FINAL REPORT

Rhode Island Non-Residential New Construction Industry Standard Practice Study

Rhode Island Energy

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1 EXECUTIVE SUMMARY

1.1 Study purpose, objectives, and research questions

DNV carried out the Rhode Island Non-Residential New Construction (RI NRNC) Industry Standard Practice (ISP) Study (NRNC Study) for Rhode Island Energy (RIE or RI Energy) from March 2023 to March 2024. The study's overall objectives were as follows:

1. **Assess and/or inform Industry Standard Practices (ISPs) where possible based on the data collection.** This includes updating the interior lighting power density (LPD) adjustment factor developed through prior MA Code compliance studies, adopted by RI, as well as the analysis of other envelope, mechanical, and electrical measures to identify other ISPs that are supported by the NRNC data.
2. **Assess energy Code compliance for select Code measures**. This study did not assess building-level energy Code compliance for each site. Instead, evaluators gathered building design data for a select subset of measures and assessed Code compliance for those measures, normalized to estimate compliant square footage where possible.

The study results clearly showed ISP for interior lighting, exterior lighting, above-grade wall insulation, hot water boilers, air-cooled air conditioning, and heat pump heating systems. The state of RI adopted IECC 2024 90 days after its publication on August 14, 2024. Starting on January 1, 2025, RIE formally adopted IECC 2024 for program planning purposes.

To account for this change, DNV has developed new ISP values applicable to IECC 2024 for these equipment types using the IECC 2015-based NRNC results. To prospectively apply the findings from the RI NRNC study, DNV completed the following activities:

1. Compare observations from sites permitted under IECC 2015 to the IECC 2024 code requirements.
2. Identify any code evolution, technology advancement, or construction trends that would influence market practices.
3. Finalize the ISP applied to IECC 2024 with project stakeholders.

The results of the ISP study update applicable to IECC 2024 are provided in APPENDIX A as an addendum report. The rest of this report is based on the original IECC 2015 study results.

1.2 Methodology overview

This study was designed to gather new construction building practice data relative to the 2015 International Energy Conservation Code (IECC 2015), to update lighting LPD, and to explore whether additional baseline ISP adjustments are warranted for NRNC.

The study was conducted in two phases. Phase 1 included a literature review of prior compliance studies, reviewed RIE programs, and engaged RIE and the Consultant team (C-team) to achieve a consensus that the primary focus of this study should be on informing ISPs versus a full energy Code compliance study. Phase 2 executed the recruitment, data collection, and analysis of site-level data from a representative sample of NRNC buildings permitted under IECC 2015 to assess NRNC ISPs. With the help of RIE staff, the DNV team worked with municipal building departments to obtain the records that allowed for review of construction drawings for sites permitted between August 1, 2019, and February 1, 2022, gathering building envelope, mechanical, and lighting details to assess ISPs and measure-level Code compliance.

1.3 Implications

The study's conclusions regarding ISPs should be considered for program planning, design, and evaluation to adjust measure baselines to reflect the best available data regarding standard practices for NRNC. The specific measures for which ISP adjustments can be made from this study are detailed in the following sections.

1.4 Conclusions, recommendations, considerations, and guidance for future research

1.4.1 Conclusions

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

1. Current standard practice is better than Code for six of the measures examined in this study. Clear indications of ISP were found for the following measures:
   - **Interior LPD.** The DNV team determined that interior LPD design is 58% better than the LPD allowed by Code (0.42 ± 0.06)) for buildings permitted under IECC 2015. The non-participant sites were found to be more efficient than participant sites.
   - **Exterior LPD**. The DNV team examined exterior lighting design and found that standard practice for exterior lighting design was 0.27 ± 0.17 of the LPD Code requirements (73% better) for buildings permitted under IECC 2015.
   - **Above-grade wall insulation**. The DNV team assessed envelope design and found that standard practice for wall insulation was 14% ± 10% better than Code.
   - **Boilers**. The NRNC Study found that standard practice for boilers is to specify condensing boilers, while the Code efficiency levels reflect a baseline of a non-condensing boiler. The study results suggest that the median boilers specified in NRNC are 20% better than Code requirements.
   - **Air conditioning**. Air conditioning systems included multiple sized systems from small mini splits to large roof top units. The DNV team assessed these systems and found that standard practice for air conditioning equipment is 5% better than Code.
   - **Heat pump heating**. The NRNC study found that while a majority (65%) of floor space in new buildings is heated by warm-air furnaces, heat pumps account for most of the heating systems identified (64 units) and serve the second greatest portion of square footage (23%). The study results suggest that the median heat pump heating specified in RI NRNC are 3% better than Code requirements. All heat pumps observed in this study were air-source heat pumps.

In addition to clear indications of ISP, there are also ISPs that are at Code or inconclusive:

2. **Heat pump cooling.** Heat pump cooling systems included traditional air source and variable refrigerant flow (VRF) systems. Using the ineligible ISP metric, the study found there is no difference in the median percent efficiency better or worse than Code, which indicates that ISP is at Code.
3. **Warm Air Furnaces.** The NRNC study observed several warm air furnace systems that are typically standalone direct fired or packaged roof top units. The study found that sites are installing Code compliant equipment and ISP should remain at Code levels.
4. **Chillers, warm air duct furnaces and PTACs.** There is insufficient observed data for these systems to conclude a meaningful ISP.

Additional observations and conclusions were made on the following:

5. Mechanical equipment is largely compliant with the energy Code efficiency requirements. This is consistent with prior Code compliance study findings and reflects the market aligning with the Code such that it is difficult to purchase equipment that does not comply with Code requirements.
6. Compliance is difficult to assess for mechanical equipment controls. For mechanical equipment controls, the presence of controls can be identified, but this study was not designed to provide insights regarding control commissioning or operations - which are key components of successful control strategies. ISPs developed from this study are based on stated equipment efficiencies from construction drawings. Actual equipment and controls performance cannot be determined from plan review and would require on-site evaluation once the buildings are fully operational.
7. Opportunities remain for improving Code compliance and assessing building performance. While this study focused on individual measures in lieu of whole building compliance, opportunities remain to improve compliance for select measures such as slab thermal break requirements, air barrier documentation, and daylighting. Additionally, many benefits of Code compliant systems rely on proper installation of components and system commissioning, particularly for controls and envelope sealing/insulation requirements, which were not assessed as part of this study.
8. The recruitment approach in this study effectively mitigated self-selection bias and provides results reflective of the RI NRNC market. The NRNC Study mitigated this bias by recruiting directly from municipal building departments and ensuring that sites included in the study represented a broad range of municipalities.
9. There is limited new construction in RI, so DNV's original sample included major renovations and additions to existing space. During site reviews, several of these renovations and additions were removed from the sample as not having new construction components. Gut rehab renovations and facility additions that involved new lighting, mechanical or envelope systems triggered by Code were included. The majority of NRNC square footage in RI that this study collected data on is within warehouse space. Four sites are categorized as warehouses, representing more than three million of the total 4.8 million unweighted square footage observed in the study.

1.4.2 Recommendations

The DNV team makes the following recommendations based on data collected, results, and conclusions from the study:

1. Based on the results of this study, DNV recommends adoption of the ISP values summarized in Table 1-1. The product of a Code adjustment factor and the Code specified minimum efficiency yields the ISP baseline efficiency to be used for calculating savings. These values reflect the best available ISP data. There are no ISP recommendations for chillers, warm air furnaces, warm air duct furnaces, PTACs, or heat pump cooling systems. This study did not examine spill over between NRNC program participants.

   To calculate the adjustment to Code baselines, multiply the Code baseline by the recommended Code adjustment factor. Lighting baselines are expressed in lighting power density (LPD) measured in watts per square foot where lower values are more efficient, and thus these adjustment factors are less than one. For the other measures, higher numbers represent more efficient equipment, so adjustment factors are greater than 1.

Table 1-1. Recommended ISP Code adjustment factors[1]

Equipment type	Recommended Code adjustment factor	Notes
Above-grade wall insulation	1.14	Fourteen percent better than Code.
Interior lighting	0.42	Fifty-eight percent better than Code.
Exterior lighting	0.27	Seventy-three percent better than Code.
Hot water boilers	1.20	Twenty percent better than Code. Observed boilers were all condensing, which appears to be standard practice in NC.
Heat pumps – heating	1.03	Three percent better than Code. Includes all heat pumps (air-source heat pumps, VRF heat pumps) except for packaged terminal heat pumps.
Air conditioning	1.05	Five percent better than Code. Includes multiple sized systems.

Focus energy Code training on targeting Code provisions that are not readily complied with and/or require proper installation to capture energy benefits. DNV found that a substantial number of sites were not compliant with the thermal break requirement. While all buildings had slab insulation, it often did not extend to the top of the slab—as required by the Code—to achieve thermal break. Most commonly, it was located under the slab and along the footing. This is an opportunity for designer and/or builder education and training to improve building design and construction such that thermal breaks are established in alignment with the Code requirement.

1.4.3 Considerations

DNV makes the following considerations from the NRNC Study:

1. **Consider targeted studies to further investigate building envelope practices**. Envelope window components are typically difficult to assess because their performance details are often not documented in building plans and are usually provided in specifications or other additional documentation. To better understand thermal envelope performance, RIE should consider doing a more focused study of fenestration design and building practices, using a combination of both primary and secondary research methods. With increasing glazing levels in NRNC building design, sound understanding of this performance will be critical to understanding standard practice.

2. **Consider expanding RIE program participation database to include more detailed information about program participation**. The RIE program participation database provides limited details on the specific measures incentivized by the programs. Additional details on participation, including the specific type, size, make, and model of equipment incentivized by the program, could help improve the classification of program participation and enable more detailed comparisons of participants and nonparticipants beyond lighting measures.

1.4.4 Guidance for future research

1. **Pursue additional ISP heat pump research to validate results in this study.** This study gathered data across different heat pump cooling technologies with 93 air-cooled VRF systems observed to be less than 65,000 Btu/hr. DNV was not able to identify the efficiency for several of these units. To better understand heat pump ISP, DNV would recommend a targeted study to understand the different sizes and efficiencies of heat pumps impacting ISP.

[1] Relative to IECC 2015.

2. **Conduct a selection of on-site visits to recently completed and occupied buildings to assess ISPs for mechanical and lighting controls**. While construction drawing reviews can identify the presence of some controls, they cannot provide any data regarding control commissioning and operations. As these controls are expected to comprise a larger share of future RIE programs, field verification is essential to understand ISPs, gathering data regarding controls commissioning and any overrides in place that may change design intent. This could involve revisiting a select sample of sites when buildings are occupied to understand controls through an impact evaluation.

2 INTRODUCTION

2.1 Study overview and objectives

DNV carried out the Non-Residential New Construction Industry Standard Practice (ISP) Study (NRNC Study) for RI Energy from March 2023 to March 2024. The NRNC Study recruited from 39 municipal building departments to provide data on a sample of recently constructed NRNC buildings in RI. Out of the 39 building departments, DNV received NRNC construction documentation (plans) from 18 departments. DNV reviewed the plans obtained directly through these building departments explicitly to limit self-selection bias. In total, 24 envelope, 26 lighting, and 24 HVAC NRNC sites had sufficient information from their plans to collect data on.

The study's overall purpose was to assess Industry Standard Practices (ISPs) for NRNC buildings permitted under the 2015 International Energy Conservation Code (IECC 2015). The team's objectives were as follows:

1. **Assess and/or inform ISPs where possible based on the data collection**. This includes updating the interior lighting power density (LPD) adjustment factor developed through prior Code compliance studies, as well as the analysis of other envelope, mechanical, and electrical measures to assess whether any additional adjustment factors are supported by the NRNC data.
   Assess energy Code compliance for select Code measures. This study did not assess building-level energy Code compliance for each site; instead, evaluators gathered building practice data for a select subset of measures and assessed Code compliance for those measures, normalized to estimate compliant square footage where possible.

2.2 Study background and context

During the most recent commercial energy Code study (RI Commercial Energy Code Compliance Study,[2] 2016), the DNV team developed an estimate and provided an update on the compliance of commercial buildings with the 2012 Rhode Island Energy Code, provided a qualitative assessment of the effectiveness of the Code Compliance Enhancement Initiative (CCEI), and provided feedback on improving the Code compliance process.

While prior studies focused primarily on developing building-level and statewide Code compliance results, this NRNC Study's primary focus was assessing ISPs for a selected subset of Code measures. Figure 2-1 presents a graphical timeline of completed and current Code ISP and compliance studies in relation to RI Code cycles and Stretch Code versions.

[2] Rhode Island Commercial Energy Code Compliance Study, October 2016. Available on the State of Rhode Island Energy Efficiency & Resource Management Council website. http://rieermc.ri.gov/wp-content/uploads/2017/08/20161025_ri_commercial_Code_compliance_study.pdf

Figure 2-1. Timeline of Rhode Island Code adoption and compliance studies

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Base Code	IECC 2006	IECC 2009				IECC 2012 with Amendments					IECC 2015 with Amendments			IECC 2018 with Amendments		
Stretch Code										RI Stretch Code (2015 IGCC + RI Amendments)						
Compliance Study				2012 NRNC Study				2016 NRNC Study							IECC 2015 NRNC ISP Study	

While the stretch Code is shown in this figure for context, the evaluators assessed ISPs and Code compliance in the NRNC Study against the base IECC 2015 Code. This is primarily due to RI energy efficiency program design, which is based on the IECC Code and not the stretch Code.

IECC 2015 was selected because that was the Code in effect at the start of the study.[3]

[3] The NRNC Study Addendum is included as an appendix to this report relative to IECC 2024.

3 METHODOLOGY AND APPROACH

This section describes the methodology for the project. This project was broken into two phases:

- Phase 1: Finalize data collection scope and methodology
- Phase 2: IECC 2015 data collection and analysis

3.1 Phase 1: Finalize scope and methodology

During Phase 1, the DNV team collaborated with RI Energy, the Consultant team (C-team), and other project stakeholders to finalize the project objectives and methods that were executed during Phase 2. The key activities during Phase 1 were two working group sessions with project stakeholders to achieve a consensus that the scope of Phase 2 should focus primarily on collecting building practice information to inform ISPs rather than a full energy Code compliance study. The primary activities the team completed during Phase 1 are described below.

3.1.1 Literature review and population estimation

The DNV team conducted a literature review to identify a list of building practices to discuss with Rhode Island Energy and the C-team. This included a review of the working group webinar from the MA19C08-B-NRNCMKT study[4] recommendations and similar Code compliance studies conducted in other states in similar climate zones such as Massachusetts, Connecticut, and New York. The literature review identified an initial list of building practices for discussion during the working group sessions.

The team used the Dodge Database to estimate the NRNC building population in Rhode Island. Projects permitted under IECC 2015 served as the sample frame for the analysis. This data was used to develop the preliminary sample.

3.1.2 Facilitate working group session

In March 2023, DNV facilitated the first working group session with project stakeholders to share findings from the literature review and present preliminary Dodge data that would be used for sample design for data collection efforts. The result of this working group session was a consensus that the best path forward for Phase 2 was to conduct a targeted assessment of ISPs rather than a full energy Code compliance study, though the working group agreed that capturing Code compliance data for the targeted subset of building practices should also be included in the Phase 2 scope.

A second working group session was held in May 2023 with project stakeholders to share details of the final project population frame and proposed sample design, and to review the key building practices included in data collection. The result of this working group was a consensus agreement in sample design and data collection approach.

3.1.3 Develop Phase 2 scope

Following the working group session, the DNV team developed the work plan for Phase 2, summarized below, and created the data collection instrument to facilitate assessment of the building practices in scope.

3.2 Phase 2: IECC 2015 data collection and analysis

During Phase 2, the DNV team finalized the sample design, collected site data, and conducted analysis of building practice data to inform ISP development.

[4] DNV, *Massachusetts NRNC Market Characterization Study*. 2021. https://ma-eeac.org/wp-content/uploads/MA19C08-B-NRNCMKT-NRNC-Market-Characterization-Study-Final-Report.pdf

3.2.1 NRNC population estimation

The population frame for this study is the set of NRNC buildings permitted on or after August 1, 2019, through February 1, 2022. To estimate this population, the DNV team purchased a subscription to the Dodge Data & Analytics database for construction information within the State of Rhode Island for the same dates[5] in Phase 1 and scrubbed the data to develop an estimate of the NRNC building population permitted under IECC 2015. This data scrubbing excluded many projects, such as municipal paving projects and minor renovations, and can be considered a decent proxy for NRNC activity in Rhode Island. While we expect some projects to be deemed ineligible during recruiting, as they may have been canceled and/or delayed without corresponding updates to the Dodge database, this approach was consistent with prior studies leveraging Dodge data and was presented at the first working group session. The findings of this Dodge data scrubbing resulted in a final sample of approximately 276 eligible sites. Table 3-1 presents the disposition summary from the population estimation activity.

Table 3-1. Dodge data NRNC results

Disposition	Count of records
Original Dodge export	1,916
Ineligible Scope of Work, Renovations, Project, Construction type	1,303
Interior fit outs	6
Parking, Unconditioned space	32
Apartments/Condos 1-3 stories, 4+ stories, Custom homes, multi-family excluded	63
Not Enough Documentation	236
Total buildings removed	1,640
Remaining buildings (draft sample frame)	**276**

3.2.2 Sample design

The sample frame was developed using the Dodge database referenced in Section 3.2.1. The study also used new construction program participation data and mid-stream lighting and HVAC participation data to identify program participants for the sample design.

As noted in Section 3.2.1, the Dodge data contained 276 projects identified as relevant to this study. These projects were spread across all 39 Rhode Island municipalities and 15 building-use categories. Among the projects, DNV identified 143 as program nonparticipants and 133 as program participants in the new construction, upstream/mid-stream programs. A count of projects, along with total and average square footage per project by building type, is shown in Table 3-2. A count of projects, along with total and average square footage per project by the municipality, is shown in Table 3-3. Note that a large warehouse is identified separately from the other warehouse facilities in the business type table. This is due to its size, representing 38.5% of the sample frame's total new construction square footage. Therefore, we identify it explicitly for both population description and sampling purposes.

Table 3-2 and Table 3-3 are showing unverified population square footage from Dodge that DNV used in the sample design.

5 Dodge estimates that its reports cover 92% of construction projects in the country, including both the public and private sectors.

Table 3-2. Building counts and square footage by building type

Business type	Number of projects	Total square feet (SF)	Average square feet	Percent of projects	Percent of square feet
Education	37	943,491	25,500	13.4%	9.4%
Industrial	8	1,167,977	145,997	2.9%	11.6%
Inpatient Health Care	6	248,471	41,412	2.2%	2.5%
Lodging	9	237,912	26,435	3.3%	2.4%
Military	9	56,594	6,288	3.3%	0.6%
Mixed Use	19	835,407	43,969	6.9%	8.3%
Office	26	401,991	15,461	9.4%	4.0%
Other	3	10,984	3,661	1.1%	0.1%
Outpatient Health Care	15	85,481	5,699	5.4%	0.9%
Public Assembly	41	393,495	9,597	14.9%	3.9%
Public Order and Safety	3	4,918	1,639	1.1%	0.0%
Restaurant	12	40,798	3,400	4.3%	0.4%
Retail	59	838,158	14,206	21.4%	8.4%
Service	7	86,695	12,385	2.5%	0.9%
Warehouse – Large	1	3,864,972	3,864,972	0.4%	38.5%
Warehouse – Other	21	814,077	38,766	7.6%	8.1%
Total	**276**	**10,031,421**	**36,346**	**100%**	**100%**

Table 3-3. Building counts and square footage by the municipality

Municipality	Number of projects	Total square feet	Average square feet	Percent of projects	Percent of square feet
Barrington	2	9,551	4,776	0.70%	0.10%
Block Island	1	694	694	0.40%	0.00%
Bristol	3	23,977	7,992	1.10%	0.20%
Central Falls	1	9,259	9,259	0.40%	0.10%
Charlestown	1	7,292	7,292	0.40%	0.10%
Coventry	1	2,308	2,308	0.40%	0.00%
Cranston	17	358,306	21,077	6.20%	3.60%
Cumberland	4	44,430	11,107	1.40%	0.40%
East Greenwich	6	106,658	17,776	2.20%	1.10%
East Providence	9	226,541	25,171	3.30%	2.30%
Exeter	1	1,000,000	1,000,000	0.40%	10.00%
Greenville	1	29,660	29,660	0.40%	0.30%
Jamestown	3	22,887	7,629	1.10%	0.20%
Johnston	6	4,149,269	691,545	2.20%	41.40%
Kingston	4	10,465	2,616	1.40%	0.10%
Lincoln	5	65,230	13,046	1.80%	0.70%
Middletown	9	136,578	15,175	3.30%	1.40%
Narragansett	1	19,355	19,355	0.40%	0.20%

Municipality	Number of projects	Total square feet	Average square feet	Percent of projects	Percent of square feet
Newport	20	207,398	10,370	7.20%	2.10%
North Kingstown	12	250,831	20,903	4.30%	2.50%
North Providence	1	3,655	3,655	0.40%	0.00%
North Scituate	2	1,024	512	0.70%	0.00%
North Smithfield	1	13,566	13,566	0.40%	0.10%
Pawtucket	9	204,501	22,722	3.30%	2.00%
Portsmouth	3	49,528	16,509	1.10%	0.50%
Providence	72	1,932,344	26,838	26.10%	19.30%
Richmond	3	53,809	17,936	1.10%	0.50%
Riverside	2	8,685	4,343	0.70%	0.10%
Saunderstown	1	3,400	3,400	0.40%	0.00%
Scituate	2	9,038	4,519	0.70%	0.10%
Smithfield	7	140,170	20,024	2.50%	1.40%
South Kingstown	8	45,922	5,740	2.90%	0.50%
Wakefield	4	20,951	5,238	1.40%	0.20%
Warren	4	143,020	35,755	1.40%	1.40%
Warwick	29	400,049	13,795	10.50%	4.00%
West Greenwich	2	100,500	50,250	0.70%	1.00%
West Warwick	3	15,998	5,333	1.10%	0.20%
Westerly	6	28,534	4,756	2.20%	0.30%
Woonsocket	10	176,039	17,604	3.60%	1.80%
Total	**276**	**10,031,421**	**36,346**	**96%**	**98%**

In prior recent baseline studies that used a methodology requiring contacting municipalities, a two-stage cluster sample design was implemented to first sample municipalities and then sample projects among those municipalities to limit the amount of outreach required to meet confidence and precision targets. For this Rhode Island study, given the relatively small number of municipalities and the relatively few projects within each municipality outside of Providence, Warwick, Newport, and Cranston, the team used a simpler stratified, systematic random sample of projects, where projects were randomly selected independent of their presence in a municipality. This required the study to contact a census of the municipalities in Rhode Island for data collection but still represented a lower recruitment burden than studies in states with greater numbers of municipalities and reduced recruitment tracking and analysis burden as compared to a two-stage cluster design.

For the sample design, the study attempted to achieve at least 10% overall relative precisions at the 90% confidence level for square-footage weighted measures expected to occur across the population (e.g., LPD), assuming a coefficient of variation (CV) of 0.5 for those measures. This same assumption was used in other recent non-residential new construction baseline study sample designs. To do this, we drew a systematic random sample of 33 projects explicitly stratified by energy efficiency program participation status and building square footage, with the large warehouse placed in its own stratum due to its size. We implicitly stratified the sample by the municipality and building type with the goal of capturing information for as many different building types and municipalities as possible, since the proposed sample was not large enough to support explicit stratification by those additional categories.

The proposed sample design is shown in Table 3-4. This proposal was a sample of 19 sites across nonparticipant facilities to result in a relative precision of 15% at the 90% confidence level for measures as described above. DNV also proposed a sample of 14 participant facilities, including the large warehouse, to result in a relative precision of 8% at the 90% confidence level for variables with results applicable to the entire sample and with CVs matching our sampling assumption. The overall relative precision for the sample design is 8% at the 90% confidence level.

Table 3-4. Proposed sample design

Participation status	Size group	# projects	Estimated SF	% projects	% SF	Sample allo-cation	CL 90 precisions (FPC)	CL 80 precisions (FPC)
	≤25,000	118	792,735	42.8%	7.9%	6	33%	26%
	25,000-100,000	16	819,336	5.8%	8.2%	7	24%	19%
Nonparticipant	>100,000	9	2,188,174	3.3%	21.8%	6	21%	16%
Nonparticipant total		143	3,800,245	51.8%	37.9%	19	15%	11%
	≤25,000	102	684,886	37.0%	6.8%	6	33%	25%
	25,000-100,000	29	1,567,317	10.5%	15.6%	6	30%	24%
	>100,000	1	114,000	0.4%	1.1%	1	0%	0%
Participant	Large Warehouse	1	3,864,972	0.4%	38.5%	1	0%	0%
Participant total		133	6,231,175	48.2%	62.1%	14	8%	7%
Participant total, excluding Large warehouse		132	2,366,203	47.8%	23.6%	13	22%	17%
Overall total, excluding Large warehouse		275	6,166,449	99.6%	61.5%	32	13%	10%
Overall total		**276**	**10,031,421**	**100.0%**	**100.0%**	**33**	**8%**	**6%**

3.2.3 Data collection

The data collection task involved recruitment and data collection. Recruitment involved reaching out to building departments and City officials – individual sites were not contacted. The site recruitment strategy, as in how DNV recruited sites, and data collection procedure are described in the subsections below:

3.2.3.1 Site recruitment

The DNV team recruited sites for the study by directly engaging municipal building departments. This approach was designed to mitigate self-selection bias in recruited sites. Selection bias is a common challenge for energy Code compliance studies and building practice assessments, as building owners and designers who are knowingly not adhering to Code requirements can decline participation without consequence. By engaging municipal departments directly, this bias was mitigated, as individual site owners were not contacted directly, and the documents reviewed were those filed with each city/town’s building department.

In many cases, the team had to submit Freedom of Information Act (FOIA) requests and/or conduct site visits to municipal building departments to identify and acquire additional documentation. The team requested construction drawings along with supporting materials, which included commissioning plans, sequence of operations documents, COMcheck assessments, and specifications. Most sites, however, could only provide construction drawings.

3.2.3.2 Data collection procedure

The target sample for data collection, per the studies sample design, was to collect information on a total of 33 complete NRNC sites. A site was considered complete if there was verifiable envelope, lighting, and mechanical systems. During recruitment and review of plans, several sets had incomplete or non-verifiable information. This is often a data collection and recruitment challenge for these types of studies, but with a total RI NRNC population of only 276, DNV made an adjustment during data collection. The way the sample design was created, based on participation, non-participation, and square footage, allowed DNV to consider individual sections (envelope, lighting, mechanical) as completes. The updated data collection target became 33 envelopes, 33 lighting, and 33 mechanical sections completed.

The DNV team reviewed the construction drawings and supporting documentation to assess building practices for each of the three primary building systems covered by the energy Code: building envelope, mechanical systems (HVAC), and electrical systems (lighting). Phase 1 of this project identified the specific building practices in scope, summarized in Table 3-6. These include measures generally with the greatest contributions to RIE program savings from August 2019 to February 2022.

When clearly identified in the Dodge data, new construction Process measures, such as cannabis, were not selected for data collection due to their unique ISPs for each site. RIE new construction program savings are detailed in Table 3-5

Table 3-5. August 2019 – February 2022 RIE NRNC savings and incentives

Category	% energy savings (kWh)	% RI energy incentives
Envelope	8.1%	11.6%
Hot Water	0.1%	0.1%
HVAC	20.5%	23.8%
Lighting	22.0%	15.4%
Other	0.3%	0.3%
Process	41.1%	43.7%
Refrigeration	7.8%	5.0%
Grand Total	100%	100%

The team used the data collection forms developed to assess compliance, primarily by conducting a full review of construction documentation filed with local municipalities for each site. These are typically not final as-built plans, and this plan review did not capture any "value engineering" that occurred during a project. The data collection instrument was modified from the MA study instrument to focus on the building practices within the scope of this study. It retains all the same functionality and enhancements to include additional data, such as a more comprehensive approach to collecting detailed HVAC equipment inventories.

Table 3-6. NRNC data collection scope

Building category	Building practices included in data collection
Building envelope	Information on how the continuous air barriers are detailed on construction documents Slab insulation R-values and assessment of thermal breaks Roof types and corresponding insulation R-values Estimate of building glazing percentage
Mechanical systems (HVAC)	Full equipment inventory based on equipment schedules including efficiency levels and controls strategies HVAC controls characterization – inventory of primary controls strategies employed for equipment and spaces/zones
Electrical systems (lighting)	Interior and exterior LPD through a space-by-space method wherever possible Inventory of lighting controls strategies, including daylighting and space-level controls

3.2.4 Project data analysis

The DNV team leveraged the data collected to assess energy Code compliance for the building practices observed, and to inform ISPs supported by the data.

3.2.4.1 Compliance assessment

While the primary objective of this study was to inform ISPs for select measures, the level of detail in the data collected facilitated the assessment of energy Code compliance for each measure. The DNV team analyzed the site observations, incorporating site weights to estimate compliance for the NRNC population in Rhode Island. Wherever possible, compliance values reflect the estimate of the percent of new construction square footage in compliance with the energy Code.

3.2.4.2 ISP assessment

ISP is the equipment or practice specific to the application or sector that is commonly installed absent program intervention. The results estimate the percentage better or worse than Code for selected measures. In general, this is the ratio of equipment rated efficiency to the building Code minimum requirements. The results are typically used as the baseline and can differ from Code.

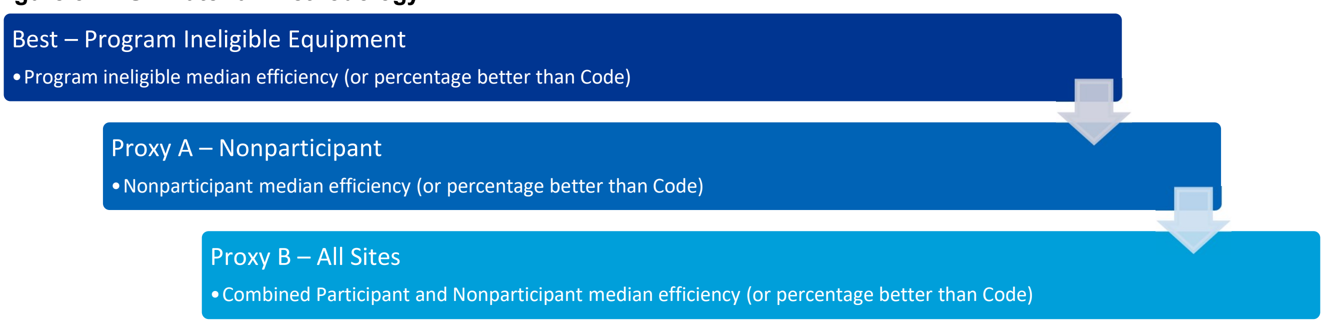
The DNV team reviewed the data collected, weighted to the population of NRNC in RI to inform ISPs for select measures where possible. This included an updated interior LPD adjustment factor for IECC 2015, as well as additional ISPs for envelope, HVAC, and lighting measures.

Figure 3-1 details the ISP approach for this RI NRNC study. This methodology was first developed by DNV in collaboration with project stakeholders during the Massachusetts NRNC Market Characterization Study[6], and was reviewed in detail with RIE and additional stakeholders of the current project. This methodology is a "waterfall" approach to assess ISPs using the best available data for each measure, as follows:

[6] Massachusetts NRNC Market Characterization Study, DNV. June 2021. Available on the Massachusetts Energy Efficiency Advisory Council website. https://ma-eeac.org/wp-content/uploads/MA19C08-B-NRNCMKT-NRNC-Market-Characterization-Study-Final-Report.pdf.

- **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 EC motors or other controls). The ISP is the population-weighted median of the ineligible systems. In this study, the program-ineligible median approach was used for the majority of HVAC equipment.
- **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 enough 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 PA programs. Including all non-participants likely includes some equipment that is eligible for PA programs, 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 boilers, as there were no ineligible boilers in the site data collected.
- **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. The DNV team used this method to assess both interior and exterior lighting ISPs. The lighting ISP section of this report contains additional detail on this method.

Figure 3-1. ISP waterfall methodology



We **verified** the findings in this report through inspection of all available construction documents. **Observable** systems are those present in a particular building, while **verified** systems are those for which we could review and confirm specific characteristics of the building or system in the construction documents. The results typically indicate the proportion of the relevant area that was observable and verified for each metric. **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.

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. This approach accounts for the variability of the equipment efficiency observations and the square footage to which they apply. When presenting these results, we also present the percentage of floor space where efficiency details could be verified to account for equipment where details could not be verified. 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. 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.

Terminology

This section provides some guidance on the terminology used in the compliance and ISP discussions throughout the results section.

- **Observable vs. verifiable systems**. This report distinguishes between observable and verifiable systems when discussing results. Observable systems are those which we identified as being present in a particular building in the construction document review, while verifiable systems were those for which we were able to determine efficiency from that review.
- **Program eligibility.** To assess ISP at the equipment level, the DNV team compared observations of the specified equipment with multiple program years (2019 – 2022) based on site permitting date under IECC 2015 for program eligibility requirements. Eligible equipment met program requirements, while ineligible equipment did not meet program requirements.
- **Program Benchmark.** DNV calculated a "Program Benchmark" for equipment impacted by an ISP recommendation for informational purposes. The Program Benchmark for each equipment category is the weighted median percent better than Code required to qualify for the program. To receive incentives, projects must demonstrate an efficiency that is above and beyond Code. This benchmark uses the same analysis procedure we use for ISP to compare the program minimum requirement to Code. This involves estimating the population cumulative distribution function of the metric (minimum program efficiency) and then taking the midpoint of that distribution[7].
- **Compliance levels**. For most measures, the results are shown across several compliance levels. While some measures were assessed as binary (either compliant or non-compliant), the DNV team sought to award partial compliance where possible. This is consistent with prior Code compliance studies. The compliance levels used throughout are defined in Table 3-7.

Table 3-7. Compliance levels used throughout NRNC Study

Compliance level	Definition
Not compliant	No compliance with the Code
Somewhat compliant	Some compliance, but generally compliance result between 0% and 50%
Mostly compliant	Compliance level found to be between 50% and 100%
Fully compliant	Full compliance of 100%. Also includes assessments greater than 100%.
n/v	Not verifiable. These values were observable, but equipment details could not be verified. Example: a boiler is listed on the drawings without an efficiency level provided.
n/a	Not applicable, representing that the measure does not apply. Example: a building that is not slab-on-grade would have "n/a" for slab insulation compliance.

[7] PROC SURVEYMEANS: Quantiles :: SAS/STAT(R) 9.2 User's Guide, Second Edition

3.2.4.3 Weighting and estimation

Since our analysis treated building systems separately, and since plans for some systems at recruited sites were missing or incomplete and had to be excluded from the analysis, DNV calculated separate case weights for each building system (Lighting, HVAC, Envelope) in the final sample based on each project's probability of selection in the stratified random sample described in the sample design section, accounting for revisions in the population of new buildings based on eligibility findings. Building systems were deemed ineligible due to several factors, though primarily this was due to a finding of projects not actually reflecting any new construction, or projects that were not permitted under IECC 2015 – either permitted too early (under the prior Code) or too late (project had not yet filed for permit and was thus not known to the municipality). Those projects that were dropped during recruitment due to the unavailability of building plans, or lack of sufficient detail in the plans, were still considered eligible for the purpose of adjusting the likely population of non-residential new construction in Rhode Island.

Note that in the weight tables Stratum 6 "Participant - > 100,000" is missing. This is because the only complete in that stratum was found to be between 25,000 and 100,000 square feet, and so was post-stratified and collapsed into the smaller size stratum. Similarly, one of the "Non-Participant" – 25,000 – 100,000" sites was found to be greater than 100,000 square feet, and so was moved into the larger size stratum with a smaller weight to avoid the site having too much leverage in the analysis, since the influence a particular site has on the results is based both on its square footage and its analysis weight.[8]

Table 3-8. Lighting weights

Stratum	Original site population	Percent eligible sites	Adjusted site population	Completed sites	Analysis weight
1. Non-Participant - ≤25,000	118	88%	103.70	6	17.28
2. Non-Participant - 25,000-100,000	16	88%	14.00	3	4.67
3. Non-Participant - >100,000	9	100%	9.00	3	3.00
4. Participant - ≤25,000	102	93%	94.44	8	11.81
5. Participant - 25,000-100,000	30	86%	25.86	5	5.17
7. Participant - Large Warehouse	1	100%	1.00	1	1.00

Table 3-9. Envelope weights

Stratum	Original site population	Percent eligible sites	Adjusted site population	Completed sites	Analysis weight
1. Non-Participant - ≤25,000	118	79%	92.97	6	15.49
2. Non-Participant - 25,000-100,000	16	88%	14.00	2	7.00
3. Non-Participant - >100,000	9	75%	6.75	3	2.25
4. Participant - ≤25,000	102	78%	79.33	6	13.22

8 DNV calculated analysis weights as the adjusted site population divided by the number of completed sites. For example, the lighting analysis weight for stratum 1 is 103.70 / 6 = 17.28.

Stratum	Original site population	Percent eligible sites	Adjusted site population	Completed sites	Analysis weight
5. Participant - 25,000-100,000	30	72%	21.71	6	3.62
7. Participant - Large Warehouse	1	100%	1.00	1	1.00

Table 3-10. HVAC weights

Stratum	Original site population	Percent eligible sites	Adjusted site population	Completed sites	Analysis weight
1. Non-Participant - ≤25,000	118	88%	103.70	6	17.28
2. Non-Participant - 25,000-100,000	16	88%	14.00	3	4.67
3. Non-Participant - >100,000	9	100%	9.00	3	3.00
4. Participant - ≤25,000	102	85%	86.89	6	14.48
5. Participant - 25,000-100,000	30	86%	25.86	5	5.17
7. Participant - Large Warehouse	1	100%	1.00	1	1.00

Weighted ratios, averages, and proportions

Once the case weights were calculated as indicated, the team calculated various parameters of interest as ratio estimators. Most of these ratios were in terms of weighted relevant square footage – that is, weighting each site's observed value by the product of the case weight and the relevant square footage.

$$y_{POP} = \Sigma_j (w_j\ RSF_j\ y_j) / \Sigma_j (w_j\ RSF_j)$$

where,

y_j = value observed for site j
RSF_j = relevant square footage for quantity y at site j

The resulting population estimate y_{POP} represents the average value of y across all relevant square footage in the new construction population.

The relevant square footage depends on the parameter y. For interior lighting, it is all interior floorspace. For HVAC, it is heated or cooled floorspace. For envelope characteristics, it is the wall, roof, or window area.

For many quantities y, it was not possible to assess the value for some sites, or for some potentially relevant square footage within some sites. In such cases, the total relevant square footage may not be known. In these cases, the assessable relevant square footage ARSF is used in its place for both the numerator and denominator in the formula for y_{POP}. With this approach, we do not assume that the portion of space we couldn't assess is the same as what we could assess. Rather, we weight all the space we could assess according to its inverse inclusion probability, which is its site weight w_j. The coverage proportion is also calculated, indicating how much of the population floorspace the calculated parameter represents directly. The coverage proportion is the similarly weighted ratio of total assessable relevant square footage to total relevant square footage.

$$Coverage(y) = \Sigma_j (w_j\ ARSF_j) / \Sigma_j (w_j\ RSF_j)$$

For systems such as heating equipment that might have multiple relevant units at a single site, each unit's observed value was multiplied by the relevant square footage associated with that unit, and by the site case weight.

$$y_{POP} = \Sigma_j \Sigma_u (w_j RSF_{ju} y_{ju}) / \Sigma_j (w_j \Sigma_u RSF_{ju})$$

where,

y_{ju} = value observed for site j, unit u
RSF_{ju} = applicable square footage for quantity y at site j, unit u

The team identified heated and cooled floorspace served by each equipment. Where there was more than one unit of the same type of equipment, the floorspace served was not identified separately by unit. For a parameter that varied across units within an equipment type, relevant floorspace for the equipment type was allocated among individual units in proportion to their output capacity.

Specific parameters estimated for the population included the following:

- Lighting power density (LPD):

  $$LPD_{POP} = \Sigma_j (w_j ARSF_j LPD_j) / \Sigma_j (w_j ARSF_j)$$

  Here, the relevant square footage is the assessed floorspace for the site. In this case, the numerator is total weighted wattage (product of LPD and floorspace) divided by total weighted assessed floorspace.
- Percent better than Code:

  $$P_{POP} = \Sigma (w_j ARSF_j P_j) / \Sigma (w_j ARSF_j)$$

  Where P_j is the percent better than Code for site j.

  For HVAC systems, assessed relevant square footage is the assessed floorspace served by the system.

  For envelope, assessed relevant square footage is the assessed wall, roof, or floor area.
- Proportion of relevant square footage that has a particular feature:

  $$f_{POP} = \Sigma (w_j ARSF_j I_j) / \Sigma (w_j ARSF_j)$$

  Where I_j is a 0/1 dummy indicating that the feature is present. Thus, the numerator totals the weighted assessed relevant square footage for sites or portions of sites with the feature present, while the denominator totals all the weighted assessed relevant square footage.

3.3 Data sources

This section describes the sources of data used in the NRNC Study.

- **Dodge database.** The population frame for this study is the set of NRNC buildings permitted on or after August 1, 2019, through February 2022 when the sample was pulled. To estimate this population, the DNV team purchased a subscription to the Dodge database in Phase 1 and scrubbed the data to develop an estimate of the NRNC building population permitted under IECC 2015. This data scrubbing excluded many projects, such as municipal paving projects and minor renovations, and it can be considered a decent proxy for NRNC activity in Rhode Island. This approach was consistent with prior studies leveraging Dodge data and was presented at the working group sessions. Table 3-11 presents the disposition summary from the Dodge data cleaning.

Table 3-11. Dodge data disposition summary

Disposition	Count of records
Original Dodge export	1,916
Ineligible Scope of Work, Renovations, Project, Construction type	1,303
Interior fit outs	6
Parking, Unconditioned space	32
Apartments/Condos 1-3 stories, 4+ stories, Custom homes, multi-family excluded	63
Not Enough Documentation	236
Total buildings removed	1,640
Remaining buildings (draft sample frame)	**276**

- **Construction documentation**. The DNV team reviewed all documentation received from municipal building departments for the 24 envelopes, 26 lighting and 24 HVAC sites included in the study to assess ISPs and Code compliance. The primary resource received was permit construction drawings for each of the recruited buildings. These drawings typically show details for the building envelope components (architectural and structural drawings), mechanical systems (HVAC or mechanical drawings), and/or electrical systems (electrical drawings). The DNV team requested all supplemental documentation from municipal building departments, including COMcheck[9] reports, sequence of operations and commissioning documentation. Municipal building departments were primarily able to provide the construction drawings but could not often furnish supplemental documentation. Table 3-12 shows the count of sites providing each of the requested construction documents that could be completed for this study and Table 3-13 details the building group each type of site was assigned. Where equipment makes and models were listed on construction drawings, the evaluators used web research to supplement efficiency details and other features where available.

Table 3-12. Construction documentation received for NRNC Study based on stratum targets

Documentation requested	Count of sites providing materials
Mechanical drawings	24
Electrical drawings	26
Architectural drawings	24
COMchecks	1
Sequence of operations	0

9 COMcheck is a software tool developed by the Department of Energy to assess compliance with energy Codes. It is often used by the design and building communities to document compliance, and also by building officials and inspectors to assess building compliance. More information on COMcheck can be found here: https://www.energyCodes.gov/comcheck.

Table 3-13. Building type categorization

Building Type	Building Group
Bank	Commercial
Community Center	Institutional
Dormitory	Commercial
Farm	Other
Fast Food	Commercial
Garage	Commercial
Grocery	Commercial
Horticulture	Other
Hotel	Commercial
Library	Institutional
Maintenance	Commercial
Manufacturing	Other
Mixed Use	Other
Pump Station	Other
Restaurant	Commercial
Retail	Commercial
School	Institutional
Self-Storage	Warehouse
Storage Facility	Warehouse
Theater	Institutional
Warehouse	Warehouse

- **DNV RIE program database**. The DNV team used information received from RIE to identify recruited sites that participated in energy efficiency programs. DNV received lighting and HVAC participation details, but HVAC participation was high level and didn't include what HVAC equipment was part of the program. The data analytics team compared the site names and addresses to the RIE-provided spreadsheets to identify matches. As a follow-up activity, the DNV team asked RIE and account manager leads to verify the program participant identification to ensure that the study captured participation data to the extent possible.

4 ANALYSIS AND RESULTS

This section presents the results from the NRNC Study, organized by building systems: envelope, mechanical systems (HVAC), and electrical systems (lighting). All results included in this section are presented at 90% confidence unless otherwise noted. For the selected measures within each building system, the DNV team assessed both Code compliance and ISPs, defined as follows:

- **Code compliance results.** For each measure selected for the study, the evaluators calculated individual site compliance results and then weighted them by site square footage to estimate the percentage of NRNC square footage in Rhode Island that is compliant with the Code. Note that this is a deviation from past Code compliance studies that assessed compliance at the building level for each measure. This NRNC Study does not assess building-level compliance, it only assesses compliance for the select measures examined.
- **ISP results.** The ISP analysis provides insights into the NRNC market by reviewing building practice observations to highlight where results support standard practices that may be at, above, or below Code. These efficiency results were averaged across the assessed systems and then weighted by floorspace to present an average efficiency for each system applicable to the NRNC population.

4.1 Site recruitment results

The DNV team recruited from 18 municipalities to participate in the NRNC Study and reviewed documentation from 33 separate sites to gather system detail for envelope at 24 sites, lighting at 26 sites, and HVAC at 24 sites. We were unable to gather full documentation from all 33 sites due to incomplete or missing plans. We received documentation for several other sites, but those sites were dropped from the sample because the site was found not to be new construction, to be the wrong Code year, or to lack sufficient information across all systems.

Table 4-1 shows the distribution of sites across the sampling strata.

Table 4-1. NRNC recruitment results by building stratum

Building stratum	Target site reviews	Recruited Sample Frame Sq Ft	Percent of Sample Frame Sq Ft	Count of envelopes reviewed	Count of lighting reviewed	Count of HVAC reviewed
1. Nonparticipant - ≤25,000	6	103,604	13%	6	6	6
2. Nonparticipant - 25,000-100,000	7	323,974	40%	2	3	3
3. Nonparticipant - >100,000	6	352,242	16%	3	3	3
4. Participant - ≤25,000	6	84,668	12%	5	6	6
5. Participant - 25,000-100,000	6	327,763	23%	6	6	4
6. Participant - >100,000	1	114,000	100%	1	1	1
7. Participant - Large Warehouse	1	3,864,972	100%	1	1	1

4.1.1 Program participation summary

The DNV team examined the program participation data to identify which of the recruited sites participated in RIE programs. Generally, the participation assessment was categorical; for example, for lighting, the RIE data indicated whether a site received midstream lighting incentives, but it did not specify an inventory of incentivized fixtures or controls. Similarly for HVAC, participation information indicated if a site was a midstream HVAC participant but didn't include what HVAC equipment was incentivized. No participation information was given for envelope measures that would typically come through as comprehensive design approach (CDA) projects. Given this data, each site was initially evaluated for program participation for each of the three primary categories of the energy Code: envelope, mechanical, and lighting. For mechanical and lighting, if a site received any incentive for any measure within the category, it was considered a participant for that entire Code area. The assumption is that since the site received some incentive for the category, their decisions reflect a more informed perspective than a site that did not receive any incentives. For participants in mechanical equipment programs, the refinements of the ISP approach to assess ISP by equipment necessitated an assessment of participation at the equipment level. Specific participation details with regards to individual mechanical systems (e.g., boilers, AC) were not available for this study. Therefore, participation metric ISPs could not be generated.

To cross-reference RIE data, the DNV team sent RIE the list of sites for confirmation of participation. This exercise identified additional participants, both for prior years and as active participants, but due to limitations in the participation data, DNV was not able to identify which specific HVAC systems went through RIE programs.

Individual sites can be deemed participants in multiple categories. Table 4-2Table 4-2 shows the participation counts by Code category; the overall total reflects the total number of unique sites participating in at least one category, not the sum of the individual categories.

Table 4-2. NRNC Study program participation by energy Code category

Code category	Participants	Nonparticipants
Envelope	0	24
HVAC	6	18
Lighting	14	12
Overall number of sites participating in at least one program	**20**	

4.2 Building envelope

This section presents the results of building envelope measure compliance and ISP analysis.

4.2.1 Envelope compliance

Table 4-3 displays the primary envelope provisions investigated during the NRNC Study. The information needed to verify compliance was not available for some of the sites. The table shows the number of sites for which compliance could be verified, and the estimated percent of relevant NRNC square footage represented. The discussion below highlights compliance for each of these provisions with additional figures showing the compliance results with upper and lower 90% confidence bounds.

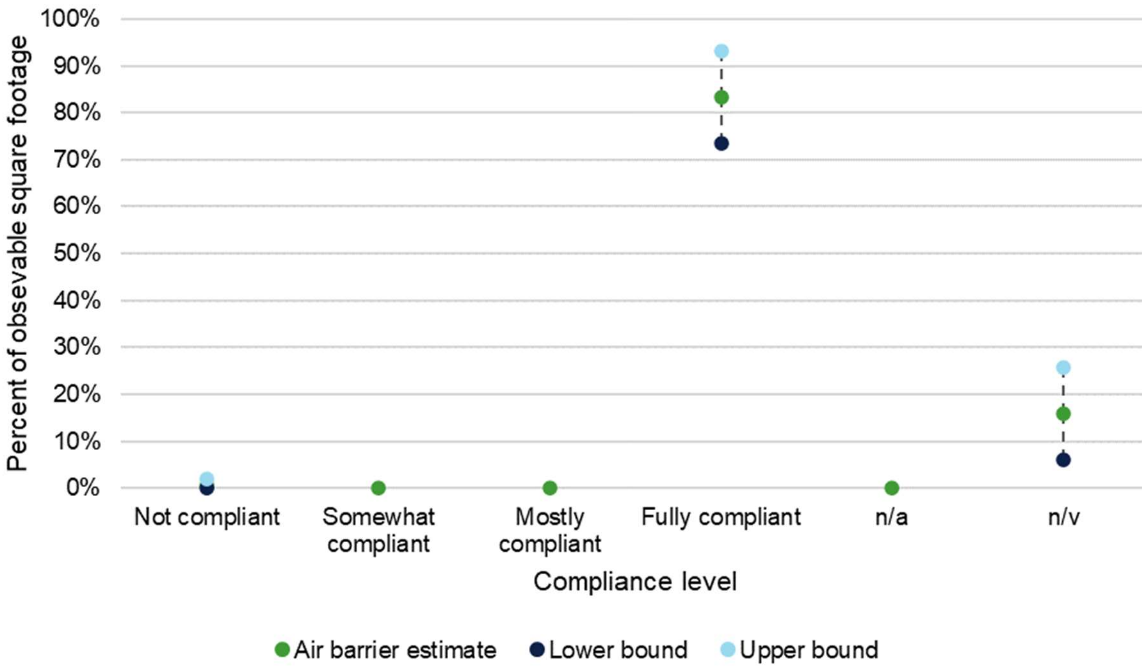
Table 4-3. Envelope measures summary

Code measure description	Number of sites verifiable	Estimated percentage of NRNC square footage represented (weighted to population)
Continuous air barrier	17	84%
Slab edge insulation R-value	24	100%
Slab edge thermal break	24	100%
Roof insulation	24	100%
Above-grade wall insulation	24	100%
Windows	4	8%

This table suggests the following observations about specific prescriptive building envelope practices:

- **Continuous air barrier.** The air barrier was added to the RI State Energy Conservation Code in the 11th edition, effective in July 2010. This measure was well documented in 70% of the sites, with about 83% of floorspace assessed as fully compliant. One percent of sites were found to be not compliant, and the rest did not provide sufficient documentation to assess the air barrier. This finding suggests that this requirement is well understood by the design community. The DNV team did not conduct any field verification of air barriers or any components, so the result here reflects the presence of air barrier documentation on the construction documents. Poor quality installation and the failure to seal penetrations and gaps in the air barrier such that it is not fully continuous would likely have significant impacts on air barrier performance; this assessment is out of scope of this study. Figure 4-1 shows the air barrier compliance results weighted to the population.

Figure 4-1. Air barrier mean compliance results



- **Slab insulation and thermal break.** Slab insulation levels met Code requirements and were fully compliant in nearly all reviewed envelope sites. However, the Code also requires the establishment of a thermal break between the slab and the exterior. DNV found that a substantial number of sites were not compliant with the thermal break requirement; weighted to the population, 65% of the square footage was not compliant. While all buildings had slab insulation, it often did not extend to the top of the slab – as required by the Code – to achieve thermal break and most commonly was located under the slab and along the footing. This is an opportunity for designer and/or builder education and training to improve building design and construction such that thermal breaks are established in alignment with the Code requirement. Compliance was assessed separately for each of these measures, as shown in Figure 4-2 and Figure 4-3, respectively.

Figure 4-2. Slab insulation weighted mean compliance results

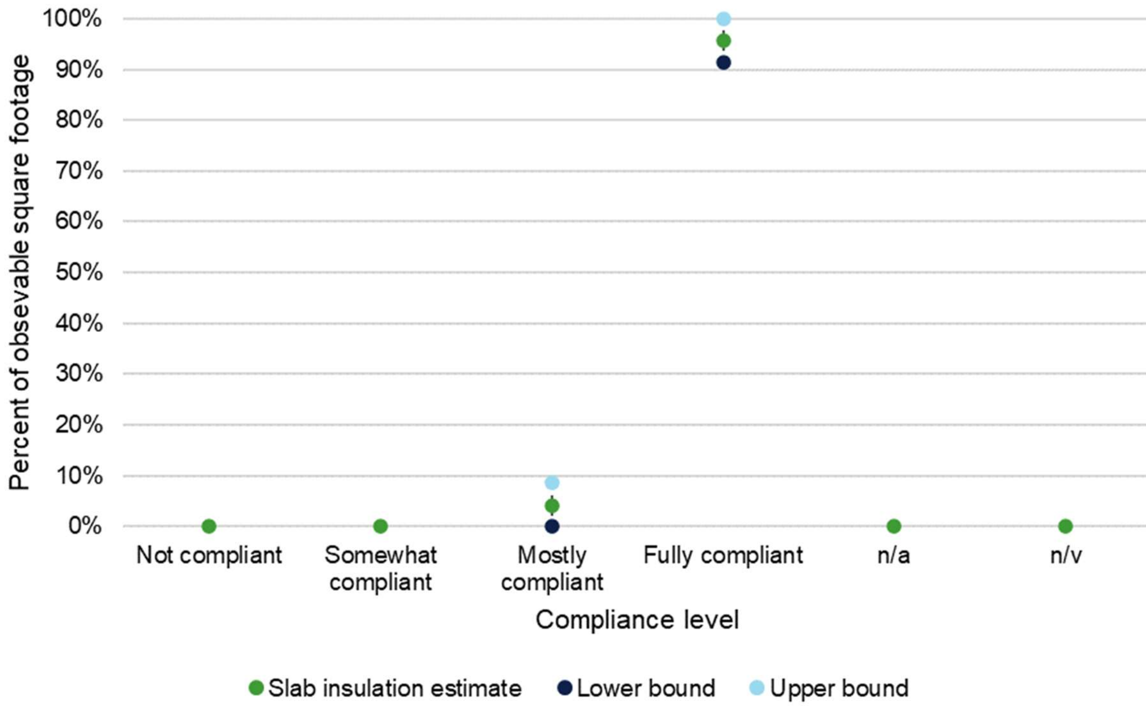
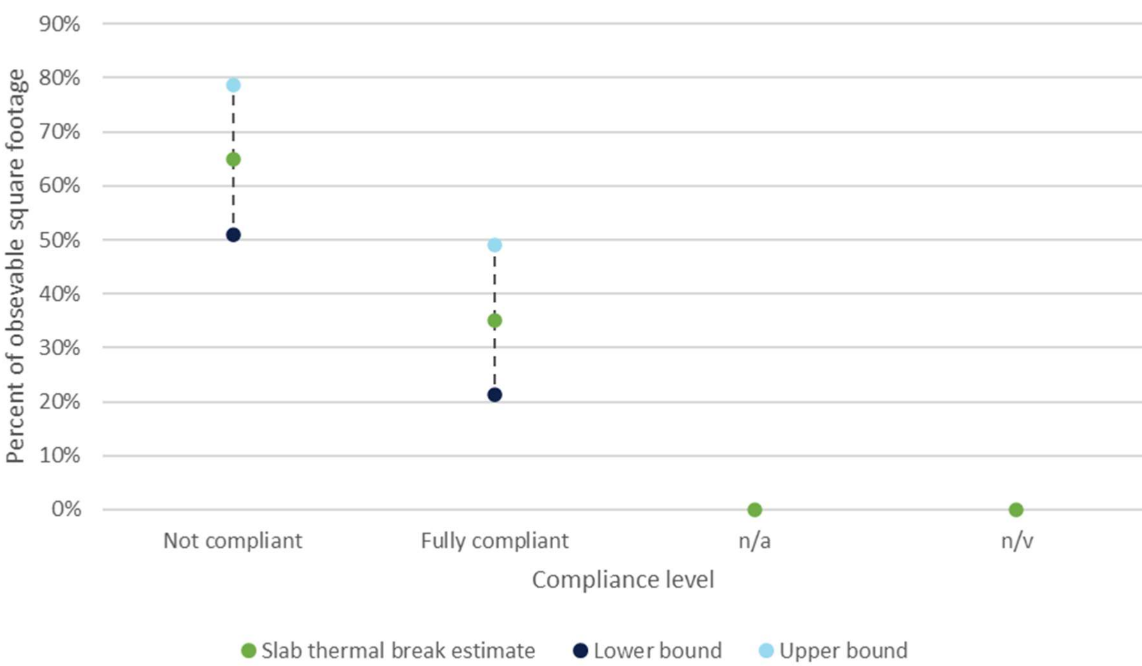
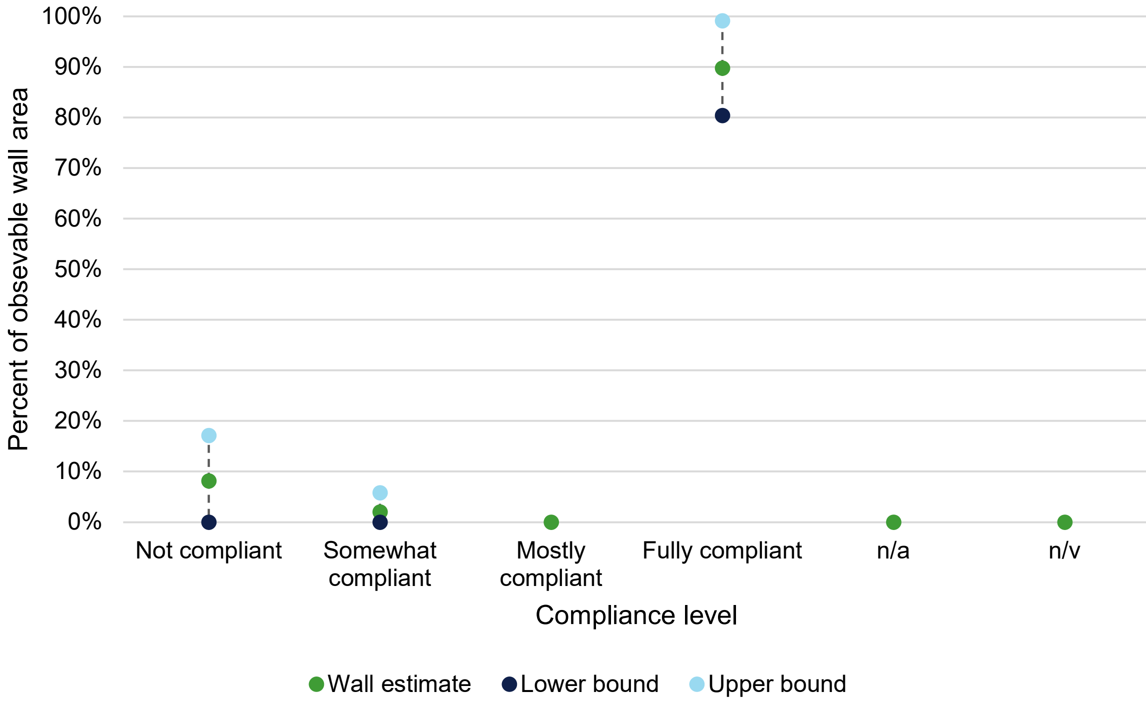


Figure 4-3. Slab thermal break weighted compliance results



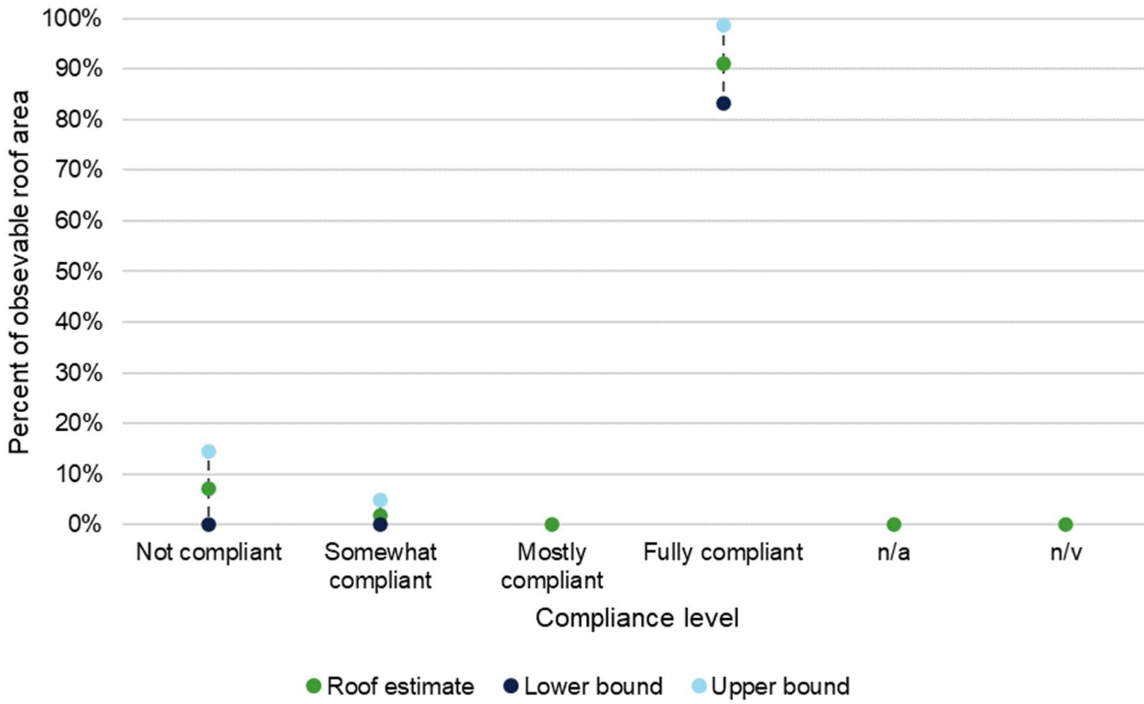
- **Above-grade walls.** The DNV team captured insulation details for each wall assembly documented on the construction drawings to assess compliance with the energy Code. While some individual wall assemblies did not meet Code requirements, when weighted to the population, approximately 90% of observable wall area was found to be fully compliant with Code.

Figure 4-4. Above-grade wall compliance



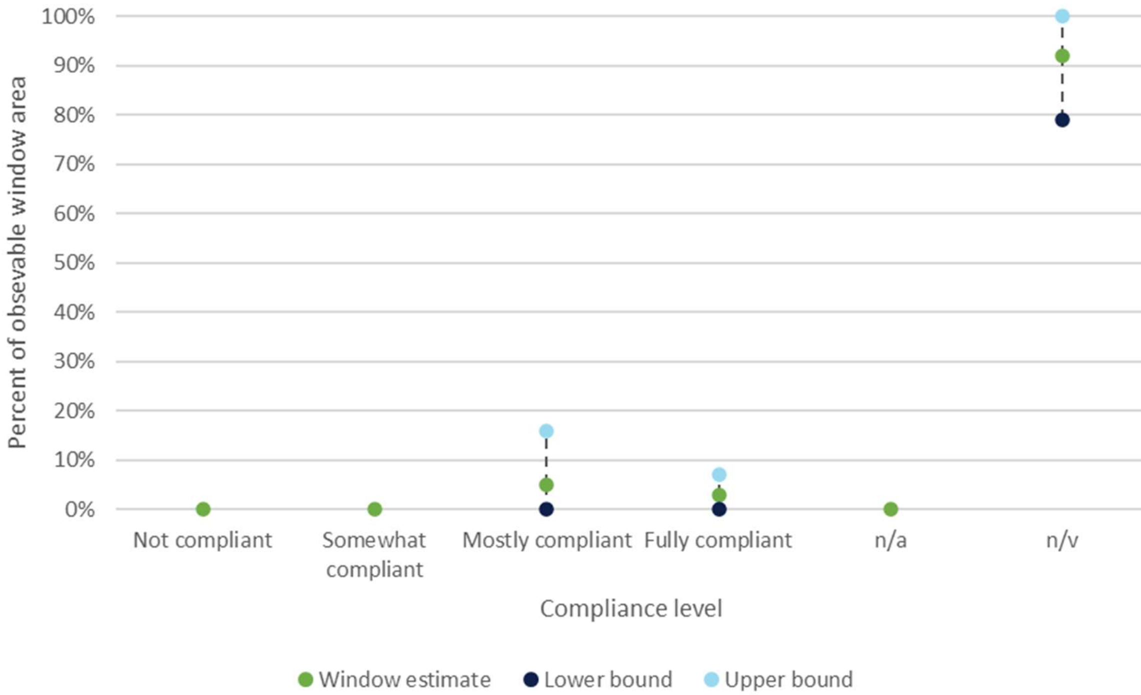
- **Roofs.** Roof insulation was well-documented on construction drawings and most observable sites were fully compliant with the Code requirements regardless of roof type. When weighted to the population, an estimated 91% of observable roof area was fully compliant with Code, 7% non-compliant, and 2% somewhat compliant reflected in Figure 4-5.

Figure 4-5. Roof compliance



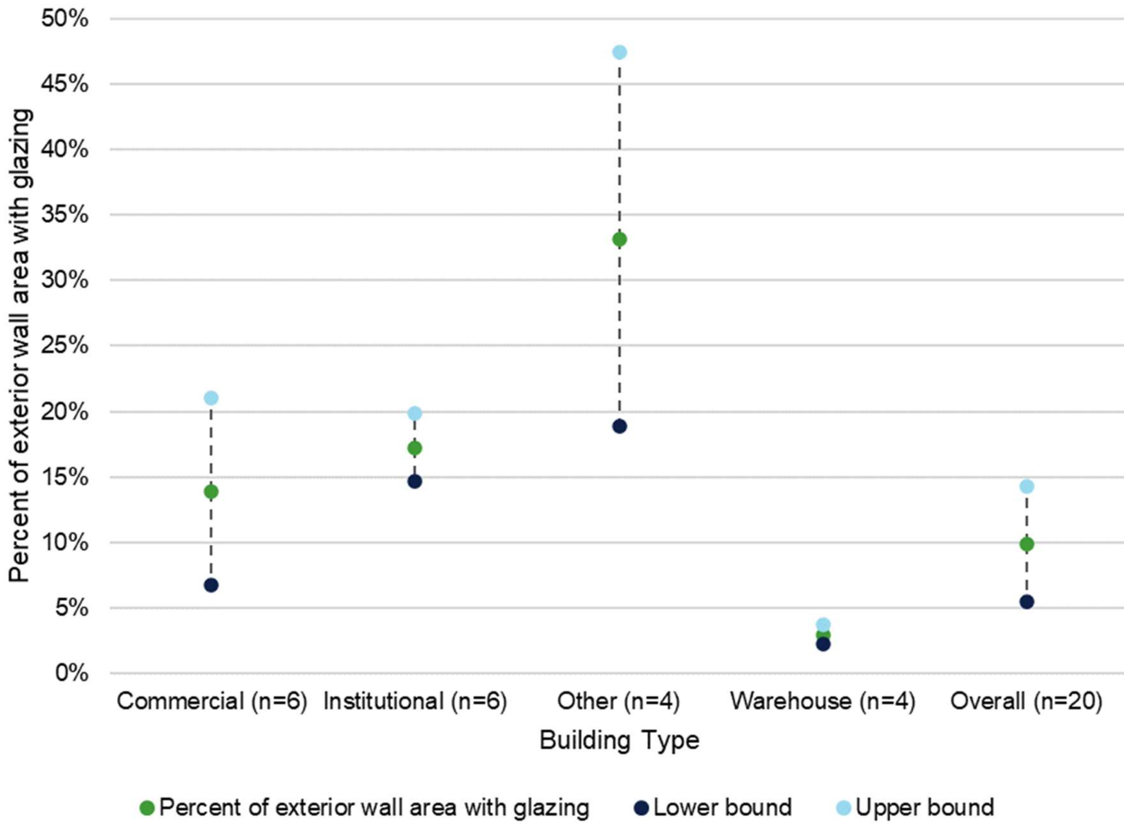
- **Windows.** Figure 4-6 presents the compliance results for windows. Out of the 24 envelope sites, four buildings did not have any windows (most likely additions), and of the remaining 20, only four supplied sufficient information to assess compliance with the window u-factor requirements. Weighted to the population, 3% of window area was fully compliant, 5% mostly compliant, while 92% of window area could not be verified. The lack of window details does not permit any conclusions to be made regarding window compliance for this study.

Figure 4-6. Window compliance



- **Window glazing.** Figure 4-7 presents the glazing percentage by building type for windows. Overall, 20 of the 24 sites had measurable window glazing area representing 97% of exterior wall area when weighted to the population.

Figure 4-7. Glazing by building type

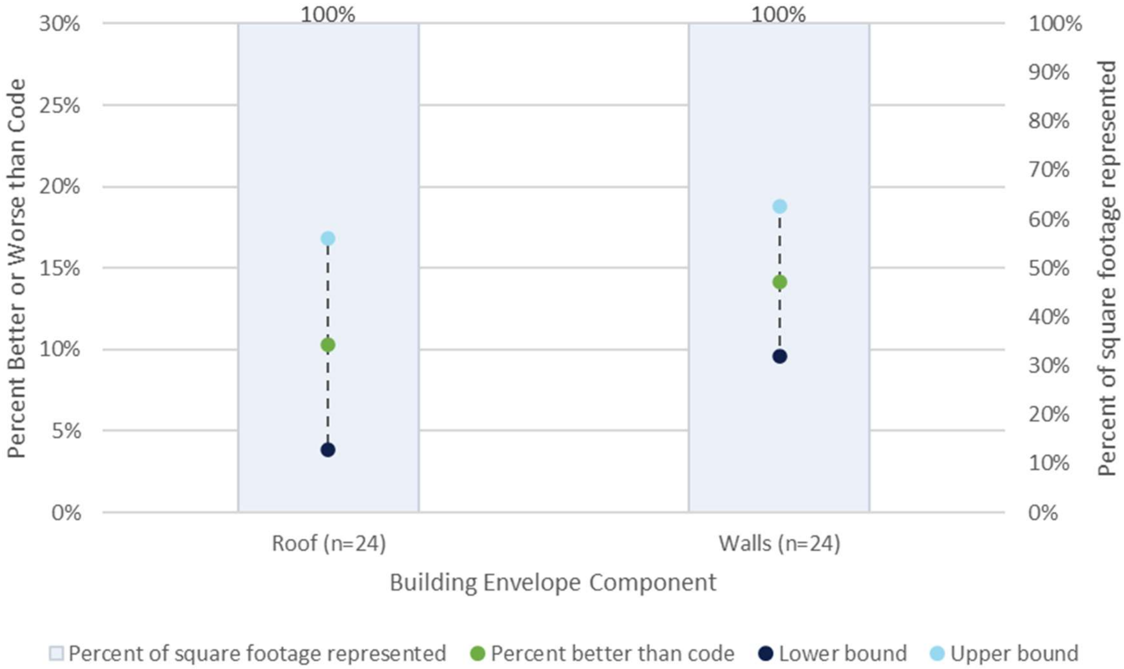


4.2.2 Envelope equipment characterizations and ISP insights

The building envelope data captured during the NRNC Study enables some insights into baseline practices in Rhode Island, as discussed below.

- Envelope components mean observations. The details gathered for roof and wall insulation enable comparisons of installed practices to Code. Figure 4-8 presents the percent better than Code along with the 90% confidence bounds for the two envelope components. The secondary axis shows the percent of square footage represented for each component. This analysis suggests that both roof (10% better) and wall (14% better) insulation are on average better than Code. Note that windows are not included here since the DNV team could not verify window u-factors for the majority of the sites. Window details are not as well documented on construction drawings as walls and roofs.

Figure 4-8. Building envelope mean observations relative to Code



- **Envelope ISP results.** In addition to reporting the mean observations for these envelope components, the DNV team applied the ISP approach (see Section 3.2.4.2) to the envelope data. There is no prescriptive RIE program for building envelope components. Envelope participation is typically captured in CDA programs for which DNV did not receive program information. Thus, assessment of program eligibility is not possible. Table 4-4 shows the nonparticipant ISP metric for wall and roof insulation. These results have median values slightly better than Code for roof insulation and 14% better than Code for wall insulation. However, the bounds at 90% confidence show worse than Code for roofs, suggesting that roof design may be above or below Code. It is also worth noting that project design teams have flexibility to trade off insulation amounts within the envelope components, so projects may purposely choose worse-than-Code elements for one component and make up any differences in the others; these are commonly detailed on COMcheck reports. Based on this analysis, the DNV team recommends an ISP of 14% better than Code for wall insulation, but no changes to Code levels for roof insulation.

Table 4-4. Median nonparticipant ISP metrics for envelope insulation

Results	Number of sites	Median % better/worse than Code	Bounds @ 90% confidence level
Roof nonparticipants	24	1%	-12% / 15%
Wall nonparticipants	24	14%	3% / 24%

4.3 Mechanical systems (HVAC)

This section presents the results of the mechanical systems measure compliance, further characterization of equipment, and a final section on ISP analysis.

4.3.1 Mechanical system compliance

This section presents the compliance results for mechanical systems, separated into heating and cooling technologies. The approach for the NRNC Study is consistent with prior studies in that site engineers recorded the specified efficiency for each individual piece of mechanical equipment where observable and compared it to the Code efficiency requirement.

Compliance is a binary value indicating whether equipment meets Code requirements or not, although a partial compliance is reported in those cases where some but not all Code requirements could be verified. The efficiency metric of percent better or worse than Code is related, but not the same, and is presented in the equipment characterization section of this report.

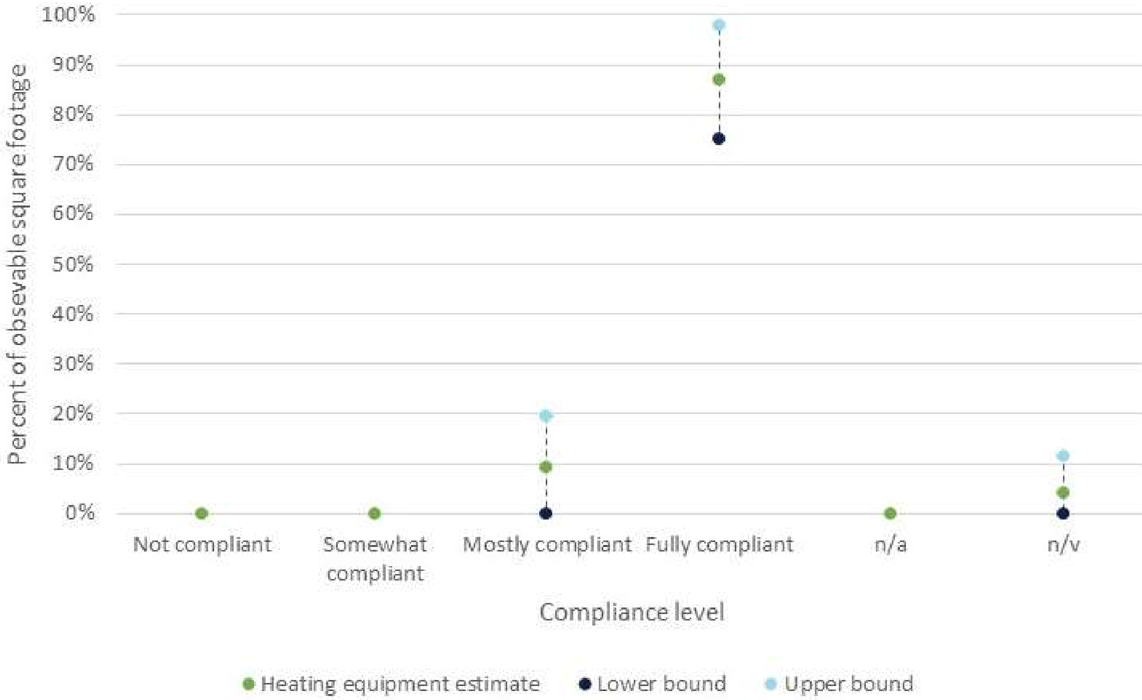
Since this NRNC Study is more focused on understanding NRNC building practices, the DNV team aggregated compliance separately for heating and cooling equipment. This provides context on compliance, supported by subsequent discussion on the distribution of equipment types for heating and cooling NRNC spaces in Rhode Island and their documented efficiencies that are better or worse than Code (detailed in the subsections below). Systems that provide both heating and cooling (e.g., heat pumps) are included in both categories, focusing on the heating and cooling efficiencies appropriately.

In the compliance graphs, each individual piece of equipment can be either compliant or not compliant with Code efficiency levels. However, the figure also includes “verifiable” for partial compliance, reflecting instances where some but not all efficiencies within a given equipment type were known. For example, a site may have four boilers in the drawings but only provide efficiency details for three. In this example, the boiler with missing efficiency was included in the analysis but not assessed as compliant, resulting in a partial compliance value when weighted.

4.3.1.1 Heating equipment compliance

Figure 4-9 shows the percentage of observable NRNC square footage by compliance level for heating equipment. Approximately 87% of square footage was fully compliant and another 9% was mostly compliant with the energy Code. Four percent of square footage could not be verified, due primarily to the lack of documentation of system details and efficiencies on construction drawings for heat pumps. Although this area was non-verifiable, it was rare that heating systems specified with enough detail in the drawings did not meet Code. In many cases, site engineers could identify the equipment types but could not determine efficiency levels and thus could not compare them to Code. This was consistent with findings from prior Code compliance studies.

Figure 4-9. Overall heating equipment efficiency compliance



The DNV team also analyzed compliance for each individual equipment type (e.g., boilers, warm air furnaces) in Table 4-5. In total, nine boilers, 64 heat pump and 37 warm air furnace (1 unit furnace) systems were observed. These systems make up 399 individual pieces of heating equipment observed. Since not all types of systems are present at each site, the mechanical systems ISP section highlights individual observations relative to Code for the equipment types with the most data.

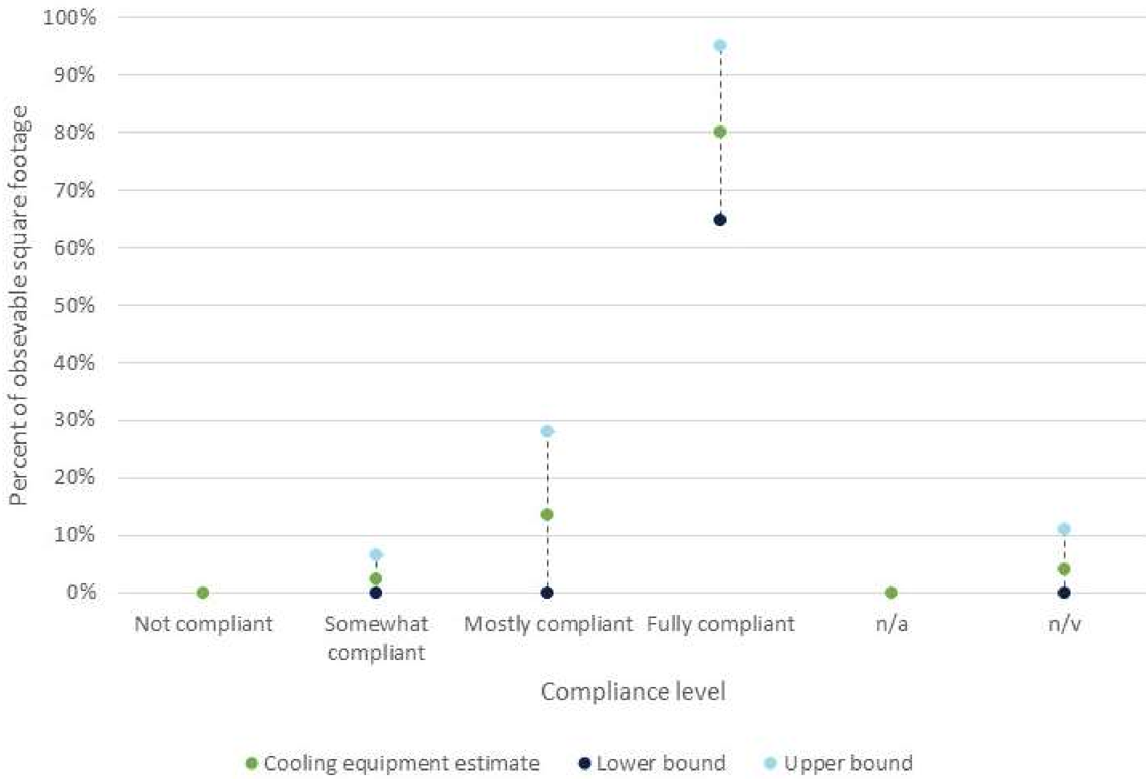
Table 4-5. Individual heating equipment compliance

Compliance	Heating equipment type			
	Boilers (n=9)	Heat pumps (n=64)	Warm air furnaces (n=37)	Warm air unit furnaces (n=1)
Fully compliant	100.0%	65.6%	92.6%	100.0%
Mostly compliant	-	17.5%	7.4%	-
Somewhat compliant	-	-	-	-
Not compliant	-	-	-	-
n/v	-	16.9%	-	-
n/a	-	-	-	-

4.3.1.2 Cooling equipment compliance

Figure 4-10 shows the percentage of observable NRNC square footage by compliance level for cooling equipment. Of the sites DNV collected data on, 80% of cooled NRNC square footage is compliant with the Code. An additional 14% was mostly compliant, 2% somewhat compliant and 4% non-verifiable. Like heating systems, it was rare that individual cooling equipment did not meet Code required efficiency levels.

Figure 4-10. Overall cooling equipment efficiency compliance



Individual cooling equipment type compliance (e.g., air conditioning, heat pumps) is provided in Table 4-6. In total, 58 air conditioning units (DX), 64 heat pumps, two PTACs and one chiller system were observed. These systems make up 526 individual pieces of cooling equipment observed. Since not all types of systems are present at each site, the mechanical systems ISP section highlights individual observations relative to Code for the equipment types with the most data.

Table 4-6. Individual cooling equipment compliance

	Equipment type			
Compliance	Air conditioning (n=58)	Heat pumps (n=64)	PTAC (n=2)	Water chilling packages (n=1)
Fully compliant	82.0%	70.1%	100.0%	100.0%
Mostly compliant	14.6%	13.1%	-	-
Somewhat compliant	3.4%	-	-	-
Not compliant	-	-	-	-
n/v	-	16.7%	-	-
n/a	-	-	-	-

4.3.2 Mechanical heating system equipment characterization

The following section presents observations and findings by system type. The DNV team verified heating equipment type for about 94% of the building validated space. As can be seen in Figure 4-11, 64% of the space is heated by warm air furnaces, 23% by air-source heat pumps and 7% with boiler systems. Another 6% of heating systems were unknown because of lack of details on plans from non-typical gas heating equipment like infrared heaters, or unconditioned space. DNV observed mostly furnaces by square footage because a furnace is a typical heat source for packaged units including rooftop units, makeup air units, and standalone heaters. DNV collected information on 37 warm air furnaces, one warm air unit furnace, 64 air-source heat pumps, and nine hot water boiler systems. Overall, heating information was observed on 111 systems, making up 399 individual pieces of equipment that had over 4.8 million square feet of heating from 24 sites. This is unweighted.

Figure 4-11. Floor space served by observed heating systems

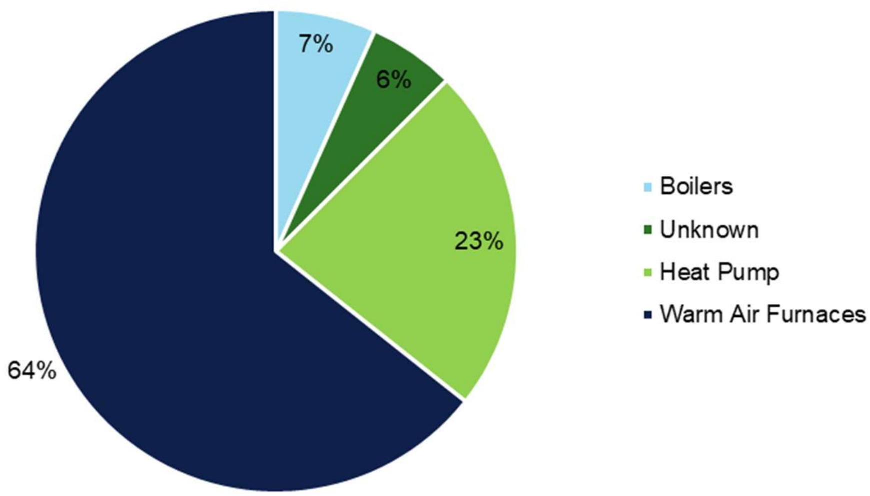


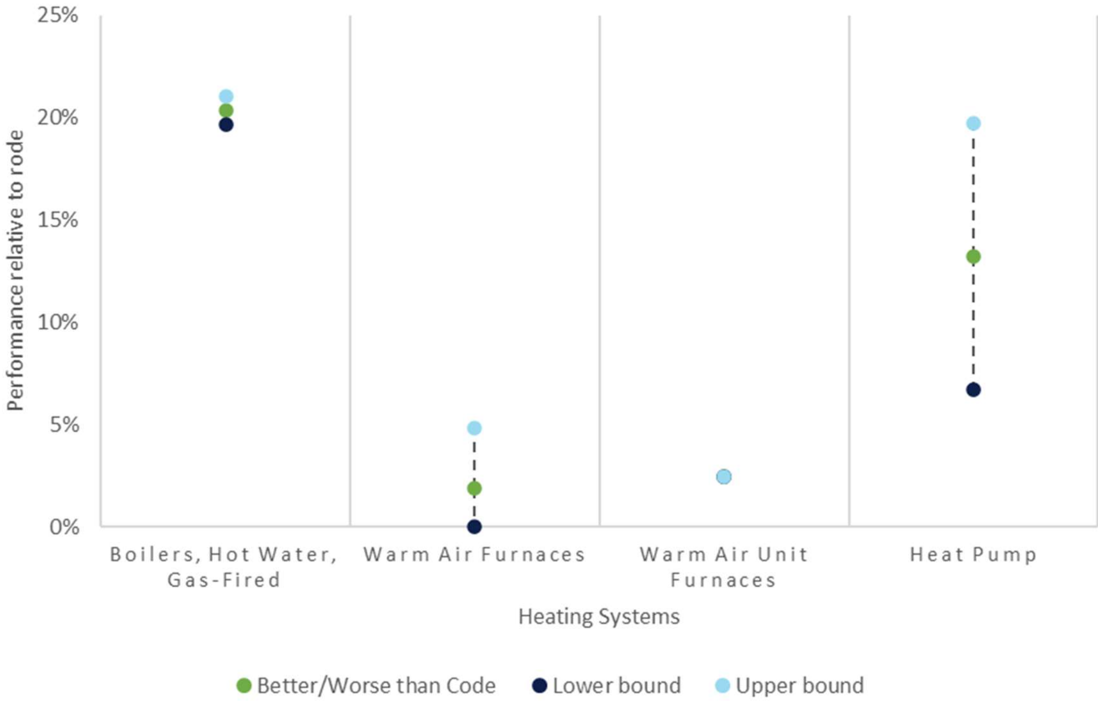
Table 4-7 defines the kinds of typical heating systems observed in NRNC studies. The DNV team verified mostly warm air furnaces in terms of SF on plans, with instances of boilers and heat pumps.

Table 4-7. Heating system definitions

Term	Definition
Warm air furnace	Indirect- or direct-fired furnace supplying heated warm air 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 duct furnace	A furnace normally installed in distribution ducts of air-conditioning systems to supply warm air. Usually does not have its own supply fan and uses air supplied through the ducts by other supply fans such as a fan for a central 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 not 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.
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.
Electric resistance	Any equipment that uses electric resistance coils as the primary heat source instead of another energy source such as gas-fired, hot water, or steam. Configurations found in this study primarily include electric unit heaters.
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.
Unknown	Unheated or indeterminate equipment

The details gathered for heating systems enable comparisons of installed practices to Code. Figure 4-12 presents each heating system's average percent better than Code result with its 90% confidence bounds. The percentage better than Code is a function of the ratio of the specified efficiency divided by the Code specified minimum efficiency. DNV notes that the number of systems observed where the efficiencies of those systems differed from Code is small. This represents less than 1% of the total heating systems observed.

Figure 4-12. Heating system mean rated efficiency relative to Code



Hot water gas-fired boilers on average were 20% better than Code, followed by heat pumps at 13%, warm air unit furnaces at 3% and warm air furnaces at 2%. Hot water boiler performance relative to Code was driven by condensing boilers, that all have an efficiency of 95% or greater. Both hot water boilers and heat pumps had similar upper bounds better than Code at 21% and 20% respectively, but heat pumps had a wider range of performance relative to Code.

Table 4-8 presents similar data in table form with additional details indicating the reliability of the data. In addition to the error bound, the table includes statistics indicating the total number of sites and percent of floorspace served and verified by each equipment type. These findings are further discussed in the following sections.

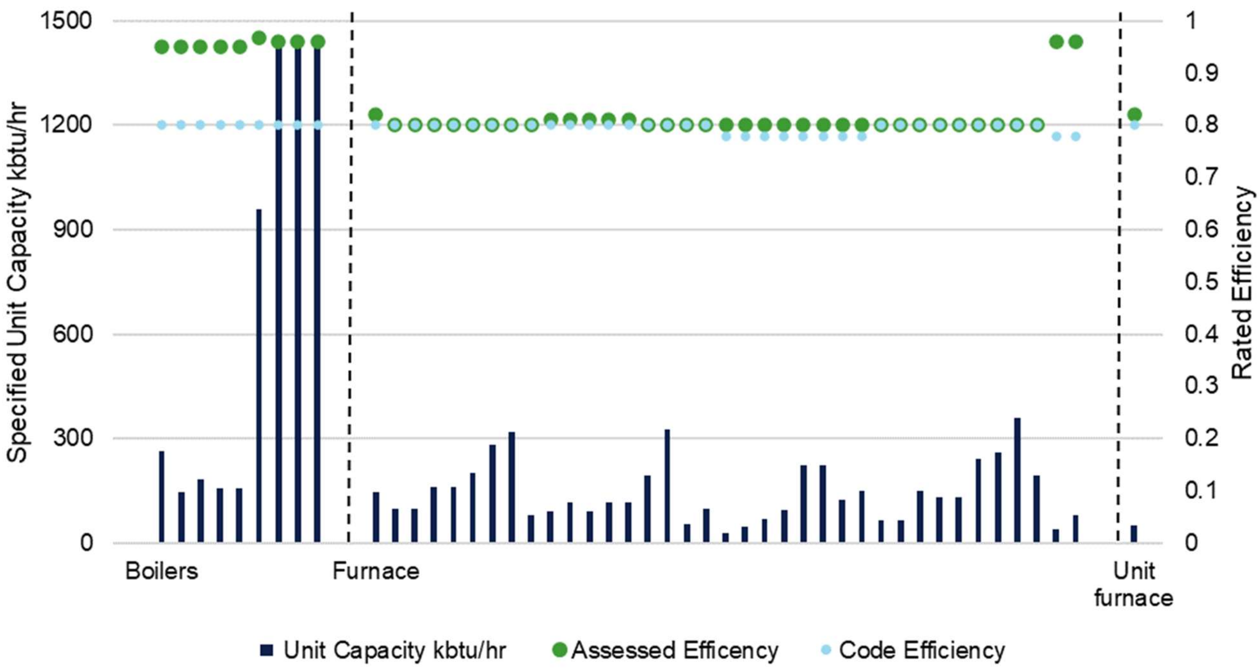
Table 4-8. Summary of heating system observations

Heating system	Mean percent +/- than Code	Better than Code bounds @ 90% confidence level	Percent of heated floor space	Count
Warm air furnaces	2%	0% - 5%	64%	37
Warm air unit furnaces	3%	3% - 3%	0.3%	1
Boilers, hot water	20%	19% - 21%	7%	9
Heat pump	13%	7% - 20%	23%	64

4.3.2.1 Boiler and furnace systems

The Code-specified minimum efficiencies for boilers and furnaces vary by fuel type, equipment type, and boiler/furnace size. Figure 4-13 presents the efficiency specified in construction drawings for gas-fired boilers and furnaces. Figure 4-13 and subsequent efficiency graphs show the specified capacity of the system in kBtu/hour. Each data point represents a unique system configuration at a site, although there may be multiple units installed at a site. The figures are unweighted and do not include unverified sites.

Figure 4-13. Natural gas fired heating specified rated efficiency and capacity



In this sample, all the boilers are condensing. The higher boiler efficiency is achieved by recovering heat from the stack exhaust to allow the gases to condense, thus condensing. Boilers rated efficiency is about 20% better than the Code specified minimum efficiency and the average efficiency specified for hot water boilers was 96%. These observations are based on verified efficiencies from 94% of the floor space served by boilers collected from nine sites.

Furnaces are common in packaged units such as rooftops and makeup air units and usually have lower overall costs, which might explain why almost 63% of the floor space uses furnaces for heating. Furnaces as part of packaged air conditioning units (heating and cooling) represent about 62% of observed square footage, with less than 1% (one unit) being a unitary furnace (heating only). Code and assessed efficiency values for these furnaces are both around 80%, with two instances of furnace efficiencies being as high as 96%. The higher efficiencies are achieved by either a condensing or direct fire design. Direct fire designs put all the heat and the combustion gases into the airstream, increasing efficiency. Direct fire applications can only be used in situations with enough outdoor air to dilute the combustion products. The two cases where furnace efficiency is 96% are for condensing furnaces in a self-storage facility.

The average efficiency for warm air furnaces and the unit furnace, which heat more floorspace than any other system, was found to be on average 81% efficient. Efficiencies could be verified for 100% of the floor space served by these furnaces.

4.3.2.2 Heat pump heating systems

Heat pump heating has minimum efficiency standards that depend on the type of equipment and the size of the unit. Figure 5-14 shows the efficiency rating by heat pump system. All heat pumps observed in the study were air cooled. Unit capacities less than 65,000 Btu/h have their efficiency units listed as heating seasonal performance factor (HSPF). Air cooled variable refrigerant flow (VRF) units with larger capacities have their efficiency expressed as coefficient of performance (COP). The graph also displays the capacity of the system in kBtu/hour. Each point on the graph represents a different system setup at a location, but there may be more than one unit installed at a location. The figures are not weighted.

Figure 4-14. Heat pump heating specified rated efficiency and capacity

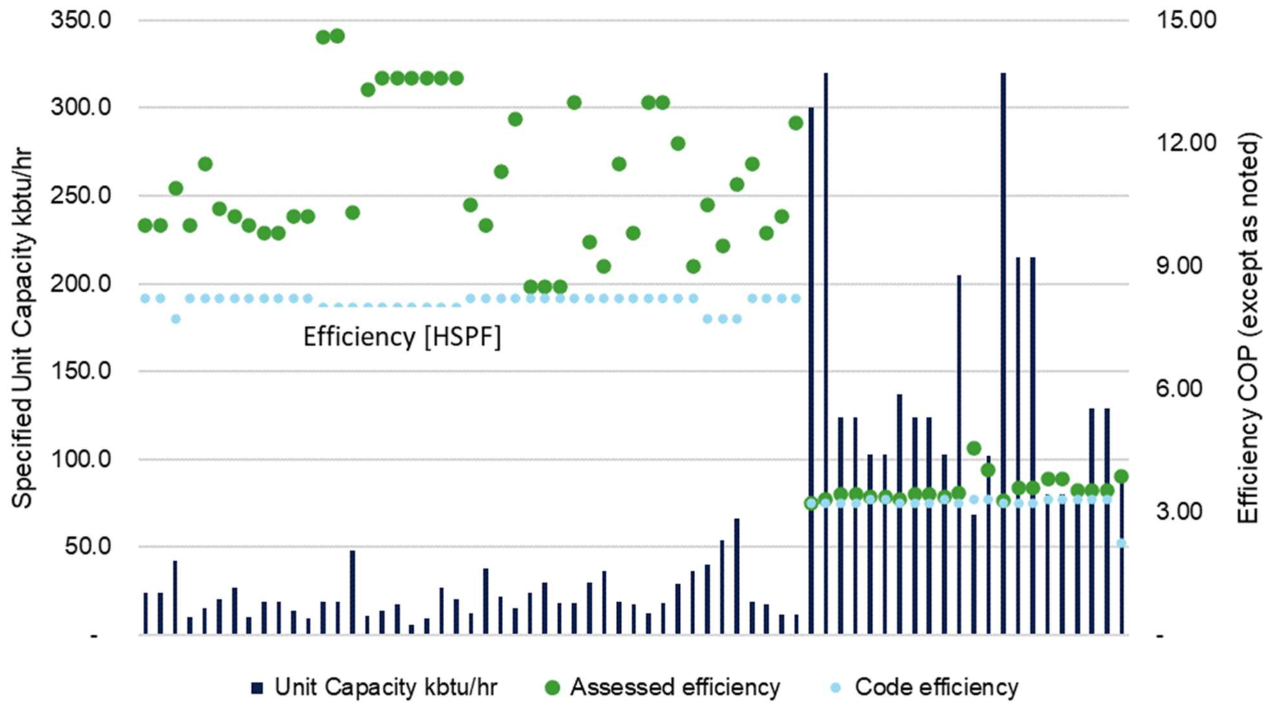


Figure 4-14 presents the heat pump efficiency data by heating capacity. Only air-source heat pumps were observed in the data. In Code, heating efficiency is usually specified as a coefficient of performance or COP. However, air-source heat pumps with a capacity of less than 65,000 kBtU/hr are specified using a Heating Seasonal Performance Factor (HSPF). Regardless of the units of efficiency, heat pumps were specified about 13% better than Code with verified efficiencies representing about 95% of the floor area served by heat pumps for heating. Although not tabulated in these tables, about 25% of the specified heat pumps included a resistance heating stage.

4.3.3 Mechanical cooling system equipment characterizations

The following section presents mechanical cooling observations and findings by system type.

Figure 4-15 presents the weighted percentage of floor area served by system type for NRNC in RI. More than two thirds of the floor space is cooled by traditional direct expansion (DX) cooling systems, which are typically packaged as rooftop units, makeup air units, and split systems where the condenser is not co-located with the compressor. Another 23% of the square footage observed is cooled via heat pumps, with 4% cooled by PTACs. These systems also provide DX cooling, but heat pumps are designed to provide heating by reversing the thermal flows and are typically more efficient. Another 4% of systems were unknown and 1% were chillers.

DNV collected information on 58 air conditioning DX units, 64 heat pumps, two PTACs, and 1 chiller. There were 11 cooling units that were unknown. The DX units represent 46%, air-source heat pumps 51%, PTAC 2%, and chillers less than 1% of cooling systems observed in this study from 24 sites. Overall, cooling information was observed on 136 types of equipment that had over 4.6 million square feet. This is unweighted.

Figure 4-15. Floor space served by cooling systems

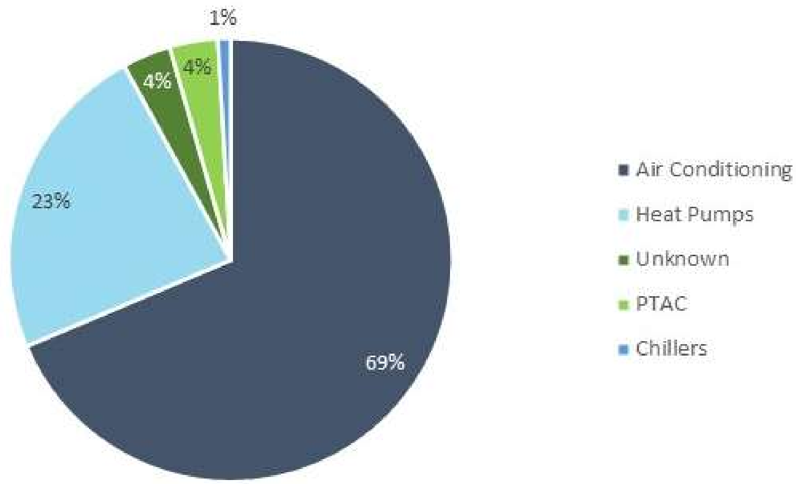


Table 4-9 defines the cooling systems observed.

Table 4-9. Cooling system definitions

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.
Chillers	Water chilling packages include air-cooled, water-cooled, and evaporatively cooled.
Other	Any equipment that did not fit into the listed categories. Includes energy recovery ventilation (ERV) units with economizing, energy wheel, or secondary cooling.
Unknown	Any equipment that could not be classified or verified due to insufficient data.

The details gathered for cooling systems enable comparisons of specified rated efficiencies to Code minimum required efficiencies. Figure 4-16 presents each cooling system's average percent better than Code percentage with its 90% confidence bounds. The percentage better than Code is as a function of the ratio of the specified efficiency divided by the Code specified minimum efficiency.

Figure 4-16. Cooling system mean rated efficiency relative to Code

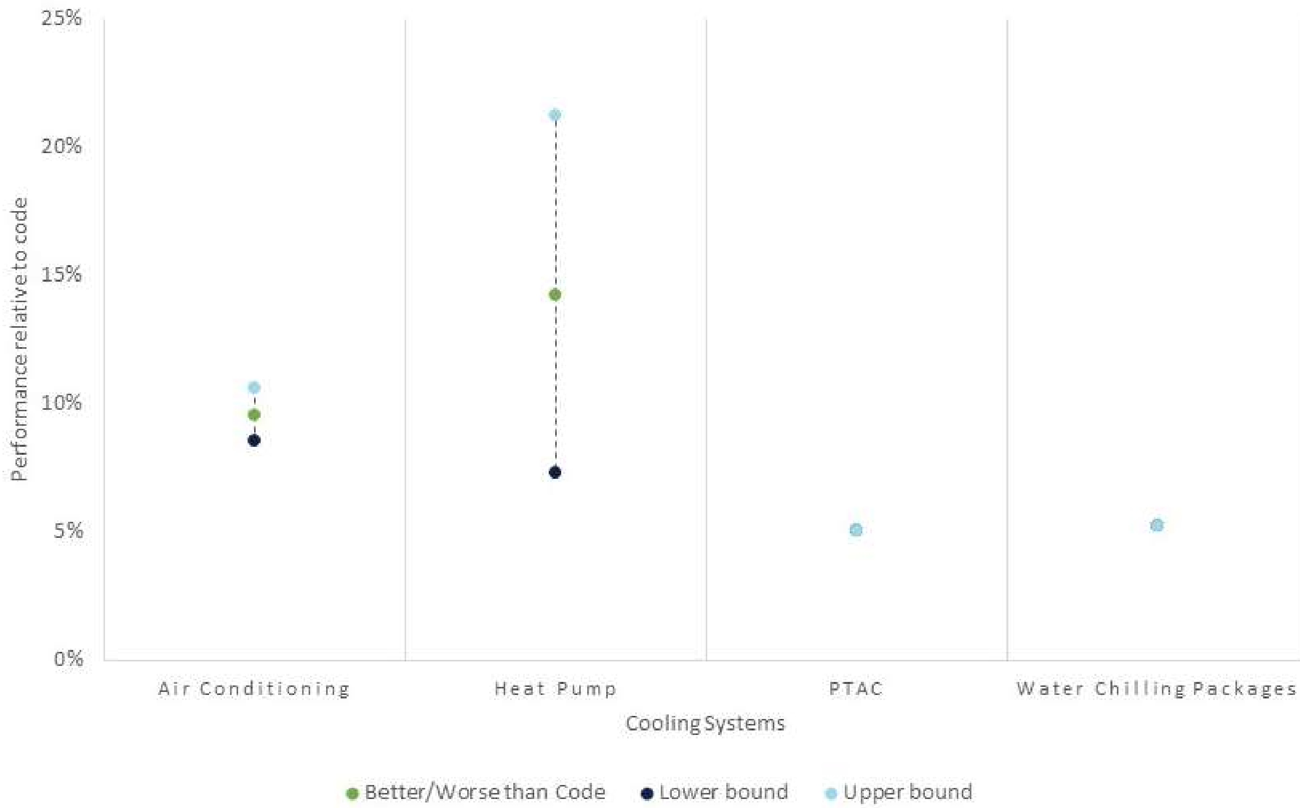


Table 4-10 presents similar data in table form with additional details indicating the reliability of the data. In addition to the error bound, the table includes statistics indicating the number of sites and percent of floorspace served and verified by equipment type.

Table 4-10. Summary of cooling system

Cooling system	Percent +/- than Code	Better than Code bounds @ 90% confidence level	Percent of cooled floor space
Air conditioning	10%	9% - 11%	69%
Heat pump	14%	7% - 21%	23%
PTAC	5%	5% - 5%	4%
Water chilling packages	5%	5% - 5%	1%

4.3.3.1 Cooling systems

Code specified minimum efficiencies for cooling equipment varies by equipment type, heat sink source (air, water, or ground) and equipment size as measured by capacity. The cooling equipment is divided between Figure 4-17, Figure 4-18, and Figure 4-19 to provide reasonable resolution. Each figure presents the efficiency specified in plans by cooling systems. Also shown on the graph is the specified capacity of the system in kBtu/hour. Each data point represents a unique system configuration at a site. Each unique configuration at a site appears as one data point, although there may be multiple units installed at a site.

Figure 4-17 includes chilled water systems (chillers). These units provide cooling for approximately 1% of the observable square footage. The systems in this category are centralized and have the largest capacity for a single unit. There was one instance of a chiller observed in NRNC plans.

Figure 4-17. Cooling systems: chiller efficiency and capacity

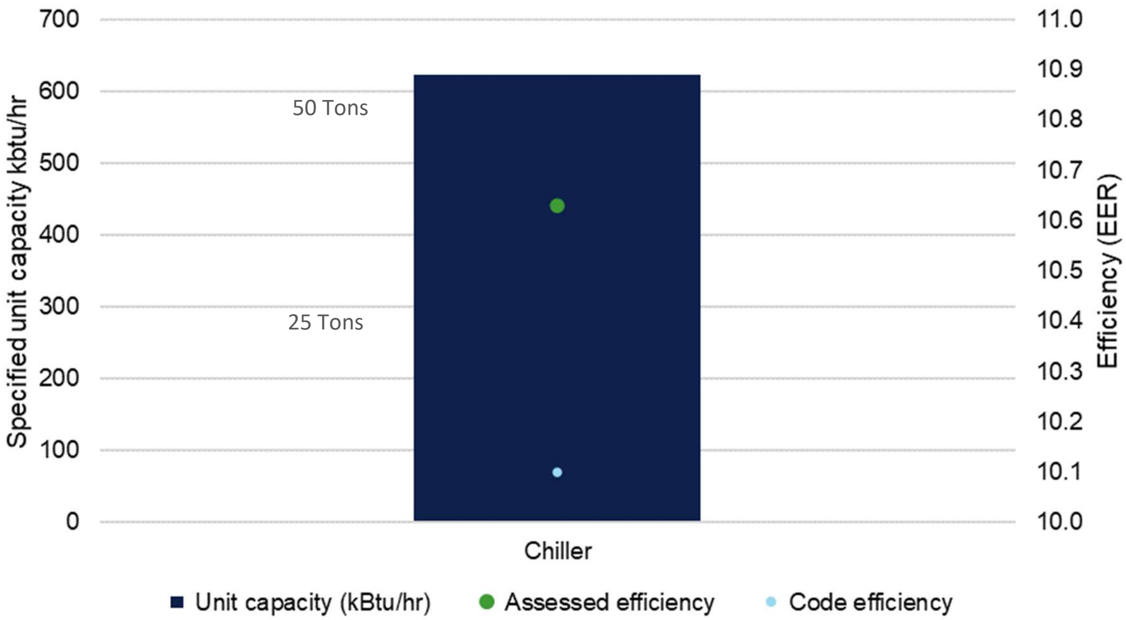


Figure 4-18 presents air-cooled DX air-conditioning and heat pumps that serve 92% of the observable square footage. The systems consist of unitary direct expansion air conditioning units which include packaged and split air-cooled, water-cooled, evaporatively cooled, and through-the-wall unit types. The airstream is cooled via an air-to-refrigerant heat exchanger (commonly called direct expansion or DX) with the heat rejected to atmosphere. As a group, they have the highest efficiency.

Figure 4-18. Cooling systems: air-cooled DX and ASHP efficiency and capacity

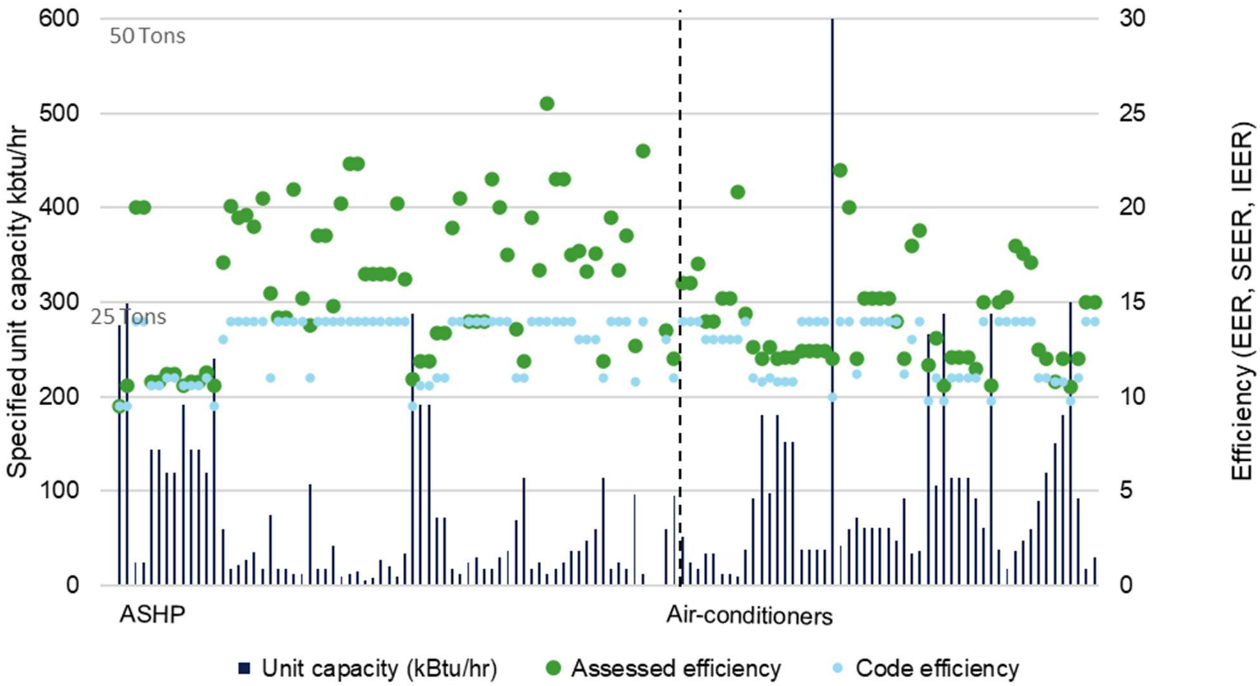
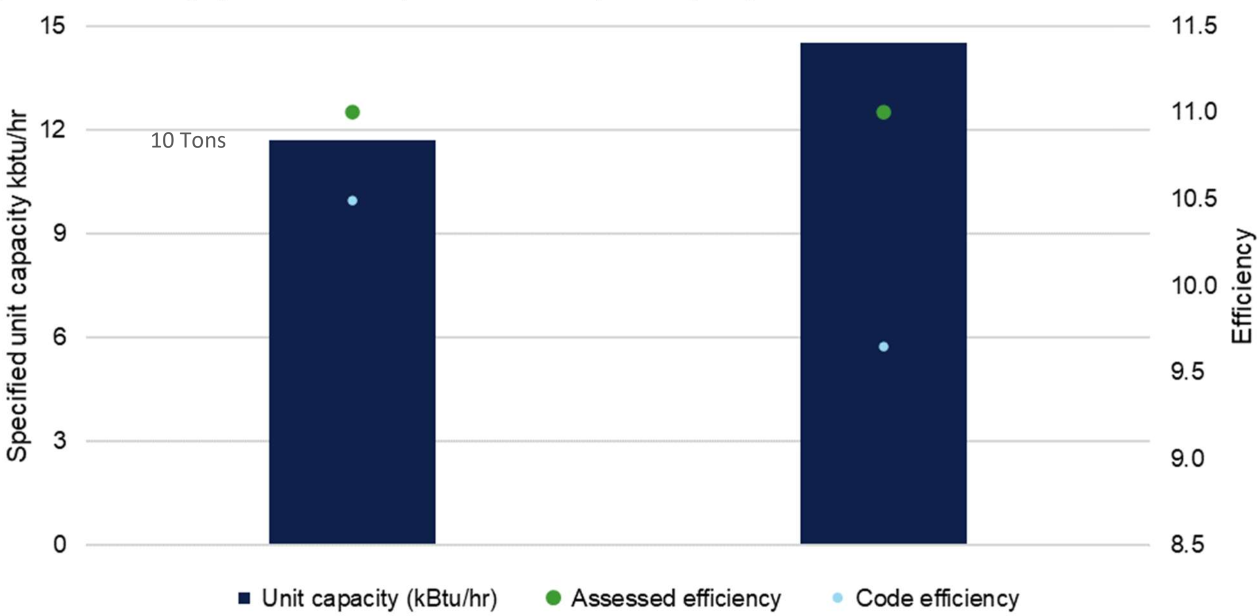


Figure 4-19 includes the two observed PTAC systems observed in NRNC plans. The PTAC show they are well above Code efficiency.

Figure 4-19. Cooling systems: PTAC specified efficiency and capacity



4.3.4 Heating and cooling equipment ISP findings

This section presents recommended ISP efficiency values for select HVAC equipment types where there were sufficient observations to support that finding. The ISP recommended values are expressed as Code adjustment factors. The product of a Code adjustment factor and the Code specified minimum efficiency yields the ISP baseline efficiency for calculating savings. The ISP recommended values are the median better than Code percentages of an equipment category using the most appropriate ISP metric (see Section 3.2.4.2). Table 4-11 summarizes the HVAC mechanical equipment ISP findings for select systems and the Code adjustment factor for those cases where one could be determined.

As noted in Section 3.3, individual system participation (e.g. boilers, heat pump) to determine program participant ISP metrics was not available to DNV. Therefore, all participation information is categorized as unknown.

Table 4-11. HVAC mechanical equipment ISP findings

Equipment type	Recommended Code adjustment factor	Notes
Hot water boilers	1.20	Observed boilers were all condensing, which appears to be standard practice in NC
Warm air furnaces	1.0	ISP is at Code
Warm air duct furnaces	1.0	Not enough information for ISP determination
Heat pumps – heating	1.03	Includes all heat pumps (air-source heat pumps, VRF heat pumps) except for packaged terminal heat pumps.
Air conditioning	1.05	Includes multiple sized systems.
Chillers	1.0	Not enough information for ISP determination
PTAC	1.0	Not enough information for ISP determination

The following sections present the information that support the ISP findings by equipment category. The tables present a by-category accounting of the HVAC equipment observed in the study and the results by ISP metric. The tables include the Program Benchmark, which is the mean percentage better than Code of the program eligible minimum efficiency requirements. The recommended ISP metric is bolded in the tables.

Hot water boilers. Table 4-12 presents the ISP metrics for boilers. The hot water boiler ISP median rated efficiency is 20% better than Code using the Nonparticipant ISP Metric. Hot water boiler participation could not be verified and zero boilers verified were ineligible. Therefore, the participant and ineligible ISP Metric could not be used.

Table 4-12. ISP metric for hot water boilers

Results	Sites	Number of Systems	Units	Median % better/worse than Code	Bounds @ 90% confidence level
TOTAL	4	9	10	N/A	N/A
Ineligible ISP Metric	0	0	0	N/A	N/A
Eligible	4	9	10	20%	N/A
Program benchmark	4	9	10	13%	12.5%/12.5%
Nonparticipant ISP Metric	**4**	**9**	**10**	**20%**	**N/A**
Participants	unknown	unknown	unknown	unknown	unknown
Unverifiable total/partial	0/0	0	0	N/A	N/A

Warm air furnace. Table 4-13 presents the ISP metrics for warm air furnaces. The warm air furnace ISP median rated efficiency is at Code using the ineligible ISP Metric. This is the same for the non-participant ISP metric. Relative to the program benchmark, the median ISP rated efficiency is 19% better than Code. DNV did not observe a furnace standard practice that is better than Code.

Table 4-13. ISP metric for warm air furnaces

Results	Number of Sites	Systems	Units	Median % better/ worse than Code	Bounds @ 90% confidence level
TOTAL	12	37	176	N/A	N/A
Ineligible ISP Metric	**11**	**35**	**145**	**0%**	**N/A**
Eligible	1	2	31	23%	23%/23%
Program benchmark	12	37	176	19%	19%/19%
Nonparticipant ISP Metric	9	20	56	0%	0%/0%
Participants	unknown	unknown	unknown	unknown	unknown
Unverifiable total/partial	0/0	0	0	N/A	N/A

Warm air unit furnaces. Table 4-14 presents the ISP metrics for warm air duct furnaces. Two units from one site were observed to have a warm air unit furnace. These units have a median ISP of 2.5% above Code compared to the program benchmark, but there are not enough units to determine an eligible or ineligible ISP metric. There is one site that had two observable warm air unit furnaces so there is not enough information to conclude an ISP metric. As discussed in Data sources, program participation is not identifiable by specific system (e.g. boiler, heat pump, etc.). It is unknown if this site was a participant for this specific furnace compared to other heating systems at this site.

Table 4-14. ISP metric for warm air unit furnaces

Results	Number of Sites	Systems	Units	Median % better/ worse than Code	Bounds @ 90% confidence level
TOTAL	1	1	2	N/A	N/A
Ineligible ISP Metric	**1**	**1**	**2**	**2.5%**	**2.5%/2.5%**
Eligible	0	0	0	0%	0%/0%
Program benchmark	1	1	2	12.5%	12.5%/12.5%
Nonparticipant ISP Metric	0	0	0	N/A	N/A

Results	Sites	Number of Systems	Units	Median % better/ worse than Code	Bounds @ 90% confidence level
Participants	unknown	unknown	unknown	unknown	unknown
Unverifiable total/partial	0/0	0	0	N/A	N/A

Heat pump heating. Table 4-15 presents the ISP metrics for heat pumps. The heat pump heating ISP median rated efficiency is 3% better than Code using the Ineligible ISP metric, since there were a substantial number of heat pumps that were verified. The Program Benchmark of 6% is greater than this ISP value but less than the median eligible ISP metric. The result medians and bounds at the 90% confidence level are unable to be calculated due to the low variability of heat pump system efficiencies observed.

Table 4-15. ISP metric for heat pump heating

Results	Sites	Number of Systems	Units	Median % better/ worse than Code	Bounds @ 90% confidence level
TOTAL	16	64	211	N/A	N/A
Ineligible ISP Metric	**5**	**14**	**63**	**<u>3%</u>**	**N/A**
Eligible	14	49	70	15%	10%/19%
Program benchmark	15	63	133	6%	5%/7%
Nonparticipant ISP Metric	11	36	68	3%	N/A
Participants	unknown	unknown	unknown	unknown	unknown
Unverifiable total/partial	1/0	1	78	N/A	N/A

Chillers. Table 4-16 presents the ISP metrics for chillers. The chiller median rated efficiency is 5% better than Code using the non-participant ISP Metric. There is one site that had one chiller so there is not enough information to conclude a meaningful ISP metric.

Table 4-16. ISP metric for chillers

Results	Sites	Number of Systems	Units	Median % better/ worse than Code	Bounds @ 90% confidence level
TOTAL	1	1	1	**N/A**	N/A
Ineligible ISP Metric	0	0	0	N/A	N/A
Eligible	1	1	1	5%	5%/5%
Program benchmark	1	1	1	5%	5%/5%
Non-Participant ISP Metric	**1**	**1**	**1**	**5%**	**5%/5%**
Participants	unknown	unknown	unknown	unknown	unknown
Unverifiable total/partial	0/0	0	0	N/A	N/A

Air-conditioning. Table 4-17 presents the ISP metrics for air conditioning. The median is 5% better than Code using the Ineligible ISP Metric since there was a substantial number of observations in this category.

Table 4-17. ISP metric for air-conditioning

Results	Number of Sites	Systems	Units	Median % better/ worse than Code	Bounds @ 90% confidence level
TOTAL	16	58	190	**N/A**	N/A
Ineligible ISP Metric	**8**	**18**	**49**	**5%**	**NA**
Eligible	11	37	138	8%	6.7%/9.6%
Program benchmark	16	55	187	3%	2.7%3.4%
Non-Participant ISP Metric	13	38	69	9%	2%/15%
Participants	unknown	unknown	unknown	unknown	unknown
Unverifiable total/partial	3/0	3	3	N/A	N/A

Heat pumps cooling. Table 4-18 presents the ISP metrics for heat pumps operating in cooling mode. The median rated efficiency is 0% better than Code using the Ineligible ISP Metric. Although there is a substantial number of units verified in this group, there is no recommended change to the ISP.

Table 4-18. ISP metric for heat pump cooling

Results	Number of Sites	Systems	Units	Median % better/ worse than Code	Bounds @ 90% confidence level
TOTAL	16	64	211	N/A	N/A
Ineligible ISP Metric	11	29	82	0%	-13%/13%
Eligible	11	34	51	19%	10%/28%
Program benchmark	15	63	133	40%	25%/55%
Non-Participant ISP Metric	11	36	68	0%	-16%/16%
Participants	unknown	unknown	unknown	unknown	unknown
Unverifiable total/partial	1/0	1	78	N/A	N/A

PTACs. Table 4-19 presents the ISP metrics for PTACs. The PTAC median rated efficiency is 5% better than Code using the non-participant ISP Metric. There is one site that had two systems of 124 units, but there is not enough information to conclude a meaningful ISP metric from one site.

Table 4-19. ISP metric for PTAC cooling

Results	Number of Sites	Systems	Units	Median % better/ worse than Code	Bounds @ 90% confidence level
TOTAL	1	2	124	N/A	N/A
Ineligible ISP Metric	0	0	0	N/A	N/A
Eligible	0	0	0	N/A	N/A
Program benchmark	0	0	0	N/A	N/A
Non-Participant ISP Metric	1	2	124	5%	5%/5%
Participants	unknown	unknown	unknown	unknown	unknown
Unverifiable total/partial	1	2	124	N/A	N/A

4.4 Lighting

This section presents the results of the lighting measure compliance and ISP analysis.

4.4.1 Lighting Code compliance

Table 4-20 describes the individual lighting Code measures assessed during the NRNC Study with the number of study sites where data was verifiable by the compliance results. For example, not all sites have sleeping units, and DNV was able to verify this at all 26 lighting sites. Individual measures are discussed below, showing the compliance results and 90% confidence bounds.

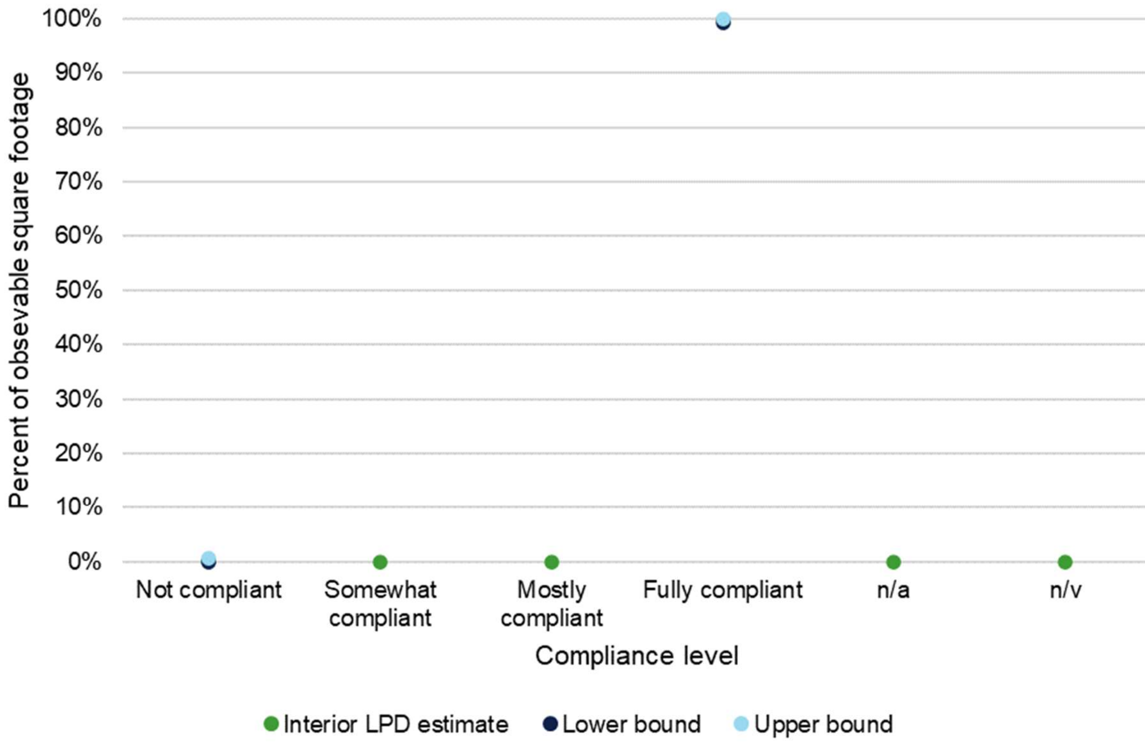
Table 4-20. Lighting measure summary

Code measure description	Number of sites verifiable
Lighting power density (LPD) in interior spaces	26
LPD in exterior spaces	26
Automatic lighting control to shut off all non-emergency building lighting (required in buildings >5,000 sq ft)	22
Daylight zones are provided with individual controls that control the lights independent of the general area lighting	17
Controls for application-specific lighting are separate from the main lighting controls throughout the building	6
Sleeping units have at least one master switch at the main entry door that controls all permanent lighting except those in the bathroom	26
Exterior lighting controlled by photocell or timer	18

Table 4-20 suggests the following observations from the analysis of the individual lighting measures:

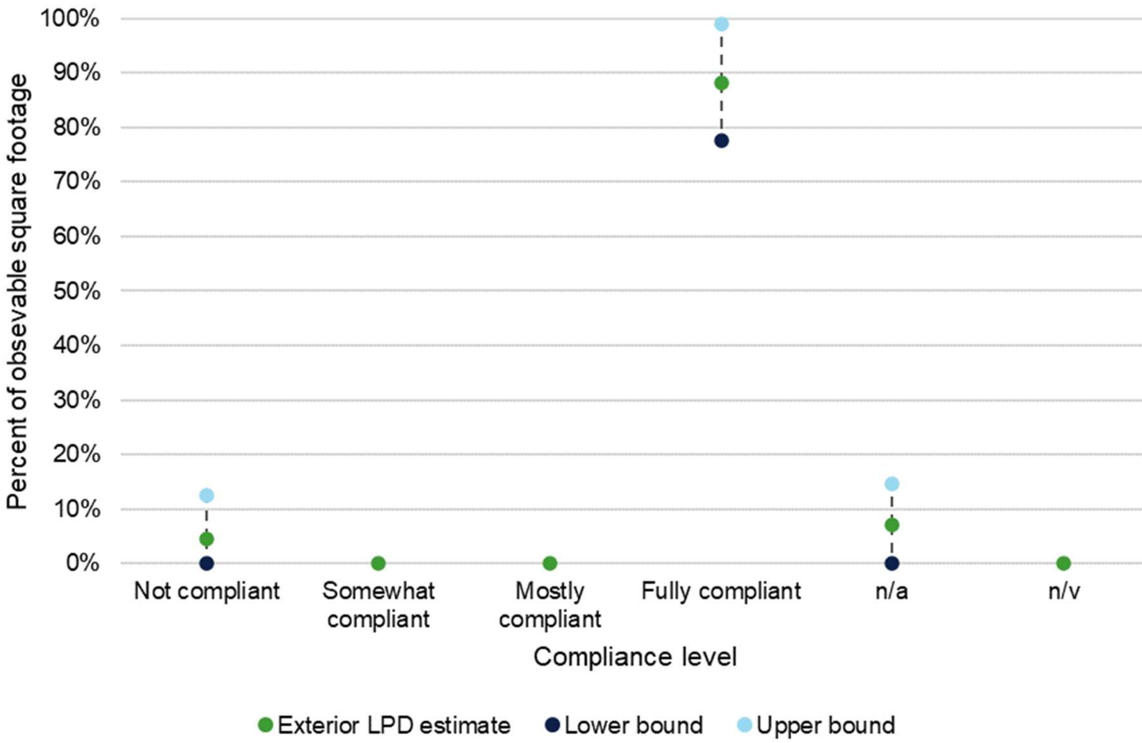
- **Interior LPD** – The DNV team assessed the majority of interior LPD using the space-by-space method. In this method, site engineers measured and estimated the square footage for each space within the building to compute the total allowed wattage for the building (trade-offs are allowed within spaces provided that the overall wattage is less than the allowed wattage). Engineers then inventoried all interior fixtures to determine the assessed wattage and compared that to the Code allowed values. Figure 4-20 presents the interior LPD compliance results; 100% of the observed square footage was compliant with the Code. This is consistent with prior studies and reflects the continued increasing penetration of LEDs in NRNC that outpace the Code LPD requirements. Additional details regarding interior LPDs are presented in the ISP section.

Figure 4-20. Interior LPD compliance results



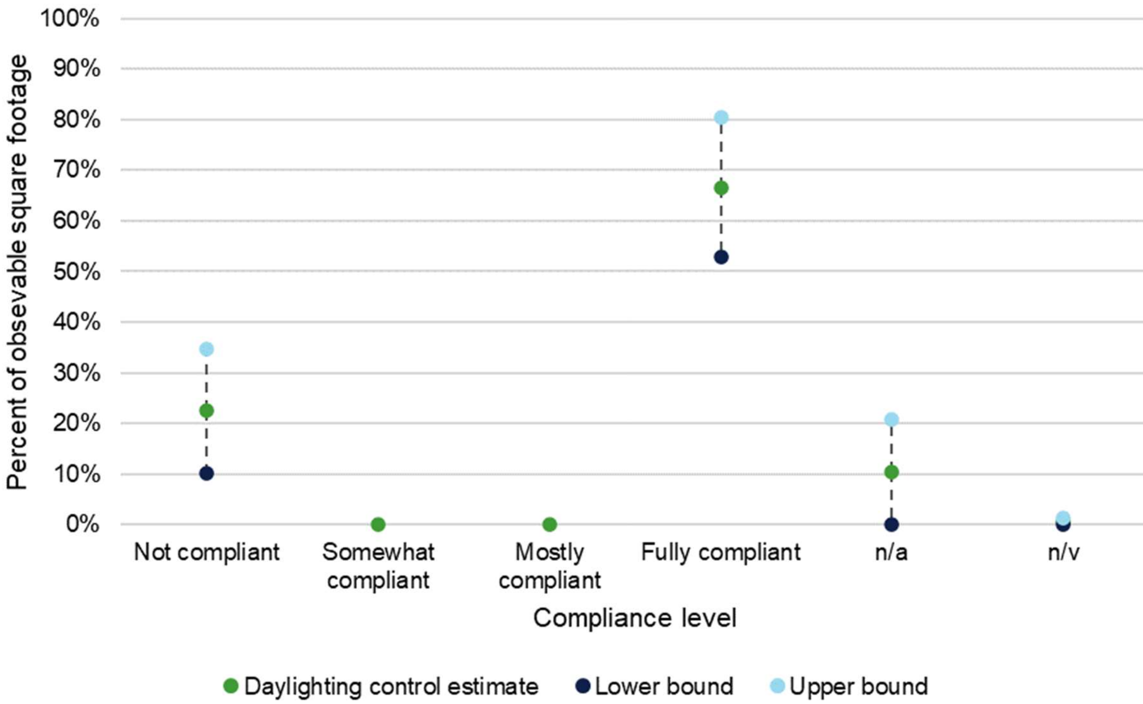
- **Exterior LPD** – For exterior lighting, the Code provides a base allowance of wattage based on the building zone and specifies wattage requirements for individual spaces (walkways, parking lots, etc.); some of these spaces are tradeable and some are not. Site engineers inventoried all available exterior fixtures and compared them to the allowed wattage to determine compliance, shown in Figure 4-21. While 88% of observable square footage was compliant, 5% was not compliant. This was due to sites exceeding wattage requirements for non-tradeable spaces, as well as over lighting walkway and parking areas.

Figure 4-21. Exterior LPD compliance results



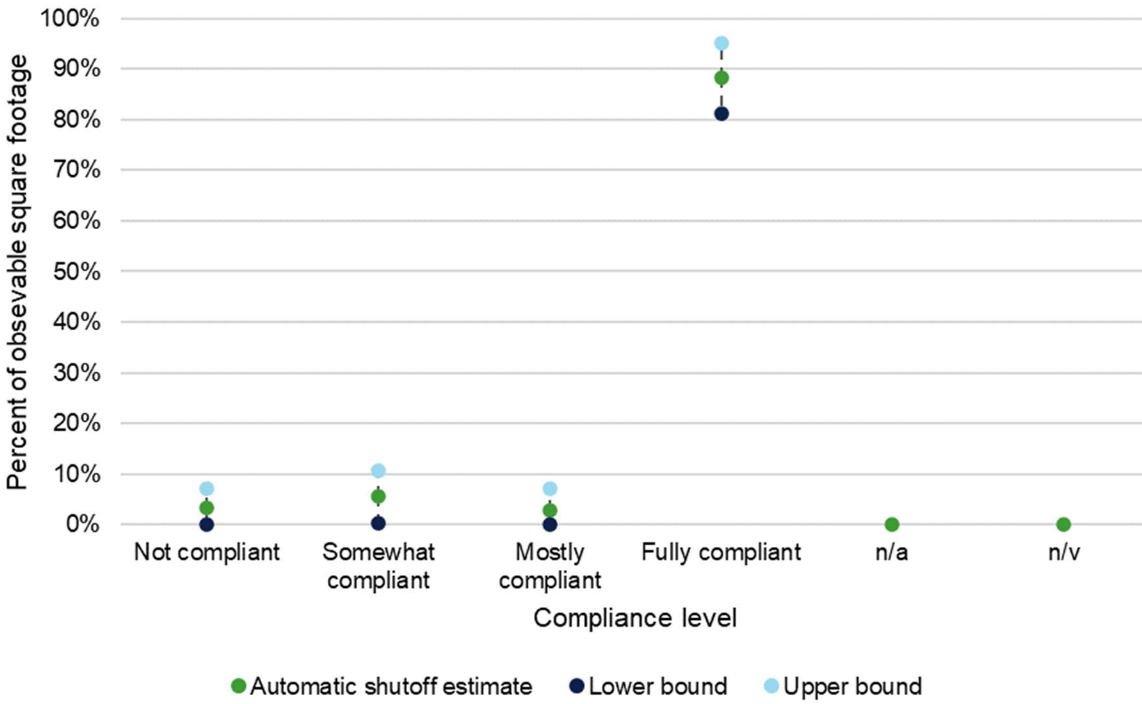
- **Daylighting controls** – The energy Code requires that daylight zones are provided with individual controls independent of general lighting controls. Recent versions of IECC have expanded the focus on daylighting, highlighting the increased interest in ensuring that daylight zones are able to incorporate natural light whenever possible. Figure 4-22 shows the compliance results for daylighting. Compliance was binary for this measure – either the individual sites did or did not have Code compliant daylight controls installed. Of the observable square footage, 67% was compliant, 22% was not in compliance, and 10% were N/A. This highlights a need for continued focus on daylighting control as a strategy to manage lighting loads.

Figure 4-22. Daylighting control compliance



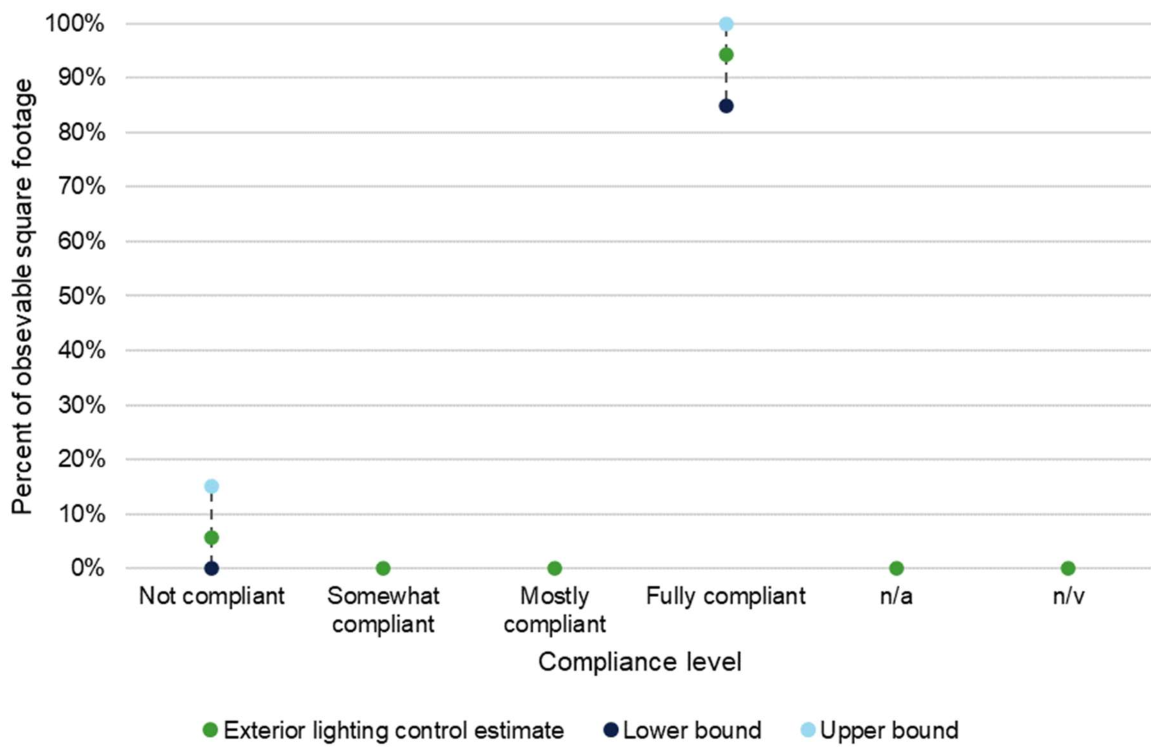
- **Automatic non-emergency lighting shut off control** – The Code requires the functionality to turn off all non-emergency lights when a building is unoccupied. Figure 4-23 shows the weighted percentage of observed floorspace distributed across compliance levels: 88% fully compliant, 5% somewhat compliant, and 3% mostly complaint. An additional 3% was not compliant.

Figure 4-23. Automatic non-emergency lighting shutoff compliance



- **Exterior controls** – The Code requires that external lighting is provided with controls that automatically turn off lighting as a function of available daylight, either by photocell control, astronomical timers with seasonal daylight adjustment, or some combination. The DNV team assessed compliance with the measure as shown in Figure 4-24. This was well-documented, with approximately 96% of observable square footage met this requirement.

Figure 4-24. Exterior lighting control compliance



4.4.2 Lighting ISP insights

The lighting data captured during the NRNC Study enables some insights into baseline practices in Rhode Island, as discussed below.

4.4.2.1 Lighting fixture distribution

As part of the lighting data collection, the DNV team gathered lighting fixture inventories for all surveyed interior and exterior spaces. The key observation here is the continued trend in the penetration of LED lighting in NRNC for both interior and exterior lighting.

4.4.2.2 Interior lighting power density

The lighting data collected during the RI NRNC study enables an assessment of ISP for LPD. This is typically expressed in terms of an adjustment factor for interior LPD that can be applied to analyses of new commercial construction buildings permitted under the IECC 2015. Based on our observations, the DNV team recommends that an adjustment factor of 0.45 ± 0.06 be used to "de-rate" Code required interior LPD for analyses of new commercial construction buildings.

The DNV team used a methodology consistent with estimations of this LPD adjustment factor in other jurisdictions and is summarized below:

1. **Aggregate Study data by site** – This initial step calculated a Code-allowed wattage and an assessed wattage for each of the 26 sites where LPD data was observable. For some sites, a census fixture inventory was completed, while for others a representative sample was used, capturing the square footage assessed.
2. **Weight data by square footage and site weight.** Where a complete assessment of a site was not possible, the documented space square-footage, Code allowances, and documented connected watts were aggregated to represent

the total assessed and allowed wattage for each building. The observed square-footage rather than the building total square-footage was used in expanding results. DNV then applied site weights to estimate the statewide ratio of assessed wattage to Code-allowed wattage.

3. **Review data for outliers or additional stratifications.** DNV reviewed the resulting data to identify outliers. This review showed that one warehouse facility had a significant impact on interior LPD because of the use of robots. The area impacted by these robots has a much lower LPD (better than Code) compared to the rest of the site where normal human activity occurs. Based on discussions with stakeholders, the area impacted by robots for this warehouse was assigned a weight of 0.5 to account for future lighting innovation. The rest of the warehouse area received a weight of 1.0 for the analysis.
4. **Adjust for program participation.** The DNV team adjusted for program participation in a three-step process.

   a. **Identify program participation within the sample.** The DNV team cross-referenced the sampled sites with provided RIE participation data and found that 14 sites (54%) received lighting incentives and can be classified as participants, as shown in Table 4-21 below.

Table 4-21. NRNC Study participation and LPD compliance

Study site type	Number of sites	Ratio of assessed wattage to Code allowed wattage
Participants (P)	14	0..44
Nonparticipants (Np)	12	0.42

   b. **Adjust the participant compliance ratio to account for program influence**. While there was no statistical difference between participants and nonparticipants, the DNV team elected to adjust for program influence to be consistent with prior calculations of this adjustment. The compliance ratio for participants was adjusted to account for (i.e., remove) the influence of the programs using the free ridership (FR) rate. The team utilized the FR value of 28% for C&I new buildings from the Rhode Island Technical Reference Manual for lighting systems.[10] This FR value was used to approximate the proportion of the difference between the nonparticipant and participant compliance ratios that is not attributable to program influence.

   c. **To reflect the market compliance ratio from the perspective of participants,** we calculated the participant-adjusted value (Padj), by accounting for program influence (1-FR) from the difference between Np and the P values, as shown in the following equation:

$$Padj = P + [(Np - P) \times * (1 - FR)] = 0.44 + [(0.42 - 0.44) \times (1 - 0.28)] = 0.42$$

   As shown above, 72% (1 – 0.28) of the difference between the nonparticipant and participant compliance ratios is used to approximate program influence, and we estimate an adjusted compliance ratio (Padj) of 0.45 for program participants without program influence.

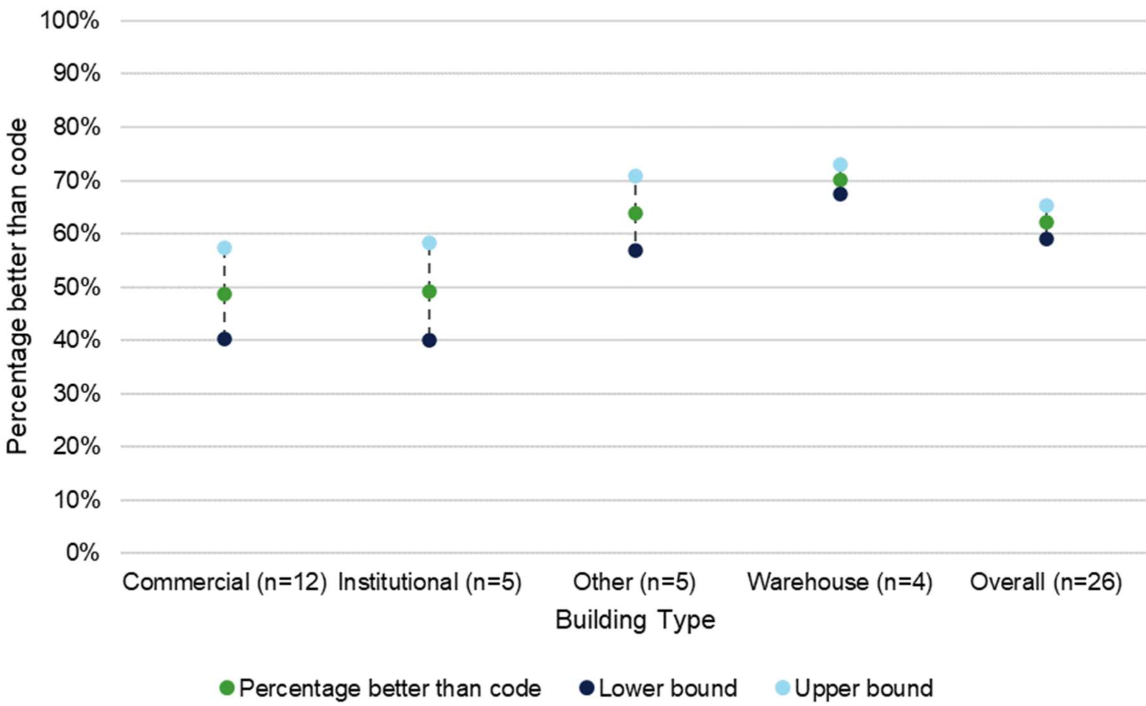
[10] The Rhode Island Technical Reference Manual for 2022 Program year leverages the PY2019 C&I Free Ridership/Spillover study conducted by Tetratech. TRM can be found here: https://ripuc.ri.gov/sites/g/files/xkgbur841/files/eventsactions/docket/1-PY2022-RI-TRM.pdf/ Tetratech study here: http://rieermc.ri.gov/wp-content/uploads/2021/01/national-grid-rhode-island-2020-ci-fr-so-report_final.pdf.

Table 4-22. NRNC interior LPD adjustment

Study site type	Number of sites	Unweighted compliance ratio	Adjusted compliance ratio	Population participation rate
Participants (P)	14	0..44	0.42	0.65
Nonparticipants (Np)	12	0.42	N/A	0.35
Weighted average adjustment factor at 90% confidence				0.42 +/- .06

Interior lighting by building type. Figure 4-25 presents the interior lighting by building type, shown as percent better than Code (the additive inverse of the LPD adjustment). Overall interior LPD was 62% better than Code, though some building types fared better and worse.

Figure 4-25. Interior lighting by building type



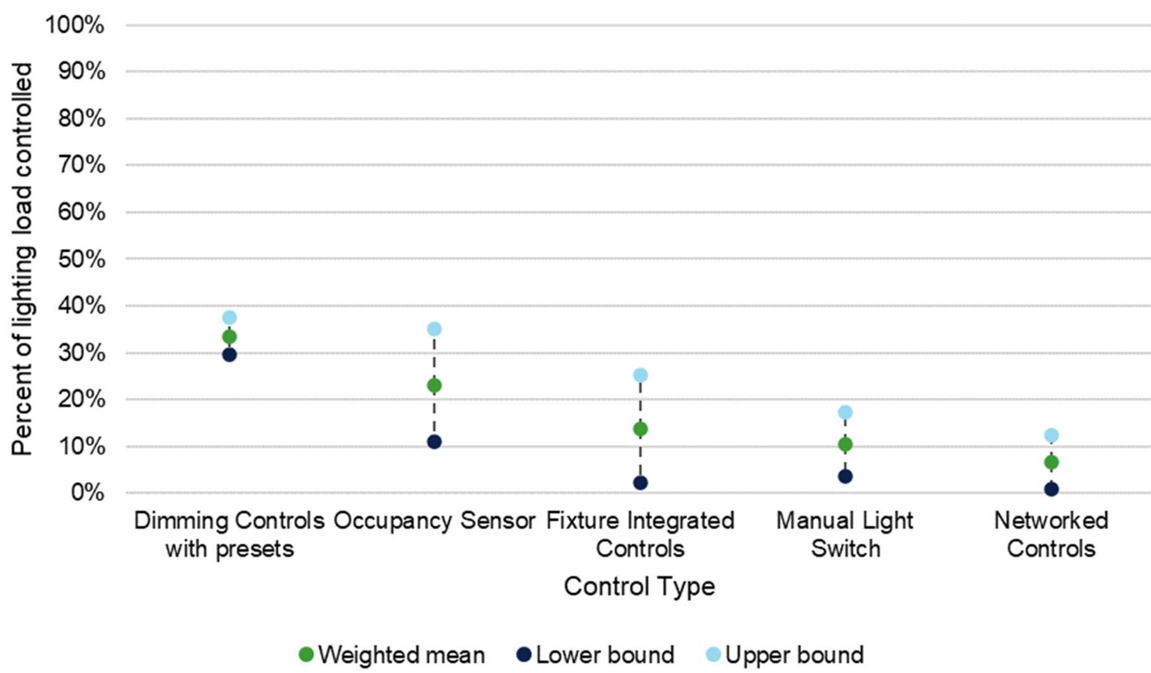
4.4.2.3 Interior lighting controls

As part of the interior fixture inventory, the DNV team attempted to identify the lighting controls for each fixture wherever possible, capturing the types of controls detailed on the construction drawings and calculating the percent of the lighting load controlled by control strategy for each site. Note that while this analysis reflects the controls detailed on drawings, the DNV team did not assess whether any of these controls are functioning – these results should thus reflect insights on the design intent of lighting controls and not their performance or proper commissioning.

Figure 4-26 shows the top five control strategies by estimated load controlled, weighted to the population. Note that individual fixtures can be controlled by multiple strategies such as occupancy/vacancy sensors with a manual switch override; thus, these values do not sum to 100%. This analysis supports the following observations:

- **Dimming controls.** Fixtures with dimming controls presets was identified to represent 33% of the NRNC lighting load, the greatest percentage of control types documented.
- **Manual light switches**. The NRNC data collection indicates new construction sites are moving away from manual switches. It is likely that the manual-controlled load is underrepresented in this data due to inconsistent and incomplete documentation of light switching on electrical drawings, as well as lighting control redundancy where dimming or occupancy sensors overlap. Manual switches are not often included on lighting schedules but can be detailed on lighting and power plans, while other controls are more consistently detailed on fixture schedules and in lighting plans.
- **Occupancy sensors are commonly utilized to satisfy Code requirement**s. The Code requires occupancy sensors in select spaces and allows the use of occupancy and vacancy sensors to satisfy additional control requirements. This trend is consistent with observations from prior studies.
- **Advanced lighting controls**. This analysis shows that networked controls of advanced lighting is not prevalent in new construction in RI. Approximately 7% of the lighting load documented has networked controls, allowing users to control lighting remotely or through an onsite energy or building management system.
- **Fixture Integrated Controls**. Fixture-integrated controls are commonly used in networked systems but also can provide increased functionality on their own. While not overly prevalent, approximately 14% of the lighting load has integrated controls. It's possible these integrated controls may end up connected to an advanced network.

Figure 4-26. Top five lighting controls by load



4.4.2.4 Exterior lighting power density

While prior studies did not have sufficient data points to support an exterior LPD ISP assessment, the NRNC Study collected exterior LPD data for 26 of the 26 lighting study sites that were able to be recruited for this study. The DNV team applied the same methodology used for interior LPD to assess standard practice in exterior lighting, adjusting for free ridership and population participation. Based on our observations, the DNV team recommends that an adjustment factor of 0.27 ± 0.17 be used to “de-rate” Code required exterior LPD for analyses of new commercial construction buildings.

Table 4-23. NRNC exterior LPD adjustment

Study Site Type	Number of Sites	Unweighted Compliance Ratio	Adjusted Compliance Ratio	Population Participation Rate
Participants (P)	14	0.34	0.28	0.65
Nonparticipants (Np)	12	0.25	n/a	0.35
Weighted average adjustment factor at 90% confidence				0.27 +/- 0.17

5 CONCLUSIONS, RECOMMENDATIONS, AND CONSIDERATIONS

This section presents conclusions, recommendations, and considerations for the NRNC Study.

5.1 Conclusions

1. Current standard practice is better than Code for many of the measures examined in this study. Clear indications of ISP were found for the following measures:
   - **Interior LPD.** The DNV team determined that interior LPD design was 0.42 ± 0.06 of the LPD allowed by Code (58% better) for buildings permitted under IECC 2015.
   - **Exterior LPD**. The DNV team examined exterior lighting design and found that standard practice for exterior lighting design was 0.27 ± 0.17 of the LPD Code requirements (73% better) for buildings permitted under IECC 2015.
   - **Above-grade wall insulation**. The DNV team assessed envelope design and found that standard practice for wall insulation was 14% ± 10% better than Code.
   - **Boilers**. The NRNC Study found that standard practice for boilers is to specify condensing boilers, while the Code efficiency levels reflect a baseline of a non-condensing boiler. The study results suggest that the median boiler specified in NRNC are 20% better than Code requirements. The median units for both equipment types were determined to be specified at Code.
   - **Warm air furnaces**. The NRNC study found that Code compliant warm air furnaces were installed at several sites (37 units) and represented the majority of observed SF. While the program incentivizes higher efficient equipment in this category, customers are not widely installing higher than Code efficient furnaces. No changes are recommended for this category.
   - **Air conditioning**. Air conditioning systems included multiple sized systems from small mini splits to large roof top units. The DNV team assessed these systems and found that standard practice for air conditioning equipment is 5% better than Code.
   - **Heat pump heating**. The NRNC study found that while a majority (65%) of floor space in new buildings is heated by warm-air furnaces, heat pumps account for most of the heating systems identified (64 units) and serve the second greatest portion of square footage (23%). The study results suggest that the median heat pump heating specified in RI NRNC are 3% better than Code requirements. All heat pumps observed in this study were air-source heat pumps.

In addition to clear indications of ISP, there are also ISPs that are at Code or inconclusive:

2. **Heat pump cooling.** Heat pump cooling systems included traditional air source and variable refrigerant flow (VRF) systems. Using the ineligible ISP metric, the study found there is no difference in the median percent efficiency better or worse than Code, which indicates that ISP is at Code.
3. **Warm Air Furnaces.** The NRNC study observed several warm air furnace systems that are typically standalone direct fired or packaged roof top units. The study found that sites are installing Code compliant equipment rather than higher efficient furnace systems.
4. **Chillers, warm air duct furnaces and PTACs.** There is insufficient observed data for these systems to conclude a meaningful ISP.

Additional observations and conclusions were made on the following:

5. Mechanical equipment is largely compliant with the energy Code efficiency requirements, though compliance is difficult to assess for mechanical equipment controls. This is consistent with prior Code compliance study findings and reflects the market aligning with the Code such that it is difficult to purchase equipment that does not comply with Code

requirements. For mechanical equipment controls, the presence of controls can be identified, but this study was not designed to provide insights regarding control commissioning or operations, key components of successful control strategies. ISPs developed from this study are based on stated equipment efficiencies from construction drawings. Actual equipment and controls performance cannot be determined from plan review and would require on-site evaluation.

6. Opportunities remain for improving Code compliance and assessing building performance. While this study focused on individual measures in lieu of whole building compliance, opportunities remain to improve compliance for select measures such as slab thermal break requirements, air barrier documentation, and daylighting. Additionally, many benefits of Code compliant systems rely on proper installation of components and system commissioning, particularly for controls and envelope sealing/insulation requirements, which were not assessed as part of this study.
7. The recruitment approach in this study effectively mitigated self-selection bias and provides results reflective of the RI NRNC market. The NRNC Study mitigated this bias by recruiting directly from municipal building departments and ensuring that sites included in the study represented a broad range of municipalities.
8. There is limited new construction in RI, so DNV's original sample included major renovations and additions to existing space. During site reviews, several of these renovations and additions were removed from the sample as not having new construction components. Gut rehab renovations and facility additions that involved new lighting, mechanical or envelope systems triggered by Code were included. The majority of NRNC square footage in RI that this study collected data on is within warehouse space. Four sites are categorized as warehouses, representing more than three million of the total 4.8 million unweighted square footage observed in the study.

5.2 Recommendations

The DNV team makes the following recommendations based on data collected, results, and conclusions from the study:

1. Based on the results of this study, DNV recommends adoption of the ISP values summarized in Table 5-1. The product of a Code adjustment factor and the Code specified minimum efficiency yields the ISP baseline efficiency to be used for calculating savings. These values reflect the best available ISP data. There are no ISP recommendations for chillers, warm air furnaces, warm air duct furnaces, PTACs, or heat pump cooling systems.

Table 5-1. Recommended ISP Code adjustment factors[11]

Equipment type	Recommended Code adjustment factor	Notes
Above-grade wall insulation	1.14	14% better than Code.
Interior lighting	0.42	58% better than Code.
Exterior lighting	0.27	73% better than Code.
Hot water boilers	1.20	20% better than Code. Observed boilers were all condensing, which appears to be standard practice in NC.
Heat pumps – heating	1.03	3% better than Code. Includes all heat pumps (air-source heat pumps, VRF heat pumps) except for packaged terminal heat pumps.
Air conditioning	1.05	5% better than Code. Includes multiple sized systems.

[11] Relative to IECC 2015.

2. **Focus energy Code training on targeting Code provisions that are not readily complied with and/or require proper installation to capture energy benefits.** DNV found that a substantial number of sites were not compliant with the thermal break requirement. While all buildings had slab insulation, it often did not extend to the top of the slab – as required by the Code – to achieve thermal break and most commonly was located under the slab and along the footing. This is an opportunity for designer and/or builder education and training to improve building design and construction such that thermal breaks are established in alignment with the Code requirement.

3. **Account for new baselines**. Other program, evaluation, and analysis methods should account for the baseline revisions, including attribution research and equipment costs used in benefit cost analysis.

5.3 Considerations

DNV makes the following considerations from the NRNC Study:

1. **Consider targeted studies to further investigate building envelope practices**. Envelope window components are typically difficult to assess because their performance details are often not documented in building plans and are usually provided in specifications or other additional documentation. To better understand thermal envelope performance, consider doing a more focused study of fenestration design and building practices, using a combination of both primary and secondary research methods. With increasing glazing levels in NRNC building design, sound understanding of this performance will be critical to understanding standard practice.

2. **Consider expanding RIE program participation database to include more detailed information about program participation**. As was a consideration in the MA study, RIE program participation database provides limited details on the specific measures incentivized by the programs. Additional detail on participation could help improve our classification of program participation and enable more detailed comparisons of participants and nonparticipants beyond lighting measures.

5.4 Guidance for future research

1. **Pursue additional ISP heat pump research to validate results in this study.** This study gathered data across different heat pump cooling technologies with several systems (64 units) observed to be less than 65,000 btu/h. To better understand heat pump ISP, DNV would recommend a targeted study to understand the different size and efficiencies impacting heat pumps.

2. **Conduct a selection of on-site visits to recently completed and occupied buildings to assess ISPs for mechanical and lighting controls**. While construction drawing reviews can identify the presence of some controls, they cannot provide any data regarding control commissioning and operations. As these controls are expected to comprise a larger share of future RIE programs, field verification is essential to understand ISPs, gathering data regarding controls commissioning and any overrides in place that may change design intent. This could involve revisiting a select sample of sites when buildings are occupied to understand controls.

APPENDIX A. NRNC IECC 2024 ADDENDUM REPORT

Memo to: Rhode Island Energy (RIE, RI Energy)

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Date: March 7, 2025

NRNC IECC 2015 Addendum – IECC 2024 Update

A.1 Introduction

DNV carried out the Non-Residential New Construction (NRNC) Industry Standard Practice (ISP) Study for Rhode Island Energy (RI Energy or RIE) from March 2023 to March 2024. The NRNC Study recruited from 39 municipal building departments to provide data on a sample of recently constructed NRNC buildings in Rhode Island (RI) permitted under the 2015 International Energy Conservation Code (IECC).

The study's overall objectives were as follows:

1. **Assess and/or inform Industry Standard Practices (ISPs) where possible based on the data collection.** This includes updating the interior lighting power density (LPD) adjustment factor developed through prior MA code compliance studies, adopted by RI, as well as the analysis of other envelope, mechanical, and electrical measures to identify other ISPs that are supported by the NRNC data.
2. **Assess energy code compliance for select code measures**. This study did not assess building-level energy code compliance for each site. Instead, evaluators gathered building design data for a select subset of measures and assessed code compliance for those measures, normalized to estimate compliant square footage where possible.

The study results clearly showed ISP exceeding code requirements for interior lighting, exterior lighting, above-grade wall insulation, hot water boilers, air-cooled air conditioning, and heat pump heating systems. The state of RI adopted IECC 2024, 90 days after its publication on August 14, 2024. Starting January 1, 2025, RIE formally adopted IECC 2024 for program planning purposes. To account for this change, DNV developed new ISP values applicable to IECC 2024 for these measure types using the IECC 2015-based NRNC study. This addendum serves as an update to the NRNC study IECC 2015-based results.

A.2 Methodology

A.2.1 Applying results to IECC 2024

To prospectively apply the findings from the RI NRNC Study, DNV completed the following activities:

1. **Compare observations from sites permitted under IECC 2015 to the IECC 2024 code requirements.** DNV tracked code changes from IECC 2015 through IECC 2024 for all affected measures in the NRNC study to understand how code efficiencies have evolved since the study period. DNV then re-analyzed the results from the study against the 2024 IECC to understand how the observations from the NRNC study compare to the current code. This generally provides a floor estimate of ISP – assuming no changes to construction practices, technology, or anything else that would affect standard practice. This floor ISP was used as a starting point for investigations with the internal review panel to account for any changes in industry practices.
2. **Identify any code evolution, technology advancement, or construction trends that would influence market practices.** DNV convened an internal review panel to review the re-analysis of observations, comparing results against IECC 2015 and IECC 2024. The review panel comprised of three senior DNV engineers with significant experience in new construction and general C&I building practices across envelope, lighting and HVAC measures. The NRNC project team held two working sessions with the panel to review the IECC 2015 and IECC 2024 results, and to consider industry trends and developments that should be incorporated into the final ISP recommendations. Additionally, the panel discussed any changes in the construction industry, including technology limitations and advancements, and reviewed the results of similar studies in other jurisdictions that could affect ISP.
3. **Finalize the ISP applied to IECC 2024.** DNV incorporated the results of the internal review panel to finalize the ISP recommendations for IECC 2024. For measures such as lighting, the panel identified additional research for the NRNC team to better understand technology evolution. These ISPs are presented in the findings section below.

Based on the results of this study, DNV recommends adoption of the ISP values summarized in Table for IECC 2024 code adjustment factors. These values reflect the best available ISP data.

To calculate the adjustment to code baselines, multiply the code baseline by the recommended code adjustment factor. Lighting baselines are expressed in lighting power density (LPD) measured in watts per square foot where lower values are more efficient, and thus these adjustment factors are less than one. For the other measures, higher numbers represent more efficient equipment, so adjustment factors are greater than 1. In general, ISP adjustment factors are lower because of improvements to code from IECC 2015 to 2024.

A.3 Findings

Table A-1. Recommended ISP code adjustment factors

Equipment type	Recommended IECC 2015 code adjustment factor	Recommended IECC 2024 code adjustment factor	Notes
Above-grade wall insulation (R-value and U-factor)	1.14 (R-value) 0.86 (u-factor)	1.10 (R-Value) 0.90 (u-factor)	Code adjusted from 14% to 10% better than code.
Interior lighting (LPD)	0..42	0.56	Code adjusted from 58% to 44% better than code.
Exterior lighting (LPD)	0.27	0.43	Code adjusted from 73% to 57% better than code.
Hot water boilers (efficiency)	1.20	1.14	Code adjusted from 20% to 14% better than code.
Heat pumps – heating (efficiency)	1.03	1.02	Code adjusted from 3% to 2% better than code.
Air conditioning (efficiency)	1.05	1.045	Code adjusted from 5% to 4.5% better than code.

A.3.1 Envelope findings

In the RI NRNC Study, DNV applied the ISP framework to the envelope observations to assess ISPs. There is no prescriptive RIE program for building envelope components. Envelope participation is typically captured in Comprehensive Design Approach (CDA) programs for which DNV did not receive program information. Thus, assessment of program eligibility is not possible and DNV used the non-participant ISP metric for assessment, which resulted in an ISP estimate of 14% better than code for wall insulation.

To assess how this ISP should be applied prospectively under IECC 2024, DNV conducted the following analyses:

1. **Compare envelope wall insulation details for sites permitted under IECC 2015 to the IECC 2024 wall insulation requirements.** DNV re-ran the wall insulation analysis using the 24 sites where envelope insulation was recorded to compare the observations from the RI NRNC study with the insulation code requirements for IECC 2024. This resulted in an estimated ISP of 6% better than code for IECC 2024, a reduction from the 14% better than RI's version of IECC 2015. Note that the code allows insulation either by R-value (where the higher the value, the better the performance) and u-factor (where the lower the value, the better the performance). This 6% is the minimum ISP that could be considered for wall insulation and assumes no significant changes to envelope above-grade wall insulation practices since the prior study.
2. **Identify any building envelope code evolution and/or construction trends that would influence market practices**. DNV convened with the internal review panel to review the comparison of envelope results and discuss changes in building envelope construction practices that would necessitate any additional adjustment of the IECC 2024 ISP. While there is an increasing body of literature overall on ISP, most of that work focuses on lighting and HVAC ISP applications and does not address envelope in detail. Without additional supporting evidence of envelope construction practices, DNV, in conjunction with project stakeholders, agreed to take an average adjustment between the IECC 2015 and IECC 2024 ISP estimates.

3. **Finalize the ISP applied to IECC 2024**. DNV incorporated the internal review panel and stakeholder perspectives to finalize the recommended ISP for wall insulation for IECC 2024. Overall, the wall insulation requirements did not change significantly between the base codes for IECC 2015 and IECC 2021. However, in IECC 2024, wall insulation requirements became more stringent across most above-grade wall types. The stakeholder review anticipates that future building practices may evolve throughout IECC 2024 implementation, so DNV recommends that the adjustment factor represent an average between IECC 2015 and 2024 estimates for a recommended ISP of 10% better than IECC 2024.

A.3.2 Lighting findings

In the RI NRNC study, DNV was able to develop an assessment of ISP for both interior and exterior LPD. This is typically expressed in terms of an adjustment factor for LPD that can be applied to analyses of commercial new construction buildings.

To assess how this ISP should be applied prospectively under IECC 2024, DNV conducted the following analyses:

1. **Compare interior and exterior baseline LPD for sites permitted under IECC 2015 to the IECC 2024 LPD requirements.** After comparing LPD values and re-running the LPD analysis using the 26 sites where lighting power density was recorded in the NRNC Study, the base level estimated ISP LPD adjustment factors were 38% better than code for IECC 2024 for interior lighting and 52% better than code for IECC 2024 for exterior lighting.
2. **Identify any lighting code evolution, lighting technology advancement and/or construction trends that would influence market practices.** The review panel agreed that increases in LED lighting saturations and efficiency advancements within LED technology since 2019 should be considered and applied to the base level estimated LPD adjustment factors calculated for IECC 2024. This finding is also observed in building practices from studies completed by DNV in other jurisdictions where building practices have outpaced code. DNV also reviewed LED saturations and efficacy values of DesignLights Consortium (DLC) approved LED lighting from the year of RI's adoption of IECC 2015 (2019) to 2024. DNV found that LED saturations increased from 24% to 60% and efficacy values have increased by an average of 10% from 2019 to 2024.
3. **Finalize the ISP applied to IECC 2024.** DNV incorporated the review panel and stakeholder perspectives to finalize the recommended ISP for interior and exterior LPD for IECC 2024. The expert panel agreed that lighting technology has advanced since 2019 and therefore a 10% adjustment factor should be applied to the recalculated base LPD for IECC 2024. This resulted in the recommended adjustment of 44% and 57% better than IECC 2024 for interior and exterior LPD, respectively.

A.3.3 HVAC findings

In the RI NRNC Study, DNV developed recommended ISP efficiency values for select HVAC equipment types where there were sufficient observations to support that finding. DNV recommended ISP adjustments expressed as code adjustment factors. The recommended ISP adjustments convened with the expert panel are limited to three equipment groups: hot water boilers, heat pump heating efficiency, and air-cooled air conditioning systems.

To assess how ISP should be applied prospectively under IECC 2024 for these equipment groups, DNV conducted the following analyses, discussed results with the internal review panel, and reviewed conclusions with project stakeholders.

Hot water boilers. The initial study found that buildings permitted under IECC 2015 code installed condensing efficiency boilers, with an average observed efficiency of 96%. Thermal heating systems cannot exceed 100% thermal efficiency. The recommended ISP is already nearing the limit that these systems can achieve. IECC 2024 increased the gas-fired hot water boiler minimum efficiency from 80% to 84% for systems with a capacity less than 2,500,000 Btu/hr. There are no changes for larger capacity gas-fired hot water boilers. It should be noted that the minimum code efficiency also changed for oil-fired hot water boilers, with capacities below 300,000 Btu/hr., from 80% to 86%. However, zero oil-fired hot water boilers were present in the collected data sample. All hot water boiler systems in the sample data are gas-fired boilers with a capacity less than 2,500,000 Btu/hr.

DNV incorporated the internal review panel and stakeholder perspectives to finalize the recommended ISP for hot water boilers for IECC 2024. The adjusted recommendation for ISP is from 20% to 14% better than code relative to IECC 2024, without any additional adjustment for market or technology improvements since buildings constructed under IECC 2015. Based on our findings for HVAC applications, condensing hot water boilers appear to be standard practice.

RI TRM measures impacted by recommended boiler ISP adjustment:

1. Boiler
2. Condensing boiler
3. Non-condensing boiler

Note: Only applicable for hot water boilers, does not apply to steam boilers or combination boiler/water heater measures.

Heat pump heating. In IECC 2015, the code used an efficiency unit of heating season performance factor (HSPF). In IECC 2024, code adopted the new efficiency unit HSPF2 for heat pumps with capacities less than 65,000 Btu/hr. DNV estimated an equivalent HSPF value to recalculate the ISP findings when applied to IECC 2024. The ISP adjustment factor for heat pump efficiencies shifted from 3% better than code relative to IECC 2015, to 1% better than code relative to IECC 2024. This code adjustment factor applies to air-cooled heat pumps and variable refrigerant flow (VRF) systems of all capacities. Due to the code adjustment in new efficiency units with different testing requirements and uncertainty of market trends, DNV incorporated the internal review panel and stakeholder perspectives to finalize the recommended ISP for heat pump heating. DNV recommends that the adjustment factor represent an average between IECC 2015 and 2024 analyses for an average ISP of 2% better than code.

RI TRM measures impacted by recommended heat pump, heating ISP adjustment:

1. Air-source HP
2. VRF HP

Note: Only applies to air-cooled heat pump and VRF systems. Not applicable for water-cooled, ground-source, or packaged terminal heat pump units.

Air conditioning. In IECC 2015, the code used an efficiency unit of seasonal energy efficiency ratio (SEER). IECC 2024 adopted the new efficiency unit SEER2 for air conditioning systems with capacities less than 65,000 Btu/hr. DNV estimated an equivalent SEER value to recalculate the ISP findings when applied to IECC 2024. The ISP adjustment factor for air conditioning efficiency shifted from 5% better than code relative to IECC 2015 to 4% better than code relative to IECC 2024. This code adjustment factor applies to air-cooled air conditioning systems of all capacities. Due to the code adjustment to new efficiency units with different testing requirements and uncertainty in market and technology trends, DNV incorporated the internal review panel and stakeholder perspectives to finalize the recommended ISP for air conditioning. DNV recommends that the adjustment factor represent an average between IECC 2015 and 2024 analyses for an average ISP of 4.5% better than code

RI TRM measures impacted by recommended air conditioning, air-cooled ISP adjustment:

1. Air-cooled AC

2. Split system AC to 5.4 tons

Note: Only applicable for air-cooled air conditioning systems, not water-cooled or packaged terminal air conditioner units.

A.4 Conclusions and Recommendations

A.4.1 Envelope

DNV recommends adjusting the wall insulation ISP from 14% better than code to 10% better than code when applied to RI IECC 2024. This is the result of applying the RI NRNC observations to the IECC 2024 wall insulation requirements. With IECC 2024, the wall insulation requirements are now more stringent, so DNV's recommended approach is to average the analysis of observations against IECC 2015 and IECC 2024, which shifts the ISP from 14% to 10% better than code.

A.4.2 Lighting

DNV recommends adjusting the interior lighting LPD ISP from 55% to 44% better than code when applied to IECC 2024. DNV recommends adjusting the exterior lighting LPD ISP from 73% to 57% better than code when applied to IECC 2024. This is the result of applying RI NRNC observations to the IECC 2024 LPD requirements and a 10% adjustment factor being incorporated based on the industry advancements in lighting since 2019.

A.4.3 HVAC

DNV recommends adjusting the ISP efficiency for hot water boilers to 14% better than code, air-cooled heat pumps (heating only) to 2% better than code, and air-cooled air conditioning to 4.5% better than code.

The ISP recommendations for heat pump heating and air conditioning systems represent the average of comparing the observations against IECC 2015 and IECC 2024 code values. A focused ISP study for heat pumps and air conditioning systems with expanded sample size or building variety could provide data to determine if construction practices or market trends have continued to push for higher efficiency systems beyond this study's results or if they have remained static.

A.5 TRM Updates

DNV reviewed the RI TRM – 2025 Program Year (2025 TRM) to apply the recommended ISP updates as outlined in this memo. As part of this task, DNV reviewed TRM measure input assumptions and calculations used for prescriptive deemed based savings. In addition, DNV reviewed and updated the value tables referenced in Appendix A of the TRM. DNV outlined how to apply those changes below and provided red-lined and clean versions of the updated measures included as separate attachments to this memo.

A.5.1 Envelope

The 2025 TRM contains nine NRNC wall insulation measures. As indicated in Table A-2, those nine measures apply to Multifamily High Rise (MFHR) buildings and, as such, DNV concluded that the findings of this study do not apply to the prescriptive deemed based savings approach. For this reason, DNV did not make any changes to the 2025 TRM or Appendix A values.

Table A-2. Wall insulation measures in 2025 TRM

Measure group	Chapter name	Measure name	TRM update
Wall Insulation	Renovation Rehab Multifamily High Rise Cooling, Gas	Renovation Rehab MFHR - Gas Cooling Tier 1	Not applicable
Wall Insulation	Renovation Rehab Multifamily High Rise Cooling, Gas	Renovation Rehab MFHR - Gas Cooling Tier 2	Not applicable

Measure group	Chapter name	Measure name	TRM update
Wall Insulation	Renovation Rehab Multifamily High Rise Cooling, Gas	Renovation Rehab MFHR - Gas Cooling Tier 3	Not applicable
Wall Insulation	Renovation Rehab Multifamily High Rise CP, Gas	Renovation Rehab MFHR - Gas Cooling CP	Not applicable
Wall Insulation	Renovation Rehab Multifamily High Rise CP, Gas	Renovation Rehab MFHR - Heating CP	Not applicable
Wall Insulation	Renovation Rehab Multifamily High Rise CP, Gas	Renovation Rehab MFHR - DHW CP	Not applicable
Wall Insulation	Renovation Rehab Multifamily High Rise Heating, Gas	Renovation Rehab MFHR - DHW Tier 1	Not applicable
Wall Insulation	Renovation Rehab Multifamily High Rise Heating, Gas	Renovation Rehab MFHR - DHW Tier 2	Not applicable
Wall Insulation	Renovation Rehab Multifamily High Rise Heating, Gas	Renovation Rehab MFHR - DHW Tier 3	Not applicable

A.5.2 Lighting

The 2025 TRM contains 15 NRNC interior and exterior lighting measures.[12] As indicated in Table A-3, those measures include: LEDs, lighting systems, performance lighting, and prescriptive lighting. Table A-3 summarizes the measures and describes how the ISP changes are applied to the measures in the redlined 2025 TRM document and redlined Appendix A.

Table A-3. Interior and exterior lighting measures in 2025 TRM

Measure group	Chapter name	Measure name	TRM update
Interior and Exterior Lighting	LEDS	LEDS	Added footnote to Baseline Description.
Interior and Exterior Lighting	Lighting Systems, Custom	Lighting Systems, Custom	Added footnote to Baseline Description.
Interior and Exterior Lighting	Performance Lighting	Performance Lighting - Tier 1 Exterior	Updated text in Baseline Description. Updated Table 1 and Table 2 in Appendix A.
Interior and Exterior Lighting	Performance Lighting	Performance Lighting - Tier 1 Interior	Updated text in Baseline Description. Updated Table 1 and Table 2 in Appendix A.
Interior and Exterior Lighting	Performance Lighting	Performance Lighting Tier 2 & 3 Exterior	Updated text in Baseline Description. Updated Table 1 and Table 2 in Appendix A.
Interior and Exterior Lighting	Performance Lighting	Performance Lighting Tier 2 & 3 Interior	Updated text in Baseline Description. Updated Table 1 and Table 2 in Appendix A.
Interior and Exterior Lighting	Performance Lighting, Custom	Performance Lighting, Custom	Added footnote to Baseline Description.
Interior and Exterior Lighting	Prescriptive Lighting	Prescriptive Lighting - EXT-24/7	Not applicable
Interior and Exterior Lighting	Prescriptive Lighting	Prescriptive Lighting - EXT-DUSKDAWN	Not applicable
Interior and Exterior Lighting	Prescriptive Lighting	Prescriptive Lighting - Compact	Not applicable

[12] Lighting controls measures are not included.

Measure group	Chapter name	Measure name	TRM update
Interior and Exterior Lighting	Prescriptive Lighting	Prescriptive Lighting - Custom	Not applicable
Interior and Exterior Lighting	Prescriptive Lighting	Prescriptive Lighting - Fluorescent	Not applicable
Interior and Exterior Lighting	Prescriptive Lighting	Prescriptive Lighting - LED Case Ref	Not applicable
Interior and Exterior Lighting	Prescriptive Lighting	Prescriptive Lighting - LED General	Not applicable
Interior and Exterior Lighting	Prescriptive Lighting	Prescriptive Lighting - LED Sign	Not applicable

A.5.3 HVAC

The following sections outline the 2025 TRM updates as they pertain to the following measure groups: hot water boilers, heat pump heating, and air conditioning.

A.5.3.1 Hot water boilers

The 2025 TRM contains 15 NRNC hot water boiler HVAC measures[13]. As indicated in Table A-4, those measures include: boilers, condensing boilers, and non-condensing boilers. Table A-4 summarizes the measures and describes how the ISP changes are applied to the measures in the redlined 2025 TRM document and redlined Appendix A.

Table A-4. Hot water boiler HVAC measures in 2025 TRM

Measure group	Chapter name	Measure name	TRM update
Hot Water Boiler	Boiler	Boiler –d 96% AFUE	Updated text in Baseline Description. Updated Table 11 in Appendix A.
Hot Water Boiler	Boiler	Boiler - 95% AFUE < 300 MBU	Updated text in Baseline Description. Updated measure name. Updated Table 11 in Appendix A.
Hot Water Boiler	Condensing Boiler	Condensing Boiler - <= 300 mbh	Updated text in Baseline Description. Updated Savings Principle. Updated Table 11 in Appendix A.
Hot Water Boiler	Condensing Boiler	Condensing Boiler - 1701+ mbh	Updated text in Baseline Description. Updated Savings Principle. Updated Table 11 in Appendix A.
Hot Water Boiler	Condensing Boiler	Condensing Boiler - 300-499 mbh	Updated text in Baseline Description. Updated Savings Principle. Updated Table 11 in Appendix A.
Hot Water Boiler	Condensing Boiler	Condensing Boiler - 500-999 mbh	Updated text in Baseline Description. Updated Savings Principle. Updated Table 11 in Appendix A.
Hot Water Boiler	Condensing Boiler	Condensing Boiler - 1000-1700 mbh	Updated text in Baseline Description. Updated Savings Principle. Updated Table 11 in Appendix A.
Hot Water Boiler	Condensing Boiler, Custom	Condensing Boiler - ≤300 mbh	Added footnote to Baseline Description.
Hot Water Boiler	Condensing Boiler, Custom	Condensing Boiler - 1701+ mbh	Added footnote to Baseline Description.
Hot Water Boiler	Condensing Boiler, Custom	Condensing Boiler - 300-499 mbh	Added footnote to Baseline Description.
Hot Water Boiler	Condensing Boiler, Custom	Condensing Boiler - 500-999 mbh	Added footnote to Baseline Description.
Hot Water Boiler	Condensing Boiler, Custom	Condensing Boiler - 1000-1700 mbh	Added footnote to Baseline Description.

[13] Only applicable for hot water boilers, does not apply to steam boilers or combination boiler/water heater measures.

Measure group	Chapter name	Measure name	TRM update
Hot Water Boiler	Non-Condensing Boiler	Non-Condensing Boiler - All	Added footnote to Baseline Description.
Hot Water Boiler	Non-Condensing Boiler	Non-Condensing Boiler - Seasonal	Added footnote to Baseline Description.
Hot Water Boiler	Non-Condensing Boiler	Non-Condensing Boiler - Year Round	Added footnote to Baseline Description.

A.5.3.2 Heat pump heating

The 2025 TRM contains eight NRNC heat pump heating measures.[14] As indicated in Table A-5, those measures include: air source heat pumps and VRF heat pumps. Table A-5 summarizes the measures and describes how the ISP changes are applied to the measures in the redlined 2025 TRM document and redlined Appendix A.

Table A-5. Heat pump heating measures in 2025 TRM

Measure group	Chapter name	Measure name	TRM update
Heat Pump Heating	Air Source HP	Air HP - Pkg to 5.4T	Updated text in Baseline Description. Updated Table 8 in Appendix A.
Heat Pump Heating	Air Source HP	Air HP - 5.4-11.25T	Updated text in Baseline Description. Updated Table 8 in Appendix A.
Heat Pump Heating	Air Source HP	Air HP - 11.25-20T	Updated text in Baseline Description. Updated Table 8 in Appendix A.
Heat Pump Heating	Air Source HP	Air HP - over20T	Updated text in Baseline Description. Updated Table 8 in Appendix A.
Heat Pump Heating	VRF HP	VRF HP - 11.25T-20T	Updated text in Baseline Description. Created new Table 22 in Appendix A.
Heat Pump Heating	VRF HP	VRF HP - 5.4T-11.25T	Updated text in Baseline Description. Created new Table 22 in Appendix A.
Heat Pump Heating	VRF HP	VRF HP - over 20T	Updated text in Baseline Description. Created new Table 22 in Appendix A.
Heat Pump Heating	VRF HP	VRF HP - to 5.4T	Updated text in Baseline Description. Created new Table 22 in Appendix A.

A.5.3.3 Air-cooled air conditioning

The 2025 TRM contains five NRNC air-cooled air conditioning measures.[15] As indicated in Table A-6, those measures include: air cooled AC and split-system AC. Table A-6 summarizes the measures and describes how the ISP changes are applied to the measures in the redlined 2025 TRM document and redlined Appendix A.

Table A-6. Air-cooled air conditioning measures in 2025 TRM

Measure group	Chapter name	Measure name	TRM update
Air-Cooled Air Conditioning	Air Cooled AC	Air Cooled AC - 5.4-11.25 T	Updated text in Baseline Description. Updated Table 7 in Appendix A to add this size.
Air-Cooled Air Conditioning	Air Cooled AC	Air Cooled AC - 11.25-20 T	Updated text in Baseline Description. Updated Table 7 in Appendix A to add this size.
Air-Cooled Air Conditioning	Air Cooled AC	Air Cooled AC - 20-63 T	Updated text in Baseline Description. Updated Table 7 in Appendix A to add this size.
Air-Cooled Air Conditioning	Air Cooled AC	Air Cooled AC - over 63 T	Updated text in Baseline Description. Updated Table 7 in Appendix A to add this size.
Air-Cooled Air Conditioning	Air Cooled AC	Split system AC to 5.4 tons	Updated text in Baseline Description. Updated Table 7 in Appendix A.

[14] Water-cooled, ground-source, or packaged terminal heat pump units are not included.
[15] Water-cooled or packaged terminal air conditioner units are not included.

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