RUTGERS
Edward J. Bloustein School
of Planning and Public Policy

MEMORANDUM

TO: BPU: Stacy Ho Richardson, Phil Chao, Rupa Deshmukh
FROM: Center for Urban Policy and Research, Rutgers University
DATE: 08 November 2023
RE: Energy Savings from Building Energy Code Adoption in New Jersey

ABSTRACT

This memo provides a summary of the Triennium 2 (FY 2025 to FY 2027) energy savings attributable to the adoption of ASHRAE 90.1 2019 for new commercial construction and IECC 2021 for new residential construction in New Jersey. Our analysis predicts building-level energy savings by estimating construction trends, compliance rate, and market adoption annually in Triennium 2. We find that the adoption of the residential building energy code, IECC 2021, provides considerably higher savings than the adoption of the commercial building energy code, ASHRAE 90.1 2019. We estimate that in Triennium 2 New Jersey will save between 123,846 to 197,323 MWh of electricity and 438,118 to 704,654 DTh of natural gas. The results are given as a range to account for uncertainty in new construction footprint, compliance rates, and Net-to-Gross ratios.

1. INTRODUCTION

New Jersey is actively working to increase building electrification across the State to help meet Clean Energy goals.[1] One major instrument is the timely adoption of building energy codes, such as IECC and ASHRAE 90.1. Building energy codes serve as an effective and efficient tool to reduce building-level energy use and energy related costs.[2] This report estimates the energy savings attributable to adopting IECC 2021 and ASHRAE 90.1 2019 over Triennium 2 (FY 2025 to 2027).[3]

In New Jersey, the adoption of building codes and building energy code amendments follow the provisions of the Uniform Construction Code Act passed in 1976. The Uniform Construction Code is divided into subcodes, which include the Energy Subcode. The Energy Subcode categorizes buildings based on three factors: use, height, and climatic zones. The Energy Subcode also categorizes buildings into low-rise residential and commercial buildings (including High-Rise Multifamily Buildings). The IECC code applies to low-rise residential buildings and ASHRAE 90.1 applies to commercial buildings and high-rise residential buildings. On September 6, 2022, IECC 2021 and ASHRAE 90.1 2019 were adopted in New Jersey for new construction[4] and enforcement began on March 6, 2023. Prior to the adoption of IECC 2021 and ASHRAE 90.1 2019, IECC 2018 and ASHRAE 90.1 2016 were enforced.

New Jersey Board of Public Utilities (NJBPU) requested this analysis of the energy savings attributable to building energy code adoption for commercial and residential new construction in Triennium 2 (FY 2025 to FY 2027). This analysis estimates a construction footprint for Triennium 2 and models code-compliant new construction across building types specific to New Jersey. Construction trends are estimated with historical (January 2014 to April 2023) Certificate of Occupancy (CO) data, published by the New Jersey Department of Community Affairs (NJ

[1] On February 15, 2023, Governor Phil Murphy outlined six pillars to serve as the foundation for a cleaner, greener, and more resilient New Jersey. These pillars include Executive Order 316 which sets a target to install zero-carbon-emission space heating and cooling systems in 400,000 homes and 20,000 commercial properties and make 10% of all low-to-moderate income (LMI) properties electrification-ready by 2030.

[2] M. Schwarz, C. Nakhle, and C. Knoeri. 2020. "Innovative designs of building energy codes for building decarbonization and their implementation challenges." Journal of Cleaner Production 248.

[3] New Jersey has a 3-year code adoption cycle. However, the United States Department of Energy has not provided affirmative determination of 2024 and ASHRAE 90.1 2022. Therefore, this report assumes that IECC 2022 and ASHRAE 90.1 2019 is in effect throughout Triennium 2.

[4] NJ uses a bespoke code for existing buildings, residential and commercial, the NJ Rehabilitation Subcode.

DCA).[5] Energy savings potential (specific to building occupancy and fuel type) are estimated per U.S. Department of Energy (DOE) prototype models[6] for New Jersey paired with New Jersey-specific Pacific Northwest National Laboratory (PNNL) reports.[7] Energy models are further modified for New Jersey specific industry standard practices.[8] The results from this analysis are used as inputs into CADMUS' energy savings potential study.

The remainder of this report presents the methodology (Section 2), results (Section 3), and conclusions (Section 4).

2. METHODOLOGY

This section provides an overview of the methodology and key assumptions used in our analysis.

A. Attribution Model

The model calculates potential, gross, and net savings (Equations 1-3) to determine the energy savings attributable to IECC 2021 and ASHRAE 90.1 2019 building energy code adoption. Potential savings (Equation 1) are the sum of the product of energy savings and construction footprint for each building occupancy, climate zone, and fuel type for each year. For residential buildings, fuel oil, natural gas, and electricity savings are considered separately for foundation types (slab-on-grade, heated basement, unheated basement, and crawlspace), equipment share (gas furnaces, heat pumps, electric resistance, and oil), ASHRAE climate zone (4A, 5A), and building occupancies (Single-Family and Multifamily). We weighted these building types as per Residential Energy Consumption Survey (RECS) 2020 microdata.[9] (Table 1). For commercial buildings, the construction footprint was specific to building use, and no further adjustments were required.

$$PS_y = \sum_{h\in H}\sum_{z\in Z}\sum_{f\in F}\sum_{t=T} S_{tzf} \times C_{tz} \times W_{thf} \quad (eq.1)$$

PS_y= Potential Savings for year *y*

S_{tzf}= Savings per unit area for building occupancy *t*, climate zone *z*, and fuel type *f*

C_{tzy}= Construction footprint for building occupancy *t*, year *y*, and climate zone *z*

W_{thf} = For residential new construction, weights for building occupancy *t*, heating type *h*, and fuel type *f*; For commercial buildings, this is 1.

Gross savings are the product of potential savings, and compliance rate for each year (Equation 2).

$$GS_y = PS_y \times CR_y \text{ (eq. 2)}$$

GS_y = Gross savings for year *y*

CR_y = Compliance rate for scenario *z*, and year *y*

[5] NJ Department of Community Affairs. 2014-2023. "Construction Reporter". https://www.nj.gov/dca/divisions/codes/reporter/co.html.
[6] Pacific Northwest National Laboratory (PNNL). "Prototype Building Models | Building Energy Codes Program". https://www.energycodes.gov/prototype-building-models.
[7] Salcido, Victor R, Yan Chen, YuLong Xie, and Zachary T Taylor. 2021 "Cost-Effectiveness of the 2021 IECC for Residential Buildings in New Jersey."; Tyler, Matthew, YuLong Xie, Eric Poehlman, and Michael Rosenberg. 2021. "Cost-Effectiveness of ANSI/ASHRAE/IES Standard 90.1-2019 for New Jersey." PNNL-31519, 1854936. https://doi.org/10.2172/1854936.
[8] Rutgers University, and DNV. 2022. "Rutgers New Jersey Commercial New Construction Industry Standard Practice." 2022, 2. ("This study found clear evidence that interior lighting design, which primarily uses LED technology, exceeded the code requirements. The non-participant ISP for interior lighting was 40% better than code, which aligns with results in other jurisdictions for similar code versions. However, the latest version of the energy code in New Jersey (ASHRAE 90.1-2016) increased the stringency of lighting requirements to account for LED market penetration by reducing allowed LPDs for many spaces. DNV estimated the impact of these reductions for the space types observed in the study to be approximately 15%, and thus recommends adjusting the median observation to 25% better than code for application to current and future codes".).
[9] U.S. Energy Information Administration (EIA). 2022. "Residential Energy Consumption Survey 2020." 2022.

The net savings for each year are the product of the gross savings and the Net-to-Gross ratio adjusted for increasing market adoption (Equation 3).

$$NS_y = GS_y \times NTG \times A_y \text{ (eq. 3)}$$

NS_y= Net Savings for year *y*
NTG = Net-to-Gross ratio
A_y = NTG Adjustment factor for year *y*

B. Key Assumptions Common to Residential and Commercial Construction

Study Period Considered
Savings have been aggregated annually for Triennium 2 (FY 2025 to FY 2027). IECC 2021 and ASHRAE 90.1 2019 have been in effect from March 6, 2023 (after a grandfather period of 6 months from September 2022). It should be noted that there may be additional savings during Triennium 2 if IECC 2024 or ASHRAE 90.1 2022 receive an affirmative determination from the U.S. Department of Energy (DOE) and New Jersey subsequently adopts these codes.

Building Codes Considered
We have calculated savings for IECC 2021 for residential new construction (which is not applicable to Multifamily High-Rise) and ASHRAE 90.1 2019 for commercial new construction (which is applicable to Multifamily High-Rise).

Quantifying Uncertainty
We have quantified the uncertainty in the results using three scenarios: Conservative, Middle-of-the-Road, and Optimistic.[10]

Savings Potential Estimated from Historical Construction Footprint Data
We used monthly CO data, aggregated quarterly, from NJ DCA,[5] which is specific to New Jersey's counties and building occupancies. We used data from January 2014 to April 2023. We identified the 3-year period with the minimum and maximum savings yieldable, applying savings reported by PNNL[6,7] to January 2014 and April 2023 CO data.[5] Different building use types have different savings associated with them. To capture the proportion of different building occupancies' contributions to savings, we applied our methodology to the savings potential as opposed to the construction footprint. Outliers were removed from the quarter-level data by removing data that was outside the 25th and 75th percentile.[11]

Adjusting for Industry Standard Practices
The survey-based Rutgers New Jersey Commercial New Construction Industry Standard Practice[8] report found that new construction exceeded ASHRAE 90.1 2016 lighting standards by 15%. The energy models provided by DOE and reports provided by PNNL considered energy savings from increased lighting standards. Therefore, the savings from DOE prototype models[6] and PNNL New Jersey-specific reports[7] may be overestimated. Based on these findings we have updated the original results (Section 3A) to account for the prevalence of above-code lighting as

[10] *Conservative*: Assumes lower bound of construction area, compliance rate does not exceed 0.95 for residential and 0.90 for commercial new construction by the third year of adoption, and we used a reasonably low Net-to-Gross ratio specified in the NJ Technical Reference Manual 2023; *Middle-of-the-road:* Assumes an average of the construction area considered in the Conservative and Optimistic scenario, compliance rate starts off high but does not exceed 0.96 by the third year of adoption with the Net-to-Gross being higher than the Conservative scenario and lower than the Optimistic scenario, but within the range given in the ratio specified in the NJ Technical Reference Manual 2023; *Optimistic:* Assumes the upper bound of construction area, compliance rate increases to 1 by the third year of adoption with a higher Net-to-Gross ratio. Factors considered are provided on page 6.
[11] We have considered a narrow range to limit the variations in the results.

recommended by the Industry Standard Practice report. To adjust for above-code lighting, we modified IECC 2018 and ASHRAE 90.1 2016 DOE prototype models to meet IECC 2021 and ASHRAE 90.1 2019 lighting standards, respectively, for lighting power density. Daylighting controls also were adjusted to be in alignment with IECC 2021 and ASHRAE 90.1 2019. Results accounting for lighting improvements are provided in Section 3B.

C. Key Assumptions Specific to Residential Construction

Typical Unit Area

NJ DCA reports residential new construction COs by the number of units and not the total footprint. New Jersey-specific mean areas for residential units were used, as given in the RECS 2020[9] (Single-Family, Multifamily Low-Rise, and Multifamily High-Rise), to convert the number of units into footprint. ASHRAE 90.1 is applicable to Multifamily High-Rise (not IECC 2021). Hence, we removed Multifamily High-Rise footprints from savings calculations for residential new construction.

Energy Savings per Square Feet

Fuel oil, natural gas, and electricity savings are considered separately for foundation types (slab-on-grade, heated basement, unheated basement, and crawlspace), equipment share (gas furnaces, heat pumps, electric resistance, and oil), climate zone (4A, 5A), and building occupancies (Single-Family and Multifamily). We weighted these building types as per RECS 2020[9] (Table 1).

Table 1 Residential building weighting as per heating fuel type (RECS 2020)

Multipliers	
Electric Resistance	8.85%
Gas Furnace	78.89%
Heat Pump	0.67%
Oil Furnace	11.60%

D. Key Assumptions Specific to Commercial Construction

Construction: Total Footprint

NJ DCA CO data building occupancy categories are different from the ones utilized in the savings produced by PNNL. The DCA categories were re-adjusted to match the PNNL reports. We partitioned the footprint for the Office Category into Small Office and Large Office using the proportion published in the Commercial Building Energy Consumption Survey (CBECS) 2018[12] microdata for the Mid-Atlantic region. We added the footprint for Multifamily High-Rise to the commercial new construction data. Public Assembly, Institutional, and Storage Buildings were combined to form the Other Buildings category. Non-Refrigerated Warehouses formed the majority of COs issued to new construction in the Other Buildings category.

Energy Savings per Square Feet

The Other Buildings category has the highest footprint for new commercial building construction, as reported in the DCA CO data.[5] The Other Buildings category includes Public Assembly Buildings, Institutional Buildings, and Storage Buildings. The majority of the construction footprint can be attributable to buildings categorized as Storage by NJ DCA (e.g., Warehouse). Therefore, we estimated savings for Other Buildings from the savings found using the Warehouse Building model. Adjustment factors (Table 2) were applied across all building occupancies, fuel type, and climate zone to calculate net savings from the potential savings.

[12] U.S. Energy Information Administration (EIA). 2021. "Commercial Building Energy Consumption Survey 2018." 2021. https://www.eia.gov/consumption/commercial/terminology_2012.php.

E. Factors for Calculating Net Savings from Savings Potential

Compliance Curve

To account for the increasing share of buildings in compliance with building energy code over time, we used Rutgers and DNV's New Jersey Energy Code Compliance Study 2022[13] to assign a compliance factor for each scenario and year. The New Jersey Energy Code Compliance Study 2022[13] above was conducted from February 2021 to June 2022 and focused on buildings permitted from 2018 to 2020, during the last two years of the IECC 2015 and ASHRAE 90.1 2013 code cycle. This is the latest New Jersey-specific primary data available. We are evaluating savings for Triennium 2, which corresponds to Year 2 to Year 4 of the current code implementation. We have assumed that the compliance rate from IECC 2015 and ASHRAE 90.1 2013 stays the same for the new codes (IECC 2021 and ASHRAE 90.1 2019).

Net-to-Gross (NTG) Ratio

The NTG ratio is a snapshot in time and accounts for current levels of commercialization, and federal and state standards, as published in DNV's New Jersey Recommended NTG Ratios Overall Report, 2023.[14] The study was based on an extensive literature review. The study established 394 residential and 282 commercial ratios, ranging from 0 to 1. Half of the residential ratios fell between 0.60-0.79, and half of the commercial ratios fell between 0.80-0.99. These numbers were included in the New Jersey 2023 Triennial Technical Reference Manual For 2024 Filings.[15] To reduce the uncertainty, the 25th to 75th percentile of the NTG ratios were considered across measures in this study.

Adjusting the NTG Ratio

To reflect the increasing market adoption of measures included in the building codes from FY 2025 to FY 2027, we have adjusted the NTG ratio over the three-year period. The adjustment progressively decreases savings that can be attributed to the energy code.[16] We use factors ranging from 0% to 2%, as per various industry practices,[17] for each year of code adoption. As earlier noted, IECC 2021 and ASHRAE 90.1 2019 went into effect in March 2023. The adjustment factor is applied from FY 2025 in alignment with the period of this analysis.

The adjustment factors are given in Table 2. The sources for the factors are summarized below:

- Compliance curve considered as per Rutgers and DNV New Jersey Energy Code Compliance Study 2022.[13]
- Net to Gross ratio considered as per DNV's New Jersey Recommended NTG Ratios Overall Report, 2023.[14]
- Range of adjustment (0% to 2%) informed by discussions held with PNNL (Michael Rosenberg and Matthew Taylor) and as published in Energy Code Compliance Improvement Program, 2020 for Illinois report.[17]

[13] Rutgers University, and DNV. 2022. "New Jersey Energy Code Compliance Report." 2022. https://cupr.rutgers.edu/wp-content/uploads/2023/04/Rutgers-New-Jersey-Energy-Code-Compliance-Report_Final_clean-2.pdf.
[14] NMR Group, Inc. 2023. "New Jersey Recommended Net-to-Gross Ratios Overall Report." https://njcleanenergy.com/files/file/BPU/2023/Energy%20Efficiency%20Triennium%202%20Net%20to%20Gross%20Report%20(2023).pdf.
[15] New Jersey Board of Public Utilities. 2023. "New Jersey 2023 Triennial Technical Reference Manual For 2024 Filings."
[16] For the "Optimistic" scenario no such adjustments were made. We used a factor of 0%.
[17] Range of adjustment (0% to 2%) informed by discussions held with PNNL (Michael Rosenberg and Matthew Taylor) and as published in Energy Code Compliance Improvement Program, 2020 for Illinois report.

Table 2 Compliance and adjusted NTG factors considered in this study.

	Compliance Factor					
	Residential			Commercial		
	FY 2025	FY 2026	FY 2027	FY 2025	FY 2026	FY 2027
Conservative	0.85	0.89	0.95	0.84	0.87	0.90
Middle-of-the-Road	0.87	0.92	0.96	0.92	0.94	0.96
Optimistic	0.88	0.94	1.00	0.94	0.97	1.00
	NTG Ratio					
	Residential			Commercial		
	FY 2025	FY 2026	FY 2027	FY 2025	FY 2026	FY 2027
Conservative	0.60	0.60	0.60	0.80	0.80	0.80
Middle-of-the-Road	0.70	0.70	0.70	0.90	0.90	0.90
Optimistic	0.79	0.79	0.79	0.99	0.99	0.99
	NTG Adjustment Factor					
	Residential			Commercial		
	FY 2025	FY 2026	FY 2027	FY 2025	FY 2026	FY 2027
Conservative	0.98	0.96	0.94	0.98	0.96	0.94
Middle-of-the-Road	0.99	0.98	0.97	0.99	0.98	0.97
Optimistic	1.00	1.00	1.00	1.00	1.00	1.00

3. RESULTS

In this section, we present the results of energy savings attributable to the adoption of IECC 2021 (Residential) and ASHRAE 90.1 2019 (Commercial and Multifamily High Rise). Results are provided for Conservative, Middle-of-the-Road, and Optimistic scenarios. We estimated energy savings potential specific to building occupancy and fuel type as per U.S. Department of Energy (DOE) prototype models[6] for New Jersey and New Jersey-specific Pacific Northwest National Laboratory (PNNL) reports.[7] These models are used to simulate buildings complying with IECC and ASHRAE 90.1 for each U.S. state, including New Jersey and for different versions of the codes. We held a detailed discussion with PNNL (Michael Rosenberg and Matthew Tyler) to ensure accuracy in modeling. PNNL also provided a detailed spreadsheet listing savings for residential buildings to support our analysis. Based on the Industry Standard Practice report,[8] we assume that all new construction met IECC 2021 and ASHRAE 90.1 2019 lighting standards prior to their adoption. Therefore, in subsection 3B of the results, we do not consider any improvement in lighting standards that are attributed to code adoption.

A. Savings Under the Original PNNL Results

Total savings for code adoption of IECC 2021 for new construction of residential buildings and ASHRAE 90.1 2019 for new construction of commercial buildings across three years (FY 2025 to FY 2027), based on DOE prototype models[6] and the savings reported in PNNL's reports,[7] are given below in Tables 3 and 4.[18] These results include lighting improvements attributed to code adoption.

Table 3 Total electricity savings in MWh for commercial and residential new construction, PNNL and DOE results

Financial Year	Conservative (MWh)	Middle-of-the-Road (MWh)	Optimistic (MWh)
2025	22,780	30,481	38,108
2026	25,596	31,241	36,177
2027	24,425	32,435	40,973
Total	**72,801**	**94,157**	**115,258**

Table 4 Total gas savings in DTh for commercial and residential new construction, PNNL and DOE results

Financial Year	Conservative (DTh)	Middle-of-the-Road (DTh)	Optimistic (DTh)
2025	19,258	24,900	30,882
2026	19,952	25,058	30,204
2027	19,943	26,860	34,389
Total	**59,154**	**76,818**	**95,475**

Distribution of electricity savings across sectors for Triennium 2:

- Residential 49,706 to 79,280 MWh
- Commercial 23,095 to 35,978 MWh
- Total: 72,801 MWh to 115,258 MWh

Distribution of gas savings across sectors for Triennium 2:

- Residential 70,378 DTh to 112,737 DTh
- Commercial -11,224 DTh to -17,262 DTh
- 59,154 DTh to 95,475 DTh

[18] Numbers might not add up to the total due to rounding.

B. Savings after Accounting for Above-Code Lighting

Total savings for code adoption of IECC 2021 for new construction of residential buildings and ASHRAE 90.1 2019 for new construction of commercial buildings across three years (FY 2025 to FY 2027), adjusted for lighting,[19] are given below in Tables 5 and 6.[18] The results do not consider any improvement in lighting standards that are attributed to adoption of IECC 2021 and ASHRAE 90.1 2019.

Table 5 Total electricity savings in MWh for commercial and residential new construction, removed savings due to lighting

Financial Year	Conservative (MWh)	Middle-of-the-Road (MWh)	Optimistic (MWh)
2025	39,768	50,092	60,188
2026	43,744	54,436	64,739
2027	40,334	55,534	72,396
Total	**123,846**	**160,062**	**197,323**

Table 6 Total gas savings in DTh for commercial and residential new construction, removed savings due to lighting

Financial Year	Conservative (DTh)	Middle-of-the-Road (DTh)	Optimistic (DTh)
2025	140,700	179,205	217,495
2026	156,165	194,144	230,659
2027	141,254	195,734	256,501
Total	**438,118**	**569,083**	**704,654**

Distribution of electricity savings across sectors for Triennium 2:

- Residential: 123,040 MWh to 196,036 MWh
- Commercial: 807 MWh to 1,287 MWh
- Total: 123,846 MWh to 197,323 MWh

Distribution of gas savings across sectors for Triennium 2:

- Residential: 434,513 DTh to 699,072 DTh
- Commercial: 3,605 DTh to 5,582 DTh
- Total: 438,118 DTh to 704,654 DTh

[19] Based on the Industry Standard Practice report, we assume that all new construction met IECC 2021 and ASHRAE 90.1 2019 lighting standards prior to their adoption. Hence, in the results shown in Section 3B, we do not consider any improvement in lighting standards that are attributed to code adoption.

4. CONCLUSIONS AND FURTHER WORK

Our key takeaways from this energy code savings attribution analysis are as follows.

1) The impact of code adoption in the residential sector is considerably higher than in the commercial sector.
2) Improvements in lighting standards reduce heating savings considerably due to reduced internal gains and a higher heating load.
3) Construction volume and compliance rates in New Jersey are the highest source of uncertainty in estimating savings due to code adoption.

Additional studies in the pipeline may help enhance these results, e.g., NMR's New Jersey Residential Appliance Saturation Study (RASS) study, DNV's Commercial & Industrial Baseline Study, and the DNV's forthcoming Net to Gross Evaluation. The attributable savings from the adoption of building energy code (IECC 2021 for new construction of residential buildings and ASHRAE 90.1 2019 for new construction of commercial buildings) for Triennium 2 (FY 2025 to FY 2027) have been input into CADMUS' rerun of energy savings potential scenarios for New Jersey. The attributable savings for the revisions are from the Middle-of-the-Road scenario with adjustments made for above-code lighting, as shown in Tables 5 and 6 in Section 3B.