FINAL REPORT

New Jersey Commercial New Construction Industry Standard Practice Analysis

Rutgers University

Date: June 2022

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1 EXECUTIVE SUMMARY

1.1 Objective and approach

DNV completed the New Jersey commercial new construction industry standard practice study (NJ ISP study) for Rutgers, The State University (Rutgers), and the New Jersey Board of Public Utilities (NJBPU). The objective of the NJ ISP study was to assess ISP for commercial new construction measures in New Jersey where there was sufficient information, leveraging data gathered by DNV during the New Jersey Energy Code Compliance study (ECC study). This includes recommendations of ISPs where they may be better than code (ASHRAE 90.1-2013), as well as recommendations and considerations for additional data collection and/or ISP research.

DNV leveraged the ISP analysis approach developed for a prior study in Massachusetts, adapting it where necessary to New Jersey commercial new construction. This approach assesses the observed building characteristic or rated performance metric for each available code measure or unit of equipment to calculate a percentage better or worse than code. These results are then aggregated by measure or equipment type and then segmented by program eligibility and/or program participation where possible to assess ISPs. The full methodology is included in Section 3.

1.2 Key findings and conclusions

The analysis and results of this study support the following conclusions:

1. Lighting power density (LPD) exceeded code requirements for both interior and exterior lighting designs.
2. Envelope component details for roofs and walls were observed for 100% of the square footage, but ISP results for these components were inconclusive due to the wide confidence bounds that include both worse than code and better than code values. Window u-factor details were observed in only 59% of the square footage, but average window u-factor specifications were better than code.
3. Mechanical equipment is largely compliant with energy code efficiency requirements. However, the median rated efficiency of program ineligible cooling equipment for the ISP analysis trended towards worse than code efficiencies. In contrast, the majority of cooling equipment observed is program eligible and exceeds code efficiency requirements. Limited ineligible equipment observations resulted in inconclusive ISP estimates for PTAC, and heat pump (cooling efficiency) units.

Table 1-1 presents a summary of key ISP analysis results.

Table 1-1. Summary of ISP analysis results

Results	Number of Sites	ISP Approach	Median % better / worse than code	Bounds @ 90% confidence level
LIGHTING				
Interior LPD	36	Non-participant median	40%	20%/61%
Exterior LPD	36	Non-participant median	60%	30%/90%
ENVELOPE				
Roof	43	Non-participant median	-15%	-36%/6%
Wall	43	Non-participant median	6%	-4%/16%
Window u-factor	17	Non-participant median	31%	18%/44%
HVAC				
Warm air furnaces	36	Ineligible equipment median	15%	7%/22%

Results	Number of Sites	ISP Approach	Median % better / worse than code	Bounds @ 90% confidence level
Heat pumps non-VRF (heating)	13	Non-participant median	19%	10%/29%
Heat pumps VRF (heating)	5	Inconclusive	n/a	n/a
PTHP (heating)	4	Non-participant median, but limited data	17%	12%/22%
Air conditioning	34	Ineligible equipment median	-1%	n/a
Heat pumps non-VRF (cooling)	13	Inconclusive	n/a	n/a
Heat pumps VRF (cooling)	5	Inconclusive	n/a	n/a
PTHP (cooling)	4	Limited data	-7%	n/a
PTAC	2	Inconclusive	-9%	n/a

1.3 Recommendations and considerations for future research

For commercial new construction, the DNV team makes the following recommendations based on data collected, results, and conclusions from the study:

1. **We recommend adjusting code baselines to reflect ISP where better than code for the following measures**:
   - **Lighting, interior LPD: 25% better than code.** This study found clear evidence that interior lighting design, which primarily uses LED technology, exceeded the code requirements. The non-participant ISP for interior lighting was 40% better than code, which aligns with results in other jurisdictions for similar code versions. However, the latest version of the energy code in New Jersey (ASHRAE 90.1-2016) increased the stringency of lighting requirements to account for LED market penetration by reducing allowed LPDs for many spaces. DNV estimated the impact of these reductions for the space types observed in the study to be approximately 15%, and thus recommends adjusting the median observation to 25% better than code for application to current and future codes.
   - **Lighting, exterior LPD: 35% better than code.** This study found clear evidence that exterior lighting design exceeded the code requirements. The non-participant ISP for exterior lighting was 60% better than code; however, the latest version of the energy code in New Jersey (ASHRAE 90.1-2016) increased the stringency of lighting requirements. DNV estimated the impact of these reductions for the space types observed in the study to be approximately 25% and thus recommends reducing the median observation to 35% better than code for application to current and future codes.
   - **Envelope, window u-factor: 31% better than code**. There is no commercial new construction prescriptive program for building envelope components, and thus DNV assessed all observable sites as non-participants. Window u-factors were consistently better than code, and this recommendation reflects the median ISP observation.
   - **HVAC, Non-VRF Heat pump heating: 19% better than code**. All non-VRF heat pumps observed were non-participants, and all had rated efficiencies at or better than code. This recommendation reflects the median ISP observation.
   - **HVAC, warm air furnaces: 15% better than code.** About three-quarters of all warm air furnaces observed are program ineligible. All of these ineligible systems had rated efficiencies at or better than code. This recommendation reflects the median ISP observation.

2. **Target code training to improve performance for measures where ISP analysis suggests worse than code design.** The following measures are potential candidates for targeted code training:

- **Envelope:** walls, roofs
- **HVAC:** air conditioning, PTAC/PTHP

3. **Conduct targeted measure-specific ISP studies to develop ISP estimates to supplement this initial analysis**. These measure-level ISP studies should include secondary research and primary interviews with distributors and/or manufacturers engaged in the New Jersey market to gather data on system/equipment sales both for new construction and potentially replace-on-failure applications. We recommend that the list of measures for study be prioritized in conjunction with Rutgers, NJBPU, the state-wide evaluator (SWE), and other commercial stakeholders. The following insights from this analysis can be used as inputs to that prioritization exercise:

   - **Heat pumps**. We recommend prioritizing a measure-specific study of heat pumps; heating non-VRF ISP showed better than code performance, though it was based primarily on small units, while cooling was inconclusive and could benefit from more data. Heat pumps are an important contributor to many jurisdictions' approach to building electrification, and additional measure-level study should be done to better understand ISP.
   - **PTAC and PTHP**. DNV observed many units of PTAC and PTHP systems but they were consolidated in only a small number of sites. These include hotels and multifamily buildings primarily. While this report includes some ISP results, we also recognize the limited datasets and suggest additional research to confirm and refine the ISP estimates. PTHPs may be able to be included in a heat pump study.
   - **Boilers and chillers**. We did not observe sufficient boilers or chillers in the ECC study to enable an estimate of ISP. If these are determined to be significant contributors to commercial new construction heating or cooling design, or for current or future programs, we recommend additional study. Several other jurisdictions have conducted measure-level ISP analyses for these measures that could be leveraged as a starting point for secondary research.

2 INTRODUCTION

Rutgers, the New Jersey Board of Public Utilities (NJBPU), and the associated sponsors of the study requested this New Jersey commercial new construction industry standard practice study (NJ ISP study) to conduct additional analysis of the data collected for the New Jersey Energy Code Compliance study (ECC study) to assess industry standard practices (ISPs) for commercial new construction in New Jersey. This study was conducted by DNV from April through June 2022, analyzing the measure-level data gathered for the 47 commercial buildings recruited during the ECC study. These buildings were permitted between January 2018 and March 2020 and the ECC study assessed compliance against ASHRAE 90.1-2013, the code in place during design and permitting, which is the basis for all the ISP results presented in this report.

2.1 Study objectives

The objective of the NJ ISP study is to assess ISP for commercial new construction measures in New Jersey where there was sufficient data gathered during the ECC study. This includes recommendations of ISPs where they may be better than code, as well as recommendations and considerations for additional data collection and/or ISP research.

2.2 Background and context

This discussion provides some brief background on energy codes and baselines and the role of ISP in relation to codes. Traditionally, most state and utility energy efficiency programs have used the energy code as the baseline against which program savings are measured. This is a straightforward application, as by definition, the energy code – whatever version is adopted by the governing jurisdiction – is the minimum standard that all new construction buildings are required to meet. Building departments and code officials are responsible for review and inspection of new buildings to ensure that they are meeting requirements. Typically, to qualify for an energy efficiency program and thus an incentive or rebate, a customer must demonstrate that the equipment specifications and/or performance in their building exceed the code values; often there are explicit thresholds or efficiency levels that must be met to be eligible for the program.

Using code as the baseline assumes that the market is installing equipment with efficiency levels right at code. However, many recent studies have found that actual market practices for some measures are worse than code and other measures are better than code. Industry standard practice (ISP) is a concept that can help states and utilities align their program design with what is actually occurring in the market. ISP is defined as the equipment or practice, specific to the application or sector, that is commonly installed absent program intervention.[1] ISP attempts to quantify what people would have done, in lieu of what they did, if the products incentivized by the programs were not available in the market. Of course, this cannot be observed directly, as incentive programs exist and in many cases can influence the purchase of both downstream and upstream equipment.

There are several methods used to assess ISP, including leveraging prior evaluation results as well as conducting original research. Original research methods could include surveys of equipment distributors or design teams, interviews with technology experts, analysis of sales/shipment data, sampling new construction drawings, customer surveying, and secondary research. The methodology used in this NJ ISP study focuses on a prescriptive review of construction drawings, and uses observations of building measures and equipment efficiencies as a proxy to estimate ISP. This methodology is further detailed in Section 3.

Typically, when ISP is found to be worse than code, no adjustments to baseline are made. In this scenario, the code remains the legal minimum standard for buildings despite observed practices. Additionally, many jurisdictions have

[1] See the Massachusetts Commercial and Industrial Baseline Framework for more comprehensive discussion of baselines and ISPs. https://ma-eeac.org/wp-content/uploads/MA-Commercial-and-Industrial-Baseline-Framework-1.pdf.

implemented code compliance programs that provide code training and other compliance support such as plan review services. These programs are focused on improving code compliance and in some cases they claim the savings from compliance increases. DNV recommended in the ECC study that New Jersey implement a code compliance support program; maintaining code as baseline for measures where ISP is found to be worse than code enables separation of code compliance and beyond code performance and avoids double counting the savings from improved compliance.

Where ISP is found to be better than code, recommendations are commonly made to adjust baselines from code to ISP levels. In some instances, initial ISP analysis produces mixed or inconclusive results and additional research is needed to form a more definitive estimate of ISP before adjusting baselines.

3 METHODOLOGY

The DNV team reviewed the data collected during the ECC study, weighted to the population of commercial new construction in New Jersey per the ECC study methodology, to inform ISPs for select measures where possible. This included assessment of ISPs for envelope components, mechanical systems (HVAC) and lighting measures where there was sufficient data available. No additional data collection was performed for this ISP analysis.

DNV developed the findings in this report through inspection of all available construction documents provided during ECC study recruitment and data collection. These documents were obtained directly from building departments and were typically the set of documents submitted to obtain a building permit (commonly called the permit set of plans). While these are not "as-built" plans, DNV has conducted analysis in prior studies and has not found significant instances of major design changes in terms of energy code performance between the permit set and the as-built buildings or documentation. We define observable systems are those as being present in a particular building, while verified systems are those where we could review and confirm specific characteristics of the building or system (e.g., insulation levels, efficiency levels, fixture counts, etc.) in the construction documents.

The ISP results are presented in a consistent format, estimating the percentage better (or worse) than code for observable and verified building systems along with upper and lower bounds at the 90% confidence level where there is sufficient variability to estimate them. This approach accounts for the variability of the equipment efficiency observations and the square-footage to which they apply. For some measures, additional study may be warranted to substantiate these results.

The percentage better (a positive number) versus worse (a negative number) than code for each system was usually calculated as ratio of the rated efficiencies. This is a relative number that is somewhat indicative of relative energy consumption performance, but it should not be interpreted as an energy savings fraction, particularly compared system to system. A 10% better performance in a window metric does not translate to 10% savings in heating energy use nor twice the heating savings compared to a boiler with a 5% better than code performance. The percentage better than code was typically calculated as the ratio of the rated efficiency verified in the construction documents and the building code minimum required efficiency.

DNV also assessed program eligibility at the equipment level. Eligible equipment has been verified as meeting or exceeding program requirements while ineligible systems were verified as not meeting program requirements. In some cases, we could assess whether equipment was code compliant, but not whether it was program eligible, in which case the eligibility was indeterminant. For mechanical equipment where possible, DNV also estimated a program benchmark that represents where the programs are setting minimum efficiencies for eligible measures relative to code. Where calculable, this minimum program efficiency is expressed as a percentage better than code based on the equipment observed during the ECC study.

3.1 ISP approach priority

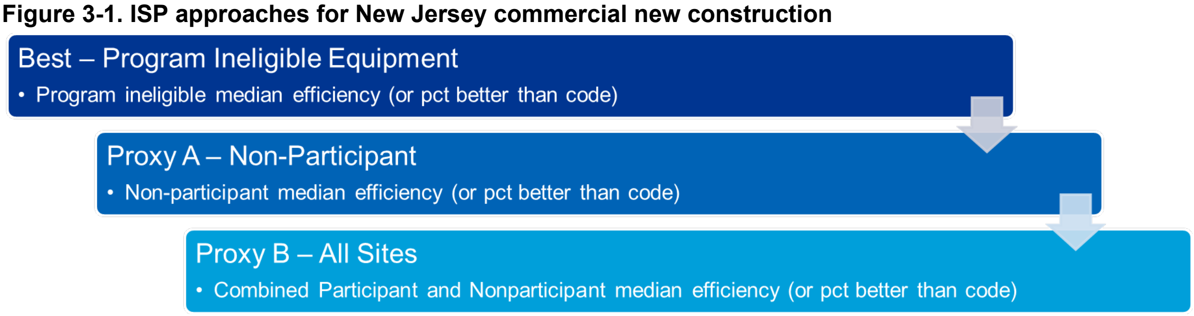
DNV leveraged the ISP approach priority developed for a prior study in Massachusetts, adapting it where necessary to New Jersey new construction. This approach includes three metrics that could be used to assess ISP, prioritized as follows:

- **Program-ineligible equipment median as ISP**. This is the ideal approach to estimating ISP, as it attempts to assess what would have been installed if the program-qualifying equipment was not available to the consumer. This method requires assessment of each observed system against program eligibility requirements – both in terms of efficiency levels and any other requirements (such as control requirements). The ISP is the population-weighted median of the ineligible systems. In this study, the program-ineligible median approach was examined for the majority of HVAC equipment, but many specific equipment types did not have sufficient ineligible equipment observations.

- **Non-participant median as proxy for ISP**. This approach is considered a second-best proxy for ISP, pursued if the evaluators are unable to assess eligibility for a sufficient number of systems to pursue the program-ineligible median approach. This method takes the population-weighted median of all observable equipment installed at sites that did not participate in the NJCEP commercial new construction programs. Including all non-participants likely includes some equipment that is eligible for PA programs and thus may be a high estimate of ISP, but this method can be used as a proxy where the first approach is not feasible. In this study, the non-participant median approach was used for all envelope and lighting measures, and most of the HVAC equipment.
- **All site results as ISP with participant adjustment**. The third approach to ISP incorporates all observations regardless of program eligibility, and it also includes both non-participants and participants, with an adjustment to participants to account for program free ridership. This adjustment is made because free riders, who by definition would have installed program measures even if they did not receive program incentives, are part of the naturally occurring market activity, and not accurately reflecting this component of the market when using all site results could introduce biases. While the DNV team has used this method in previous studies for interior and exterior lighting ISP, the ECC study sample did not include sufficient participation data to support this approach. Additional data collection for program participants and more details about the nature of NJCEP participation could enable the use of this approach in future analyses.

Figure 3-1 shows the ISP approach prioritization in graphical form.

Figure 3-1. ISP approaches for New Jersey commercial new construction



3.2 Program participant summary

In New Jersey, all commercial new construction programs are run by the New Jersey Clean Energy Program (NJCEP).[2] However, overall commercial new construction participation was limited during the ECC study period. During the ECC study, DNV incorporated program participation as a stratification variable, but found that there were not many program participants overall (an estimated 31 participating sites out of an estimated population of 1,312). Throughout recruitment, DNV was able to recruit six total participants. For this NJ ISP study, to enable participant and non-participant analysis, DNV further refined the participants from the ECC study to identify the measures or programs that were relevant to each building category. During this process, two participants did not participate in programs applicable to this ISP analysis; they only participated in a program for food service equipment. Table 3-1 shows the distribution of sites for each building category between participants and nonparticipants, as well as the sample square footage represented by the participants. The participants were not large contributors to the sample data and as such, could not be used to develop definitive ISP estimates. Thus, no participants were included in the ISP analysis.

[2] See the NJCEP website for more information about their programs. https://njcleanenergy.com/.

Table 3-1. ECC study program participation study for ISP measures.

Building category	Participants	Non-participants	Total	Participant percentage of square footage
Envelope	0	43	43	0%
HVAC	1	42	43	0.17%
Lighting	3	36	39	2%

4 ISP RESULTS

4.1 Lighting ISP

4.1.1 Lighting fixture distribution

As a key part of the ECC study data collection, DNV conducted lighting fixture inventories for all surveyed interior and exterior lighting spaces. For exterior lighting, all fixture types which were able to be verified were identified as LEDs. Figure 4-1 presents the distribution of interior fixtures by lighting technology for the ECC study. This shows a high penetration of LEDs observed in the New Jersey sites, accounting for 92% of all fixtures. Figure 4-2 shows this same interior LPD analysis across three prior studies conducted by DNV in Massachusetts; this shows the increasing trend in LED penetration over time, and also that the most recent (NRNC study completed in 2021) is very similar to the ECC study observations.

Figure 4-1. Interior Lighting Technologies

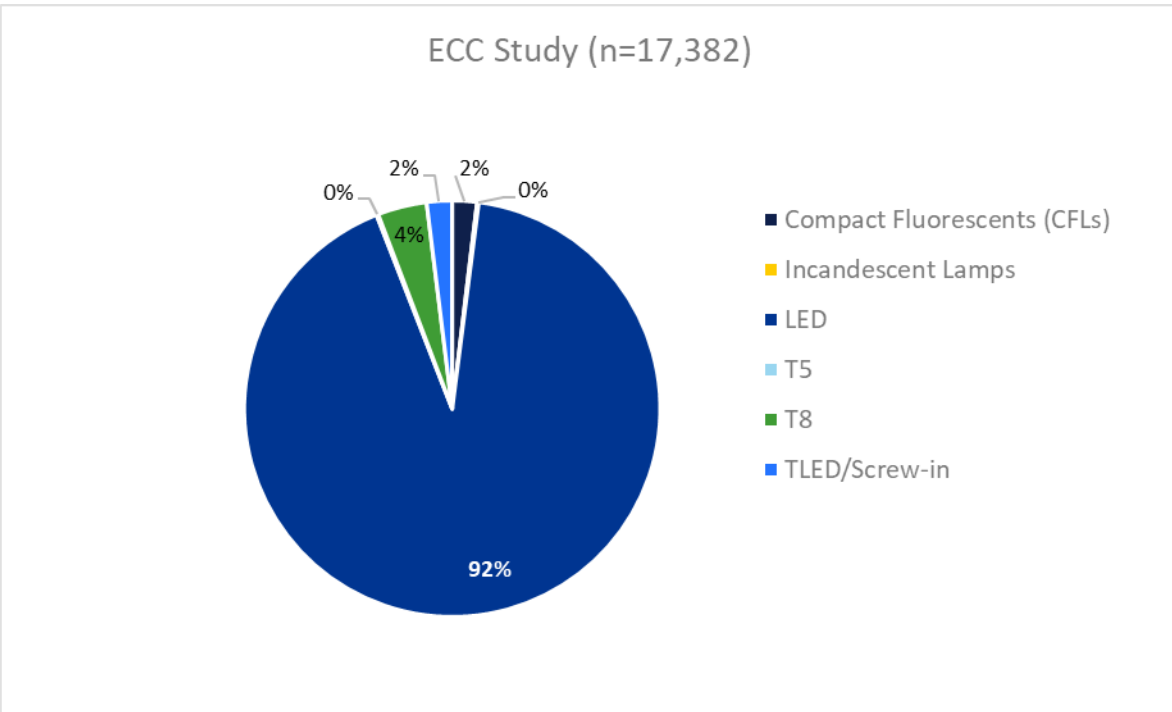
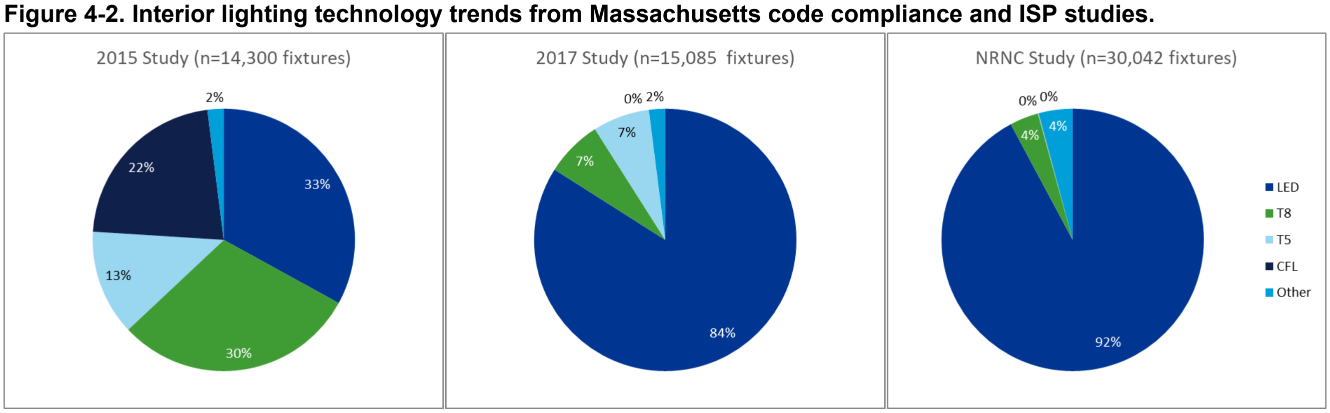


Figure 4-2. Interior lighting technology trends from Massachusetts code compliance and ISP studies.



4.1.2 Measure-level lighting ISPs

The data collected enabled assessment of measure-level lighting ISP for both interior and exterior LPD.

- **Interior LPD observations.** The data collected during the ECC study enabled assessment of interior LPD for all 39 sites where lighting documentation was provided. The NJCEP lighting program is performance based, so there are no requirements for eligible equipment. Additionally, there were only 3 participants in the performance lighting program in the sample, accounting for only 2% of the total square footage observed. With such a small participant dataset, the best ISP approach for this measure is the non-participant metric. The median using this metric is 40% better than code as shown in Table 4-1. This generally aligns with the fixture distribution that shows the high penetration of LEDs, and suggests that the code may not reflect this trend.
  Recommended ISP. The ECC study gathered data on buildings permitted under ASHRAE 90.1-2013 (2013 code). However, in the latest version of the energy code, ASHRAE 90.1-2016 (2016 code), LPD requirements were made more stringent to account for the market penetration of LEDs. While DNV's scope for the ECC study did not include data collection for buildings permitted under the 2016 code, DNV analyzed the magnitude of LPD code changes in conjunction with market trends observed in other jurisdictions to develop a recommended interior LPD ISP.

  – **Code changes**. The magnitude of the change in LPD stringency varied widely across individual spaces; a few space types saw increases in LPD allowance, some remained unchanged, and some were reduced by over 30%. Since not all space types are commonly used, DNV calculated the average adjustment for the space types observed during the ECC study and found that the average reduction in LPD allowance was approximately 15%.
  – **Market trends**. There have been several recent studies of LPD ISP in other jurisdictions and all studies have consistently found that ISP for interior lighting was better than code, at similar levels to the 40% better than code observed in this study.[3]
  – **Recommendation:** Despite code changes, there is strong evidence that interior lighting is better than code. We recommend that interior lighting baselines be adjusted to 25% better than code to reflect the market trends while factoring in the 15% increase in stringency in the 2016 code for the space types observed in the ECC study. While it should not delay a baseline adjustment, additional data and details regarding lighting program participants, including a program evaluation that assesses net-to-gross (NTG) for this program, could help to further refine this result.

Table 4-1. Interior LPD

Results	Number of Sites	Median % better / worse than code	Bounds @ 90% confidence level
Non-Participant ISP Metric	36	40%	20%/61%
Participants	3	77%	n/a
Total	39		

- **Exterior LPD observations**. The data collected during the ECC study enabled assessment of the exterior LPD for 39 sites where lighting documentation was provided. The exterior lighting dataset included the same three participant sites, as DNV did not receive enough participant information to categorize participants as interior or exterior. As with interior LPD, the best ISP approach is the non-participant metric. The median for this metric is 60% better than code as shown in Table 4-2. This metric includes very wide confidence bounds suggesting a wide variety in performance. Some factors that are contributing to the better than code performance include the full penetration of LEDs identified for exterior

[3] See prior studies in Massachusetts: Massachusetts NRNC Market Characterization Study: https://ma-eeac.org/wp-content/uploads/MA19C08-B-NRNCMKT-NRNC-Market-Characterization-Study-Final-Report.pdf; Massachusetts Commercial Energy Code Compliance and Baseline for IECC 2012: https://ma-eeac.org/wp-content/uploads/MA-CIEC-stage-5-report-P70-Code-Compliance-and-Baseline-FINAL.pdf.

lighting and the method by which the exterior LPD is calculated. The exterior LPD calculation includes an exterior base site allowance based on the zone where the building is located, as well as additional allowances for individual lighting spaces (e.g., walkways, parking lots, etc.). DNV found that the exterior base site allowance was often higher than the proposed wattage without inclusion of the additional space-specific wattage allowances. While this helps individual sites meet and exceed code requirements, the zone or location of the building can play a large role in the percentage better or worse than code. The same exact building with the same exterior lighting in a more rural or urban setting could thus have significantly different results.

Recommended ISP. Similar to interior LPD, despite code changes to increase the stringency of exterior lighting requirements, there is strong evidence that exterior lighting is better than code. The 2016 code increased the stringency of the exterior lighting requirements, both for base allowances as well as many of the individual space types. DNV assessed the magnitude of this change for the space types observed in the ECC study and found an average increase in stringency of 25% between the 2013 and 2016 code versions. DNV recommends that exterior lighting baselines be adjusted to 35% better than code to account for this increase (60% observation minus 25% code increase = 35% ISP recommendation). While it should not delay a baseline adjustment, more information on program participation and program NTG could help further refine this adjustment in the future.

Table 4-2. Exterior LPD

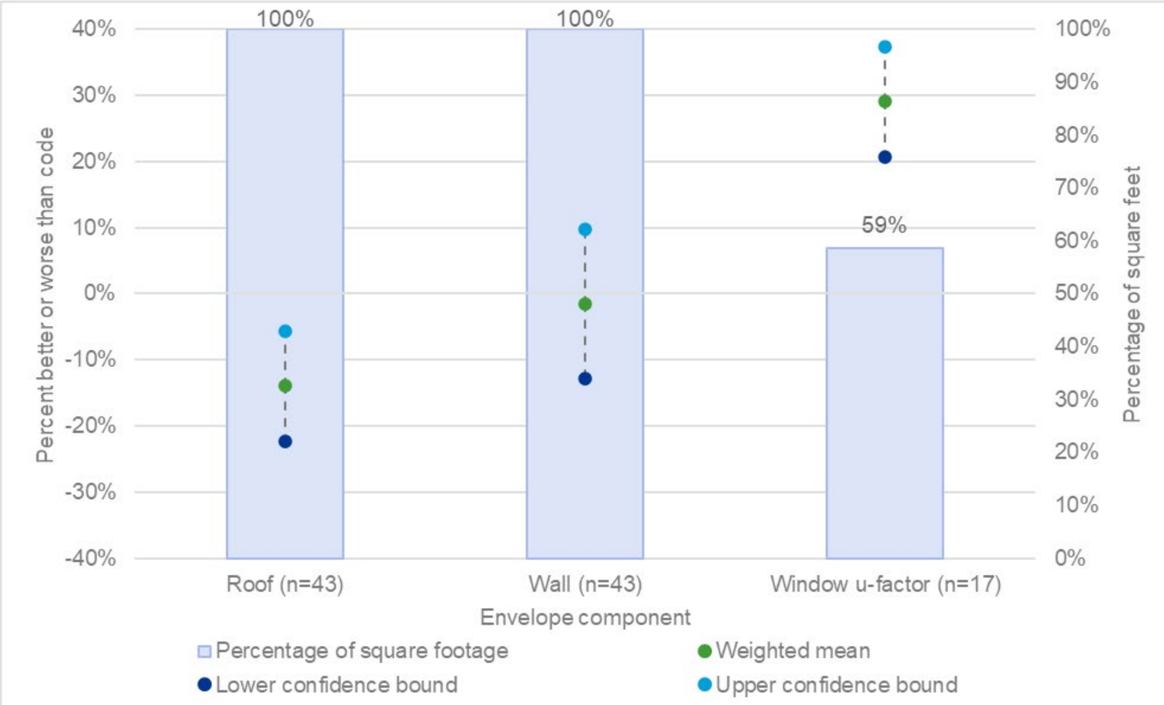
Results	Number of Sites	Median % better / worse than code	Bounds @ 90% confidence level
Non-Participant ISP Metric	36	60%	30%/90%
Participants	3	54%	n/a
Total	39		

4.2 Envelope

The building envelope data collected during the ECC study enables some insights into building practices in New Jersey:

- **Envelope components mean observations**. The details collected for roofs, walls, and window u-factors enable the comparison of installed practices to code. Figure 4-3 presents the percent better than code along with the 90% confidence bounds for the three envelope components. The secondary axis shows the percent of square footage represented for each component. For roofs and walls, DNV was able to assess the design for all 43 sites (100% of square footage) that included envelope details in the construction documentation. The mean observation for both components was worse than code. For window u-factors, details were observable for 59% of square footage but average window u-factor specifications were better than code.

Figure 4-3. Building envelope mean observations relative to code



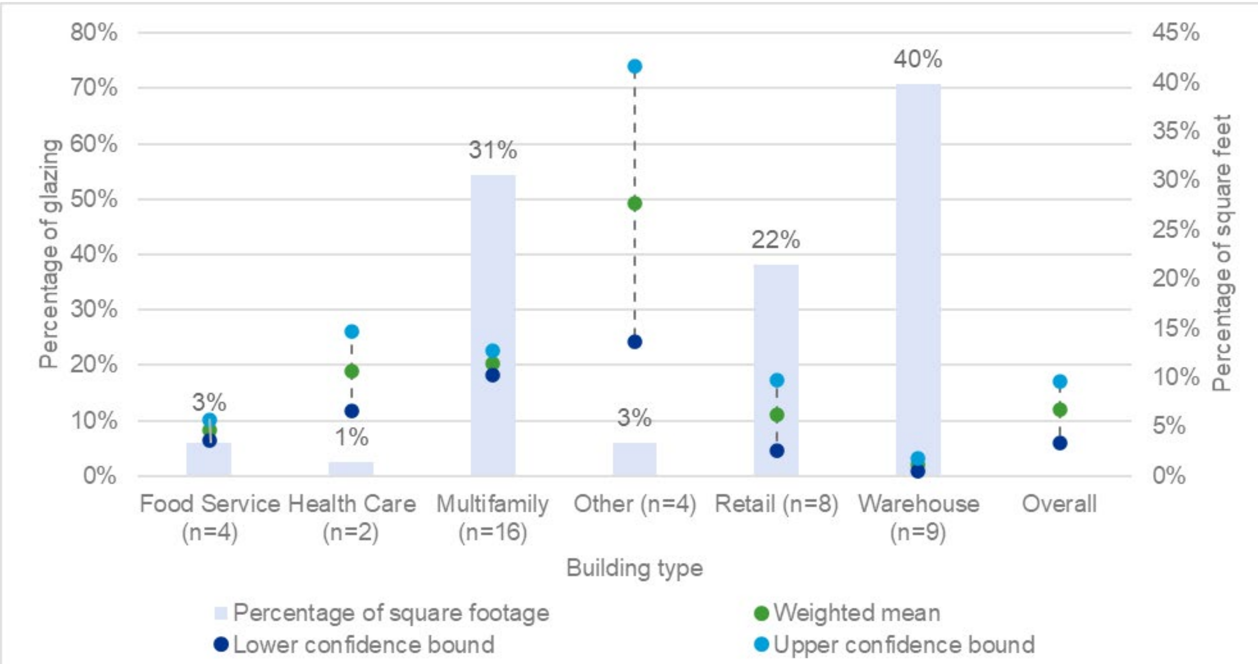
- **Envelope ISP results**. In addition to reporting the mean observations for these envelope components, DNV applied the ISP approach (See Section 3.1) to the envelope data. In New Jersey, there is no prescriptive program for building envelope components, and there were thus no envelope participants in the dataset. Thus, assessment of program eligibility is not possible. Table 4-3 shows the non-participant ISP metric for each of the three envelope components. All three of these components have fairly wide confidence bounds, with the median for roofs worse than code, 6% better than code for walls, and significantly better than code (+31%) for window u-factors. DNV recommends that ISP for window u-factors be adjusted to better than code. However, for roofs and walls, since the 90% confidence bounds include both better and worse than code values, DNV recommends leaving the ISP for these components at code levels. It's possible that this observation could be due to project design teams having the flexibility to trade-off insulation levels within the envelope such that one component is purposely worse than code and then accounted for in the other components. This also could represent a topic for targeted training, as recommended in the ECC study.

Table 4-3. Median nonparticipant ISP metrics for envelope

Envelope component	Number of sites	Median % better / worse than code	Bounds @ 90% confidence level
Roof	43	-15%	-36%/6%
Wall	43	6%	-4%/16%
Window u-factor	17	31%	18%/44%

- **Percent glazing**. DNV also calculated the percent of glazing for all 43 sites where envelope data was available. While there are no explicit code requirements for glazing, the code does have a limit of 40% glazing for prescriptive compliance; glazing percentages beyond 40% require performance-based compliance. The weighted average glazing percentage of exterior wall areas for all buildings was 12%, with a lower 90% confidence bound of 6% and an upper bound of 17%. Figure 4-4 shows the distribution of square footage and the weighted mean glazing percentage and confidence bounds for each building type. Multifamily buildings had a mean of 20% glazing with tight confidence bounds. Warehouses had very little glazing; these are typically facilities for storage of goods and are likely to have few windows. The “other” category includes an office building, a hotel, a school, and an industrial building; the higher glazing observed for these buildings reflects trends in their building design for increased curtain wall and other glazing.

Figure 4-4. Building glazing percentage by building type

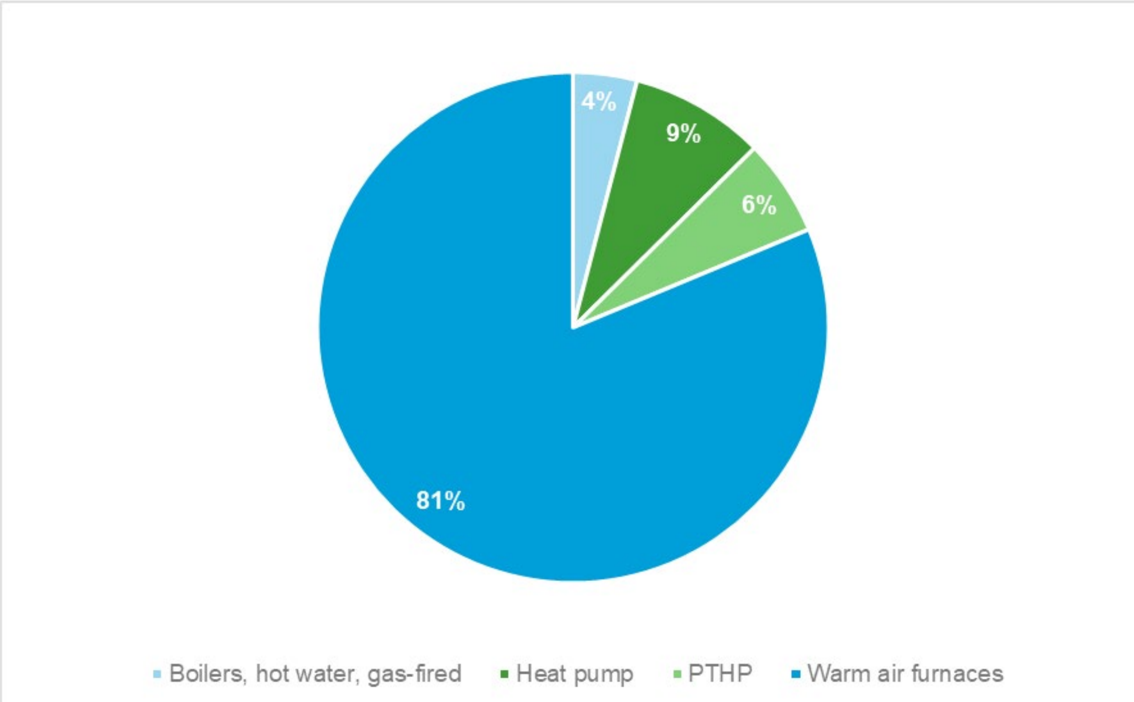


4.3 HVAC

4.3.1 Heating Equipment

The following section presents observations and findings by system type. As can be seen in Figure 4-5, about 85% of the space is heated by natural gas (shades of blue) and the balance by electricity (shades of green). About 81% of the floor space is heated by direct and indirect gas-fired furnaces that directly heat the air stream, unlike a boiler which heats water. A furnace is a typical heat source for packaged units including rooftop units, makeup air units, and standalone heaters.

Figure 4-5. Area Served by heating equipment*



*Oil-fired boilers and unit furnaces each comprised <1% of area served.

Table 4-4 defines the heating systems observed during the ECC study.

Table 4-4. Heating system definitions

Heating system	Definition
Warm air furnace	Indirect- or direct-fired furnace supplying heated war through ducts to spaces. Can be a standalone unit, but is typically integral to a rooftop-DX system or split DX system air conditioner.
Warm air unit furnace	Self-contained furnace that requires connections only to energy sources. Installed in the spaces they are intended to heat and do no use ductwork to distribute heat. Unit heaters can be direct- or indirect-fired with a heating fuel.
Boiler, hot water, gas-fired	Pressure vessel that uses natural gas fuel to supply hot water for heating.
Boiler, hot water, oil-fired	Pressure vessel that uses heating oil or fuel oil blends to supply hot water for heating.
Heat pump	A heat pump is a DX air conditioner with a reversing valve, allowing it to operate in heating and cooling modes. Heat pumps come in several configurations, such as split system, water source, ground source, packaged rooftop.
PTHP	Packaged terminal heat pump (PTHP) is a self-contained heat pump typically installed through a wall. It discharges warm or cool air directly to the space and does not use ducts for distribution.

The details gathered for heating systems enable comparisons of installed practices to code. Table 4-5 presents the total number of sites, systems, and units observed for each heating system, as well as the ISP approach, median value, and 90% confidence bounds where available. There is insufficient data to assess ISP for boilers which account for 4% of heated floorspace, but DNV applied the ISP approach to warm air furnaces, heat pumps, and PTHP systems. The percentage better than code is a function of the ratio of the specified efficiency divided by the code specified minimum efficiency. We note that the better than code metric is an approximation, as in some cases the equipment nameplate reported efficiency units (AFUE, combustion or thermal efficiency) differs from the units specified by code.

Table 4-5. Heating Equipment Summary

Equipment Type	Total Number of			ISP Approach	Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units			
Boilers - oil-fired	1	1	1	n.d.	n/a	n/a
Boilers - gas-fired	2	2	7	n.d.	n/a	n/a
Warm air furnaces	36	114	495	Ineligible equipment median	15%	7%/22%
Heat pumps non-VRF (heating)	13	36	200	Non-participant median	19%	10%/29%
Heat pumps VRF (heating)	5	13	51	Inconclusive	n/a	n/a
PTHP (heating)	4	14	641	Non-participant median, but limited data	17%	12%/22%

4.3.2 Cooling Equipment

The following section presents mechanical cooling observations and findings by system type. Figure 4-6 presents the percentage of floor area served by system type. About three quarters of the floor space is cooled by traditional direct expansion (DX) cooling systems (air conditioning), which are typically packaged as rooftop units, packaged terminal units (PTAC), makeup air units, and split systems where the condenser is not co-located with the compressor. Almost a quarter of the space is cooled via heat pumps and packaged terminal heat pumps (PTHP), which are also DX systems, although they are designed to provide heating by reversing the thermal flows. Only about 3% of floor area observed is cooled via chilled-water systems.

Figure 4-6. Area Served by cooling equipment

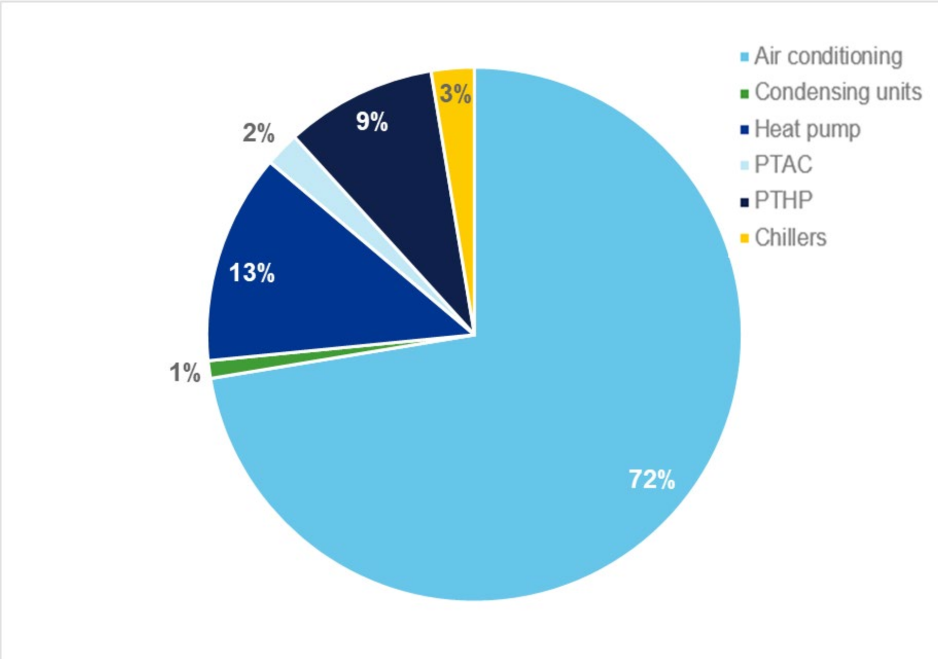


Table 4-6 defines the cooling systems observed.

Table 4-6. Cooling system definitions

Cooling system	Definition
Air conditioning	Unitary direct expansion air conditioning units which include packaged and split air-cooled, water-cooled, evaporatively cooled, and through-the-wall unit types.
Condensing units	A factory-made assembly of refrigeration components designed to compress and liquefy a specific refrigerant. The unit consists of one or more refrigerant compressors, refrigerant condensers (air-cooled, evaporatively cooled, or water-cooled), condenser fans and motors, and factory-supplied accessories.
Heat pumps	A heat pump is a DX air conditioner with a reversing valve, allowing it to operate in heating and cooling modes. Heat pumps come in several configurations, such as split system, water source, ground source, packaged rooftop.
PTHP	Packaged terminal heat pump (PTHP) is a self-contained heat pump typically installed through a wall. It discharges warm or cool air directly to the space and does not use ducts for distribution.
PTAC	Packaged terminal air conditioner (PTAC) is a self-contained air conditioning unit typically installed through a wall. It discharges cool air directly to the space and does not use ducts for distribution.
Chillers	Water chilling packages include air-cooled, water-cooled, and evaporatively cooled.

Table 4-7 shows a summary of the cooling equipment observed during the ECC study data collection, along with the ISP results. There is insufficient data to assess condensing units (1% of cooling area served) and chillers (3% of cooling area served), but DNV applied the ISP approach to air conditioning, heat pumps, PTHP, and PTAC systems.

Table 4-7. Cooling Equipment Summary

Equipment Type	Total Number of			ISP Approach	Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units			
Air conditioning	34	152	563	Ineligible equipment median	-1%	n/a
Heat pumps non-VRF (cooling)	13	36	200	Inconclusive	n/a	n/a
Heat pumps VRF (cooling)	5	13	51	Inconclusive	n/a	n/a
PTHP (cooling)	4	14	641	Limited data	-7%	n/a
PTAC	2	6	220	Inconclusive	-9%	n/a
Condensing units	1	2	2	Insufficient data	n/a	n/a
Chillers	1	1	2	Insufficient data	n/a	n/a

4.3.3 HVAC equipment ISP results

This section presents recommended ISP efficiency values for select HVAC equipment types where there were sufficient observations. The bullets and tables below provide additional insights into ISP observations and findings compliance for each of the HVAC equipment with significant contributions to heating and cooling loads. The equipment-specific tables show the distribution of sites, systems, and units observed for each ISP metric, along with medians and confidence bounds where possible. Note that some sites had systems and/or units that met both categories (e.g., some eligible and some ineligible units), so the total counts for each ISP metric do not match the overall total by design.

Heating equipment ISP

- **Warm air furnace.** Table 4-8 presents the ISP metrics for warm air furnaces. The warm air furnace ISP median rated efficiency is 15% better than code using the Ineligible ISP Metric. The NJCEP requires furnaces with very high condensing efficiency levels, at about 95% AFUE. While all furnaces observed during the ECC study were code compliant, many are non-condensing furnaces, or they are condensing furnaces with efficiencies below the program requirement. Thus, the ISP is better than code but worse than the program.

Table 4-8. Warm Air Furnace

Results	Number of			Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units		
TOTAL	36	114	495		
Ineligible ISP Metric	**28**	**88**	**193**	**15%**	**7%/22%**
Eligible	13	24	299	23%	22%/23%
Program benchmark	35	113	493	19%	18%/19%
Non-Participant ISP Metric	35	111	490	15%	7%/22%
Participants	1	3	5	1%	n/a
Unverifiable total/partial	2	2	3	Unknown	Unknown

- **Heat pumps - heating.** Table 4-9 and Table 4-10 present the ISP metrics for heat pump heating efficiencies. The heat pump results are split between variable refrigerant flow (VRF) heat pumps and non-VRF heat pumps since the code has slightly different efficiency requirements for them.
  - ***Non-VRF heat pump heating***. The NJCEP program does not have a heating efficiency requirement for heat pumps with 64,800 Btu/h unit capacity or less, including both split-system and single packaged units. All of the non-VRF heat pump systems observed in the ECC study have capacities less than 64,800 Btu/h. Therefore, there is no program ineligibility ISP metric for these equipment, and the ISP approach is the non-participant metric as it reflects the market. The median rated efficiency is 19% better than code using the non-participant metric.
  - ***VRF heat pump heating***. About 60% of the VRF heat pump systems observed in the ECC study have capacities less than 64,800 Btu/h. The non-participant ISP metric applies here as well, since the few larger systems were all eligible for the program. Using the non-participant metric, the median rated efficiency is 27% better than code. However, the 90% confidence bounds are fairly wide and include both better and worse than code values and thus the ISP result is inconclusive. We recommend additional analysis and a detailed look at separate heat pump types and sizes to better estimate heat pump ISPs.

Table 4-9. Heat Pumps – Non-VRF heating

Results	Number of			Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units		
TOTAL	13	36	200		
Ineligible ISP Metric	n.d.	n.d.	n.d.	n/a	n/a
Eligible	n.d.	n.d.	n.d.	n/a	n/a
Program benchmark	n.d.	n.d.	n.d.	n/a	n/a
Non-Participant ISP Metric	**13**	**36**	**200**	**19%**	**10%/29%**
Participants	0	0	0	n/a	n/a
Unverifiable total/partial	13	36	200	Unknown	Unknown

Table 4-10. Heat Pumps – VRF heating

Results	Number of			Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units		
TOTAL	5	13	51		
Ineligible ISP Metric	n.d.	n.d.	n.d.	n/a	n/a
Eligible	3	5	5	0%	-32%/32%
Program benchmark	3	5	5	0%	-29%/29%
Non-Participant ISP Metric	5	13	51	27%	-1%/56%
Participants	0	0	0	n/a	n/a

Results	Number of			Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units		
Unverifiable total/partial	2	8	46	Unknown	Unknown

- **PTHP heating.** Table 4-11 presents the ISP metrics for PTHP heating efficiencies. Only one PTHP system had an ineligible heating efficiency. With such a small ineligible equipment dataset, the best ISP approach is the non-participant metric. The median rated efficiency is 17% better than code using the non-participant metric. However, it is likely this ISP estimate is on the high-side, due to a large proportion of eligible equipment in the non-participant sites. Additional measure-specific analysis on program ineligible PTHP units, as well as additional data from more sites/system designs, could improve this estimate.

Table 4-11. PTHP- heating

Results	Number of			Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units		
TOTAL	4	14	641		
Ineligible ISP Metric	1	1	2	-20%	n/a
Eligible	3	13	639	17%	12%/21%
Program benchmark	4	14	641	2%	n/a
Non-Participant ISP Metric	**4**	**14**	**641**	**17%**	**12%/22%**
Participants	0	0	0	n/a	n/a
Unverifiable total/partial	0	0	0	Unknown	Unknown

Cooling equipment ISP

- **Air conditioning.** Table 4-12 presents the ISP metrics for air conditioning equipment. The air conditioning ISP median rated efficiency is 1% worse than code using the Ineligible ISP Metric. A few possible reasons for the worse than code efficiency is that designers may have specified equipment based on an older version of energy code, or they may have specified equipment based on currently remaining stock with local suppliers that might not meet current code efficiencies. We note that using the non-participant approach, the ISP median rated efficiency is 10% better than code. It is likely that the actual ISP is somewhere in between 1% worse than code and 10% better than code. At this time, we don’t recommend an adjustment of the baseline. However, there may be a training opportunity to bring new construction air conditioning equipment up to code. Additional measure-specific research on program ineligible air conditioning equipment could improve this estimate.

Table 4-12. Air Conditioning

Results	Number of			Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units		
TOTAL	34	152	563		
Ineligible ISP Metric	12	18	76	-1%	n/a
Eligible	29	123	473	10%	9%/11%
Program benchmark	32	146	555	2%	-1%/5%
Non-Participant ISP Metric	33	149	558	10%	8%/12%
Participants	1	3	5	1%	n/a
Unverifiable total/partial	8	11	14	Unknown	Unknown

- **Heat pump cooling.** Table 4-13 and Table 4-14 present the ISP metrics for heat pump cooling efficiency. Similar to heating, we separated VRF and non-VRF heat pumps for this analysis.
  - ***Non-VRF heat pump cooling.*** Using the ineligible ISP metric, the median rated efficiency is 6% worse than code. However, there is limited data on ineligible equipment – just 8 heat pumps systems of the 36 non-VRF systems observed. Using the non-participant ISP metric, the median rated efficiency is 16% better than code. Most of these non-participant heat pumps were eligible for the program. Given the range of results, the ISP result for this measure is inconclusive and warrants additional ISP heat pump research.
  - ***VRF heat pump cooling.*** Using the ineligible ISP metric, the median rated efficiency is 29% better than code. However, there is limited data on ineligible VRF equipment – just 2 systems of the 13 VRF systems observed. Using the non-participant ISP metric, the median rated efficiency is 2% better than code. However, the confidence bounds are fairly wide, and include both better and worse than code values. These two ISP estimates show both better and worse-than-code performance, and with limited data on ineligible systems, the results are inconclusive. Heat pumps are of particular interest in many jurisdictions, including New Jersey, due largely to anticipated contributions towards building electrification trends, so rather than recommending an ISP adjustment at this time for heat pump cooling, we suggest conducting a heat pump measure-specific ISP study to develop an ISP estimate that could be implemented by the NJCEP.

Table 4-13. Heat Pumps – Non-VRF cooling

Results	Number of			Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units		
TOTAL	13	36	200		
Ineligible ISP Metric	3	8	15	-6%	-6%/-6%
Eligible	10	28	185	16%	n/a
Program benchmark	13	36	200	2%	n/a
Non-Participant ISP Metric	**13**	**36**	**200**	**16%**	**n/a**
Participants	0	0	0	n/a	n/a
Unverifiable total/partial	11	27	169	Unknown	Unknown

Table 4-14. Heat Pumps – VRF cooling

Results	Number of			Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units		
TOTAL	5	13	51		
Ineligible ISP Metric	1	2	3	29%	n/a
Eligible	4	11	48	0%	-32%/32%
Program benchmark	4	11	48	0%	-3%/2%
Non-Participant ISP Metric	**5**	**13**	**51**	**2%**	**-6%/10%**
Participants	0	0	0	n/a	n/a
Unverifiable total/partial	1	2	3	Unknown	Unknown

- **PTAC.** Table 4-15 presents the ISP metrics for PTAC equipment. Only 2 site providing HVAC data had PTAC systems. With such a limited dataset of sites, despite the large number of units, the ISP estimates are inconclusive. It is worth noting that for the data collected, the median rated efficiency is 9% worse than code using the ineligible and non-participant ISP metric. A few possible reasons for the worse than code efficiency is that designers may have specified equipment based on an older version of energy code, or they may have specified equipment based on currently remaining stock with local suppliers that might not meet current code efficiencies. Additional measure-specific analysis on program ineligible PTAC units could help improve this estimate.

Table 4-15. PTAC

Results	Number of			Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units		
TOTAL	2	6	220		
Ineligible ISP Metric	2	5	212	-9%	n/a
Eligible	1	1	8	4%	n/a
Program benchmark	2	6	220	1%	n/a
Non-Participant ISP Metric	2	6	220	-9%	n/a
Participants	0	0	0	n/a	n/a
Unverifiable total/partial	0	0	0	Unknown	Unknown

- **PTHP cooling.** Table 4-16 presents the ISP metrics for PTHP cooling efficiency. The data for ineligible PTHP cooling efficiency units is limited, with two systems of ineligible systems observed at two sites. Using the ineligible ISP metric, the median rated efficiency is 7% worse than code. However, using the non-participant ISP metric, the median rated efficiency is 9% better than code. Additionally, the program benchmark for PTHP is 1% better than code. With these varying results and limited data across only 4 sites, we do not recommend an ISP adjustment at this time. There appears to be a lot of equipment installed that is better than code, but also many non-qualifying units that are worse. We recommend additional research, perhaps as a subset to an overall heat pump ISP, to develop a better estimate for PTHP.

Table 4-16. PTHP - Cooling

Results	Number of			Median % better/worse than code	Bounds @ 90% confidence level
	Sites	Systems	Units		
TOTAL	4	14	641		
Ineligible ISP Metric	2	2	87	-7%	n/a
Eligible	3	12	554	11%	n/a
Program benchmark	4	14	641	1%	0%/2%
Non-Participant ISP Metric	4	14	641	9%	n/a
Participants	0	0	0	n/a	n/a
Unverifiable total/partial	0	0	0	n/a	n/a

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