10 years, and upgrade lighting fixtures to match current IECC requirements. The ordinance applies to existing buildings that are 20,000 square feet or larger, new construction projects 10,000 square feet or larger, city-owned buildings 5,000 square feet or larger, and large industrial campuses. Energy reporting can be done through ENERGY STAR® Portfolio Manager or automatically uploaded through Xcel Energy. If the energy data for a building is not provided, the owner is fined $0.0025 per square foot up to $1,000 per day of non-compliance (City of Boulder 2020).

Example 3: Utility Pay-for-Performance Programs (P4P)

Pay-for-performance (P4P) programs reward project savings on an ongoing basis as they occur versus providing up-front payments to fund energy savings measures (Szinai 2017). These programs can take many forms and vary in project eligibility, duration of performance periods, how performance and payments are determined, and the frequency of payment distribution (Szinai 2017). Historically, P4P programs have targeted savings associated with specific code elements while more recent programs are determining savings based on whole building performance, which also has the potential to achieve higher savings levels (Szinai 2017). Many whole building P4P programs capture savings based on normalized metering data and are more cost-effective in the form of a new construction program rather than an existing building program (Hoye 2020). Benefits of whole building P4P programs include: "1) their scope aligns with customer perspective by thinking at a project scale not measure by measure, 2) incents operators based on performance, 3) can measure actual conservation and demand response resources" (Hoye 2020).

A 2017 study that reviewed 24 existing P4P programs in the United States found that most programs that focus on whole-building performance incentivize both electricity and natural gas savings (Szinai 2017, 26). These programs are primarily funded by utilities from ratepayer funds and can shift the associated risks onto the "entity responsible for installing and maintaining the energy savings measures rather than the utility or another program investor" (Szinai 2017, 9).

CEE recently conducted a study that investigated the potential impacts, barriers, and benefits to implementing a P4P program for Minnesota's commercial market. Interviews were conducted with national and local experts – including developers, building owners, operators, and utilities, revealing that these stakeholders are interested in a P4P program but concerned with the risks and costs associated with such a program. Concerns were analyzed and addressed with the support of a thorough literature and policy review of existing programs. The study found that a P4P program targeted at new construction and renovation projects (where direct incentives are provided to customers) could have statewide energy savings potential of 16,000 MMBtu for electricity and 8,700 MMBtu for natural gas (Hoye 2020).

Example 4: Minnesota's Sustainable Building 2030 Program (SB 2030)

Minnesota's SB 2030 program requires new construction and major renovation projects that receive the state's general obligation bond funding to meet performance-based energy and carbon standards. Based on the global Architecture 2030 Challenge, these standards follow a stepped reduction schedule from an average building in existence in 2003. Initially requiring a 60% reduction for buildings designed from 2010 through 2014, the standard is adjusted every five years so that by 2030 a 100% reduction (net-zero energy and carbon) is achieved. Project teams submit energy model documentation during the design phase and use Minnesota’s B3 Benchmarking platform to submit monthly operational energy data for the first ten years of occupancy. During these ten years, the SB 2030 Standard is weather-normalized and can be adjusted based on changes in occupancy, equipment loads, and schedules. Projects not meeting their SB 2030 Standard in operations are required to submit a plan for corrective action.

Per legislative requirements, SB 2030 projects may request an adjusted Standard if they are not able to meet the original Standard cost-effectively. The SB 2030 program also includes alternative, prescriptive paths for projects of a limited size or scope, though all projects are still required to report operational energy use.

Over 300 diverse buildings have participated in SB 2030 since 2009 when the program began. An analysis of 27 of the projects tracking operational energy use shows that 85 percent are meeting their SB 2030 Energy Standard in operations, though 55 percent are using more energy than predicted during design – highlighting the importance of tracking measured outcomes rather than relying on modeled performance (Smith et al. 2020).

Appendix F: References for Appendix E

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