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New York State Energy Code Compliance Study:

Commercial Alteration Projects Permitted Under the ECCCNYS-2010

Final Report

March 2015

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New York State Energy Code Compliance Study:
Commercial Alteration Projects Permitted Under the ECCCNYS-2010

Final Report

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NYSERDA Contract 18679 March 2015

Notice

This report was prepared by Cadmus, referred to as the project team, with help from T.Y.Lin International Group (T.Y.Lin) and Population Research Systems (PRS) in the course of performing work contracted for and sponsored by the New York State Energy Research and Development Authority (hereafter "NYSERDA"). The opinions expressed in this report do not necessarily reflect those of NYSERDA or the State of New York, and reference to any specific product, service, process, or method does not constitute an implied or expressed recommendation or endorsement of it. Further, NYSERDA, the State of New York, and the contractor make no warranties or representations, expressed or implied, as to the fitness for particular purpose or merchantability of any product, apparatus, or service, or the usefulness, completeness, or accuracy of any processes, methods, or other information contained, described, disclosed, or referred to in this report. NYSERDA, the State of New York, and the contractor make no representation that the use of any product, apparatus, process, method, or other information will not infringe privately owned rights and will assume no liability for any loss, injury, or damage resulting from, or occurring in connection with, the use of information contained, described, disclosed, or referred to in this report.

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Abstract

This report presents the results of an energy code compliance study for commercial alterations in New York State (NYS). As part of the American Recovery and Reinvestment Act of 2009 (ARRA) legislation, NYS is committed to ensuring that new and renovated residential and commercial buildings exceed the 90% compliance threshold with the Energy Conservation Construction Code of New York State – 2010 (ECCCNYS-2010) by 2017. To assess the code compliance in NYS, this research examined 78 permitted commercial building alterations projects including projects including 15 non-New York City projects and 63 New York City Projects. The research determined the degree of compliance based on energy performance of the project by conducting energy modeling and engineering calculations to estimate the energy consumption and savings. The results of the research show that code compliance and energy efficiency of alterations exceeded the minimum level required by code overall for all Climate Zones in NYS. The overall compliance with the energy code for alterations is relatively high; however, this study recommends establishing a statewide, consistently formatted database of permit information to enhance the code enforcement and compliance processes for commercial building alterations in NYS. The study also recommends that trainings on requirements of the energy code, especially for controls for mechanical systems and lighting, and requiring building facility staff to maintain code compliance information on site would also contribute to the code enforcement and compliance processes.

Acknowledgements

The project team would like to thank the following individuals:

NYSERDA	Marilyn Kaplan
	Christopher V. Sgroi
	Jonathan Steiner
	Rebecca Reed
New York Department of State	George Morehouse
	Joseph Hill
T.Y. Lin International Group	Scott Copp
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Executive Summary

In November 2012, the New York State Energy Research and Development Authority (NYSERDA) authorized Cadmus to complete an energy code compliance assessment (Code Compliance Study) for commercial alterations in New York State. This Code Compliance Study is a follow up to the previous report Cadmus prepared for NYSERDA that presented the impact evaluations of several NYSERDA programs conducted under the American Recovery and Reinvestment Act of 2009 (ARRA).

This Code Compliance Study focused on compliance of commercial building alterations with the Energy Conservation Construction Code of New York State – 2010 (ECCCNYS-2010), which took effect in December 2010.

The information from this study is intended to inform NYSERDA about energy code compliance of commercial building alterations and to inform NYSERDA's Energy Codes Training and Support Initiative, which supports the design and construction communities in the transition to a more energy-efficient built environment. In accordance with ARRA, NYS is committed to ensuring that new and altered residential and commercial buildings achieve a minimum of 90% compliance with the ECCCNYS-2010 by 2017.

Research tasks completed to fulfill study objectives included the following:

- Develop a systematic approach for assessing Commercial Alteration building projects in the context of requirements established in the ECCCNYS-2010 and the Existing Building Code of New York State (EBCNYS).
- Develop a sampling methodology and plan to gather completed alteration projects permitted for construction under the ECCCNYS-2010.
- Develop a permit data collection tool specific to the requirements of the ECCCNYS-2010 and EBCNYS to gather and record information needed to assess code compliance of selected projects at the permitting and post-construction stages.
- Collect building plans and permit documentation for selected projects.
- Conduct site visits of the selected projects and collect post-alteration compliance data.
- Complete data analysis based on review of post-construction data.
- Compile the results of data analysis to determine compliance rates for commercial alteration projects at post-construction.

Commercial building alteration data for the period January 1, 2011 through December 31, 2012 was used to develop samples and extrapolate results.

E.1 Methodology

The project team developed a comprehensive research framework to assess statewide compliance of commercial building alteration projects in NYS with the ECCCNYS-2010. Compliance is determined by comparing the energy use of buildings as if they were altered to fully comply with the ECCCNYS-2010 or ASHRAE 90.1-2007[1] or, in NYC, the 2011 New York City Energy Conservation Code[2] (NYCECC-2011), to the energy use based on actual, installed conditions. For consistency, Cadmus based the analysis approach on ASHRAE 90.1-2007 unless a project's permit documentation indicated that the project was permitted based on compliance with ECCCNYS-2010 or NYCECC-2011. Assessing compliance based on the code selected to demonstrate compliance, or ASHRAE 90.1-2007 when information is not available on which code was selected, is similar to the approach recommended by the Pacific Northwest National Laboratory (PNNL) and the U.S. Department of Energy (DOE) in their original code compliance assessment guidance under ARRA.

Alteration projects that affect energy performance impact one or more of the building systems, including: envelope, lighting, service water heating and heating, ventilation and air-conditioning (HVAC). Cadmus targeted 76 to 108 permitted commercial building alterations projects throughout the state for the on-site data collection sample and analysis. The number completed was dependent on how many projects required building simulation analyses. The project team completed the study with 78 permitted commercial building alterations projects including 15 non-New York City projects (Group A) and 63 New York City Projects (Group B). Data sources included a combination of permit data (where available), building documentation/drawings, on-site inspection and interviews with site contacts and architectural and engineering firms involved with the project.

The project team used the code requirements of each compliance path to determine if a system or multiple systems met the requisite efficiency standards. Subsequently, the project team determined the degree of compliance based on energy performance (expressed by both an Energy Compliance Index (ECI) and Savings Compliance Margin (SCM))) by conducting energy modeling and engineering calculations to estimate the energy consumption and savings. The methodology selected for each project was based on the following considerations:

- **Energy Modeling:** Energy modeling, also referred to as whole-building modeling, was used to analyze alteration projects affecting lighting, building space heating, cooling, or water heating loads. Additionally, if a project altered multiple building systems (e.g., envelope and HVAC), all altered building systems were included in the project's energy model. Energy models account for the interactive effects resulting from the installed measures and thus estimate full effects on building loads.
- **Engineering Analysis:** Cadmus used engineering analysis to calculate the lighting power densities of altered lighting systems. Lighting power densities were input to the energy model to account for the interactive effects with other building systems in a building.

[1] ASHRAE Standard 90.1-2007 Energy Standard for Buildings Except for Low-Rise Residential Buildings(ASHRAE 90.1-2007)

[2] Comprised of the ECCCNYS-2010, Local Law 85 of 2009, Local Law 48 of 2010 and Local Law 1 of 2011

E.2 Sampling Approach

The project team drew a sample of commercial building alteration projects through a framework consistent with the methodology for code compliance evaluation developed by PNNL. While the sample design maintains methodological consistency, it builds upon PNNL's approach by incorporating McGraw-Hill Dodge (Dodge) data specific to alterations and including a larger sample size to account for potentially high degrees of variation in alteration projects when compared to new construction.

The PNNL guideline require a minimum sample size of 44 sites. This sample size is based on a power calculation to test the hypothesis that the compliance rate is 90% or greater. This study used a sample of 78 sites based on budget, accuracy, and analysis tradeoffs.

The Dodge data was the primary data source for the sample design. This data includes project details and location for all permits issued for commercial alterations for 2011 and 2012. For the Group B sample, a detailed permit database extract was available at the NYC Department of Buildings (NYCDOB) website.[3] This data was used to develop size allocations. However, for aggregation purposes, these project counts were adjusted proportional to the Dodge project counts to ensure consistency in the weighting scheme.

The PNNL guideline for sample design specifies a two-stage process starting with jurisdiction selection, followed by site selection, and it emphasizes the need for representativeness. The study sample allocation follows the PNNL guideline, albeit with an expanded sample size. The study team created a list containing one entry for each relevant project by county. This list was then randomly sorted and the first 100 entries selected, providing the allocation of site visits needed by county.

E.3 Recruitment and Data Collection

Cadmus coordinated with the Department of State, Division of Building Standards and Codes (DOS) to issue an official letter to all jurisdictions included in the Sample Frame, requesting a list of all projects that met the following criteria:

- The project qualified as a commercial alteration.
- The project was permitted under the ECCCNYS-2010.
- The permit was approved with a permit application date between January 1, 2011 and December 31, 2012.

[3] http://www.nyc.gov/html/dob//html/codes_and_reference_materials/foilmonthly.shtml#permit

For Group A projects, the project team called sample jurisdictions and followed up with a letter describing study objectives and project selection criteria. When a jurisdiction declined to participate, the project team substituted a jurisdiction in an adjacent county in the same Climate Zone in order to maintain consistency in the sample. Based on the sampling approach, a goal of recruiting 25 projects was established and 27 projects were recruited.

For Group B (NYC), the NYCDOB website provided monthly statistical reports for permitted projects, and additional project-level details for the permitted projects was available from the Building Information System website. All projects were screened and a sample of qualifying projects created. Anticipating cancellation and rescheduling needs, 120 projects were recruited to reach the initial target of 75 projects.

Cadmus developed tablet-based software for site visits to collect all key data necessary for verifying code compliance and analyzing energy use. This software is a front end for a File Maker Pro back-end database that allows field engineers to enter building and equipment characteristics directly into a database while on site. Collected data was synched to the master database, compiled and reviewed.

Wherever available, field engineers reviewed relevant documentation prior to the site visit. Documentation often consisted of building code department forms, building plans obtained through e-mail from the recruitment phones calls and notes from recruitment phone calls. Field engineers used this data to identify the scope of the alteration project, resolve any technical issues relating to the project prior to the site visit, and begin pre-populating the data collection tool.

Site visits confirmed the scope of the alteration, verified installation, and collected site-specific information to model the energy consumption of the alteration project. The project team conducted 78 site visits, 19% in Group A and 81% in Group B. Table 4 shows a breakout of site visits by location. Field engineers interviewed facility staff, recorded the necessary data, and took photos of all relevant documents. After engineers completed each site visit and downloaded data from the data collection tool database, the project team reviewed the data for each site and checked for quality control. All quality-control comments and questions from this review were recorded and circulated to field engineers responsible for providing clarification and missing information.

E.4 Data Analysis

This study applied three metrics to assess how well alterations complied with code requirements in terms of their energy impacts. The first provided a measure of the *absolute* energy use of the altered space, as installed, compared to its use if the alteration had just complied with the energy code. The second provided a *relative* indicator of the space's energy use compared to its use if the alteration had just complied with the code. The third also provided a *relative* measure of compliance based on how much energy the project saved compared to what it would use if it just met the code. All three metrics required determining the energy performance of each building alteration under two conditions:

1. As-Installed Condition based on on-site verification and documentation of the alteration; and,
2. Code Baseline Condition ECCCNYS-2010/ASHRAE 90.1-2007 or NYCECC-2011 applied to the alteration.

The first metric calculates the annual energy savings by determining the difference between the As-Installed Condition energy performance to and the Code Baseline Condition performance to calculate annual energy savings relative to the code. The second metric, the Energy Compliance Index (ECI), was developed as a consistent metric of the relative performance of the alterations' As-Installed Condition energy consumption. It can be expressed as a ratio or percentage. The ECI, when expressed as a percentage, indicates how much more (>100%) or less (<100%) energy the as-installed-alteration consumes relative to its consumption if it just met the code.[4] To provide a more intuitive and direct indicator of the savings of the As-Installed Condition of the alteration, our team also calculated the Savings Compliance Margin (SCM)—the value of the SCM indicates how much the project saves relative to what it would use if it just met the code. The SCM is positive when the alteration saves energy compared to what it would have used if it just met the code. When the SCM is negative, it indicates the alteration uses more energy than it would have if it just met the code. We report the value of the SCM as a percentage of the alteration energy use if it just met the code.

Cadmus used building energy simulations to analyze envelope alterations, lighting alterations, HVAC upgrades, and service water heating system replacements. If a project altered multiple building systems that have interactive effects (e.g., envelope and HVAC), the altered building systems were included in the energy model. Energy models were built using eQUEST 3.64, a DOE-2-based whole-building energy analysis simulation tool that performs hourly analyses for 8,760 hours (annual simulation) using typical meteorological year (TMY-2) weather data to predict energy demand and consumption.

To develop the energy models, Cadmus used the following two categories of model inputs:

1. **Altered building systems**. These are building systems that are directly related to the alteration project for which data were collected during the site visit.
2. **Non-altered building systems**. These refer to building systems that impact the energy consumption, but were not replaced or altered as part of the scope of the project. During on-site verification, as much information as possible was collected pertaining to these non-altered building systems. When details for non-altered building systems were not available, default values found in widely used references were used to provide the energy model inputs for these systems.

[4] This metric is similar to the HERS Index and the new Energy Rating Index.

In addition to reporting aggregate energy impacts of each alteration project, energy impacts associated with each measure were assessed independently for projects that underwent alterations involving multiple building systems. The project team used engineering calculations to estimate the energy impacts from lighting alteration projects by applying the ASHRAE 90.1-2007 Space by Space Method or the ASHRAE 90.1-2007 Building Area Method (unless a different compliance path was indicated in the permit documentation).

The project team aggregated the results using sample weights to provide statewide values for both the ECI and energy savings beyond the level required by code.

E.5 Results

Because this study focused on code compliance, the primary outcomes of interest for this study are (1) the statewide ECI, defined as the ratio of As-Installed Condition energy consumption to Code-Baseline Condition energy consumption and (2) the SCM, defined as the percentage savings of the alteration relative to energy use if the alteration just met the code. ECI values less than 100%indicate that the As-Installed Condition uses less energy than it would if it just met the code and energy performance is better than if the project were minimally code compliant. SCM values greater than zero indicate the project saves energy compared to what it would have used if it just met the code. The table below shows the final ECI results for commercial alterations by Climate Zone and statewide. The table also shows the Savings Compliance Margin, which is the energy savings relative to the Code Baseline Condition; the Savings Compliance Margin is positive when a project performs better than code requires and negative when it does not perform as well as code requires.

Table ES-1. Energy Compliance Index and Savings Compliance Margin Results by Climate Zone

Climate Zone	Energy Compliance Index			Relative Precision (90% confidence level)		
	Electric	Gas	Total	Electric	Gas	Total
4	99%	98%	99%	±0.6%	±0.9%	±0.5%
5	92%	104%	97%	±2.3%	±2.7%	±0.9%
6	91%	91%	91%	±1.7%	±3.1%	±2.0%
Statewide	**99%**	**98%**	**98%**	**±0.5%**	**±0.8%**	**±0.6%**

Climate Zone	Savings Compliance Margin*		
	Electric	Gas	Total
4	**1%**	**2%**	**1%**
5	**8%**	**-4%**	**3%**
6	**9%**	**9%**	**9%**
Statewide	**1%**	**2%**	**2%**

***The same precision values apply to the ECI and SCM estimates.**

The statewide code Savings Compliance Margin indicates alteration projects, on the average, use 1% less electricity, 2% less gas, and 2% less energy overall than the maximum allowed under the code. Although most SCM values showed the compliance margin was positive, the value for gas in Climate Zone 5 was negative, indicating alterations used more gas than the maximum allowed under the code. The average ECI based on total energy associated with sampled commercial building alteration projects (electricity plus natural gas) is less than 100% for all Climate Zones and for the state overall, indicating that energy efficiency of alterations exceeded the minimum level required by code overall. The results in all cases are estimated well within a sampling error of 10% relative precision at the 90% confidence level, largely due to a very low level of variation in the data.

Despite these positive findings regarding code compliance, it is necessary to qualify these results. The main caveat is that the sample sizes in Climate Zones 5 and 6 were so small (9 and 3, respectively) that the compliance results are not likely to be as accurate as the calculated precision suggests. The precision is determined based on appropriate statistical calculations, but it is valid only if the projects in the sample are truly representative of the entire population of alterations in these climate zones and the population is very homogeneous. In Climate Zone 6, we tried to recruit projects from several counties, but all three projects we were able to analyze were from a single county. Because the SCM and ECI compliance results for the projects sampled in Climate Zones 5 and 6 fell in a narrow range, the calculated precision was small. But given the small sample sizes in these climate zones, we believe that the calculated precision understates how much compliance actually varies across all alterations in these areas and that there are likely to be locations or project types, not captured in the samples we studied, that have less favorable compliance.

The table below shows ECIs by system, aggregated across Climate Zones. The results do not differ significantly among systems, with all ECIs between 96% and 100%. The estimates for both the water heating (DHW) and mechanical systems, however, are relatively imprecise because the results vary significantly by project.

Table ES-2. Energy Compliance Index Results by System

System	Energy Compliance Index	Precision (90%)
Envelope	100%	±3.1%
Lighting	98%	±6.2%
Mechanical	96%	±11.3%
DHW	96%	±21.9%

Overall, these findings indicated that, from an energy perspective, commercial alterations in the state met or exceeded minimum compliance levels, on the average. This finding was consistent across Climate Zones and major systems. However, as noted above, these findings must be caveated in Climate Zones 5 and 6 because of the small samples studied.

In addition to providing a measure of code compliance, this study assessed how much the degree to which commercial alteration projects complied with the code affected building energy consumption. The project team calculated the energy impact of each project as the difference between Code-Baseline Condition energy consumption and the As-Installed Condition energy consumption. In alterations affecting only one fuel type (electricity or gas), the analysis considered only the affected energy type. In alterations comprising multiple systems, our approach analyzed the alterations sequentially to show incremental and interactive impacts. For projects with multiple alterations affecting different electric and gas end uses, the combined energy (electric and gas) impacts were accounted for.

The results shown in the next table indicate that overall substantial savings are realized due to alterations exceeding the energy code. It is estimated that alterations conducted over the study period saved a total of 807,823 MMBtu per year more than they would have if they just met the energy code, equivalent to approximately 0.07% of total energy consumption in the state's commercial building sector. The relative precision of the estimates is large because energy savings vary dramatically by building type, size and nature of alteration.

Table ES-3. Total Energy Savings over Minimum Code Compliance by Climate Zone

Climate Zone	Total Savings (MMBtu)			Relative Precision (90%)		
	Electric	Gas	Total	Electric	Gas	Total
4	117,507	562,945	680,452	±112.3%	±83.9%	±83.9%
5	113,906	-35,730	78,177	±60.6%	±422.5%	±160.7%
6	19,407	29,788	49,194	±148.2%	±338.9%	±236.4%
Statewide	**250,820**	**557,003**	**807,823**	**±58.4%**	**±88.6%**	**±72.3%**

E.6 Recommendations

The study team developed two sets of recommendations: one is meant to inform future code compliance studies and the other relates to ways to improve the compliance and enforcement process. Key recommendations about code compliance studies include the following:

- **Target the study to emphasize the most critical research needs:** Assessing code compliance comprehensively is a complex, resource-intensive process so decisions must be made about where to focus limited resources such as limiting the study to focus on elements of the code that have changed from one cycle to the next or code requirements or energy measures documented to have low compliance.
- **Work closely with Department of State (DOS) and New York City Department of Buildings (NYCDOB) to plan and conduct the study:** Both organizations have contact information and data that can help inform the research.
- **Engage municipalities in the study:** It is important to communicate the purpose of the study and the utility of the information it will provide, and to reinforce the confidentiality (to the extent permitted by law) of all collected information. It is very beneficial to have a former CEO with a strong network as a member of the study team.

- **Obtain the best possible data on building starts throughout the state:** The best data sources are permit lists from jurisdictions coordinated by DOS, or utility new building connection data.
- **Select an oversample of jurisdictions and building projects:** Because attrition is common in these studies, it is important to design a sample that allows for substitution of jurisdictions and buildings as needed. An oversample of at least 50% is recommended.
- **Minimize self-selection bias:** The researchers should identify what factors might distinguish unique characteristics that would undermine representativeness and review the sample of projects as they are recruited to detect any bias in its makeup. One means to encourage diverse participation is to offer financial or other incentives to participants, such as a brief summary of findings on their project.
- **Engage the building industry and owners/occupants in the study:** If buildings are studied before occupancy, owners and contractors must be engaged to allow site visits. For commercial buildings, it is critical to involve a facility manager or someone most familiar with the energy aspects of the building. The study team should identify incentives to encourage participation, such as a commitment to share the study findings or a financial incentive.
- **Examine options for integrating building code compliance characteristics, billing data, and modeled energy impacts:** Developing predictive relationships of actual energy impacts of various degrees of code compliance based on billing data and simulation models could provide a cost-effective means to minimize the amount of building modeling required. Such approaches are still in the concept stage and would require research such as simulation model analyses of a range of building characteristics that affect energy use and calibrated building simulations to adjust simulation model estimates.

Although overall compliance with the energy code for alterations appeared to be relatively high, there were areas in which key improvements could be made and our team recommends the following steps to improve enforcement and compliance:

- **Establish a statewide, consistently formatted database of permit information:** Because determining code compliance, trends, and impacts is likely to become increasingly important, the state should investigate ways to establish such a database with consistent data fields.
- **Commercial alteration projects should be required to maintain code compliance information on site:** For all projects, including small alterations, information about the project should be required to be retained on site.
- **CEOs should scrutinize lighting alterations more in areas that are not regularly occupied:** Non-compliance in lighting projects was only found in areas generally not consistently occupied, such as lobbies, corridors, storage areas and basements.
- **More emphasis should be placed on increasing enforcement and compliance related to controls:** Gaps exist at the facilities in knowledge and understanding of controls for mechanical systems and lighting. Facility staff often had little familiarity with HVAC controls or could not explain energy management system functionality. CEOs should be more fully trained on requirements for controls, including exemptions, and require that proper documentation is maintained on site.

1 Introduction

1.1 Background

In November 2012, the New York State Energy Research and Development Authority (NYSERDA) authorized Cadmus to complete an energy code compliance assessment (Code Compliance Study) for commercial alterations in New York State[5]. This Code Compliance Study is a follow up to the previous report Cadmus prepared for NYSERDA that presented the impact evaluations of several NYSERDA programs conducted under the American Recovery and Reinvestment Act of 2009 (ARRA).

This Code Compliance Study focused on compliance with the Energy Conservation Construction Code of New York State – 2010 (ECCCNYS-2010), which took effect in December 2010. Although initial discussions between NYSERDA and Cadmus considered both residential and commercial buildings as potential subjects, ultimately the study scope targeted only commercial building alterations.

The information from this study is intended to inform NYSERDA about energy code compliance of commercial building alterations and to inform NYSERDA's Energy Codes Training and Support Initiative, which supports the design and construction communities in the transition to a more energy-efficient built environment. In accordance with ARRA, NYS is committed to ensuring that new and altered residential and commercial buildings achieve a minimum of 90% compliance with the ECCCNYS-2010 by 2017.

1.2 Research Objectives

The research objectives encompassed the following tasks:

- Develop a systematic approach for assessing Commercial Alteration building projects in the context of requirements established in the ECCCNYS-2010 and the Existing Building Code of New York State (EBCNYS).
- Develop a sampling methodology and plan to gather completed alteration projects permitted for construction under the ECCCNYS-2010.
- Develop a permit data collection tool specific to the requirements of the ECCCNYS-2010 and EBCNYS to gather and record information needed to assess code compliance of selected projects at the permitting and post-construction stages.

[5] The contract was fully executed in June 2013. The initial study schedule anticipated completing the project by the end of 2013, but this schedule was modified due to early delays in finalizing the contract. In addition, challenges obtaining permit information from jurisdictions, identifying a source of permit data for New York City, and recruiting project sites pushed initial field data collection back to November 2013. Data analysis and reporting were completed during the first half of 2014.

- Collect building plans and permit documentation for selected projects.
- Conduct site visits of the selected projects and collect post-alteration compliance data.
- Complete data analysis based on review of the permit data and review of post-construction data.
- Compile the results of data analysis to determine compliance rates for commercial alteration projects at point of permit and at post-construction.

In the course of conducting the project, Cadmus narrowed the analysis down to information from building site visits and eliminated the analysis of compliance based on permit data. This was necessary because the New York City Department of Buildings (NYCDOB) was unable to collaborate and provide permit information for NYC and Cadmus had limited success in jurisdictions outside of NYC.

Commercial building alteration data for the period January 1, 2011 through December 31, 2012 was used to develop samples and extrapolate results.

1.3 Organization of the Report

This report consists of four chapters followed by several appendices. Chapter 2 summarizes the study methodology. Chapter 3 provides the compliance assessment results and findings for commercial building alterations. Chapter 4 discusses the challenges that Cadmus encountered conducting this study and provides recommendations. Supporting documents are presented in appendices.

2 Methodology

2.1 Compliance Assessment Framework

Cadmus developed a comprehensive research framework to assess statewide compliance of commercial building alteration projects in NYS with the ECCCNYS-2010. Compliance is determined by comparing the energy use of buildings as if they were altered to fully comply with the ECCCNYS-2010 or ASHRAE 90.1-2007[6] or, in NYC, the 2011 New York City Energy Conservation Code[7] (NYCECC-2011), to the energy use based on actual, installed conditions.

According to Chapter 5 (Commercial Energy Efficiency), Section 501.1 (Scope) of the ECCCNYS-2010, energy code compliance can be met in one of two ways:

1. Commercial buildings can meet the requirements defined by ASHRAE Standard 90.1-2007 Energy Standard for Buildings Except for Low-Rise Residential Buildings(ASHRAE 90.1-2007); or,
2. Commercial buildings can meet the requirements defined in Chapter 5 of the ECCCNYS-2010.

For consistency, Cadmus based the analysis approach on ASHRAE 90.1-2007 unless a project's permit documentation indicated that the project was permitted based on compliance with ECCCNYS-2010 or NYCECC-2011 (See Appendix A: List of Site Visits). The ECCCNYS-2010 is based on the International Energy Conservation Code (IECC) 2009, with some state-specific adjustments. The majority of mandatory efficiency requirements are the same between the two codes.[8] Assessing compliance based on the code selected to demonstrate compliance, or ASHRAE 90.1-2007 when information is not available on which code was selected, is similar to the approach recommended by the Pacific Northwest National Laboratory (PNNL) and the U.S. Department of Energy (DOE).

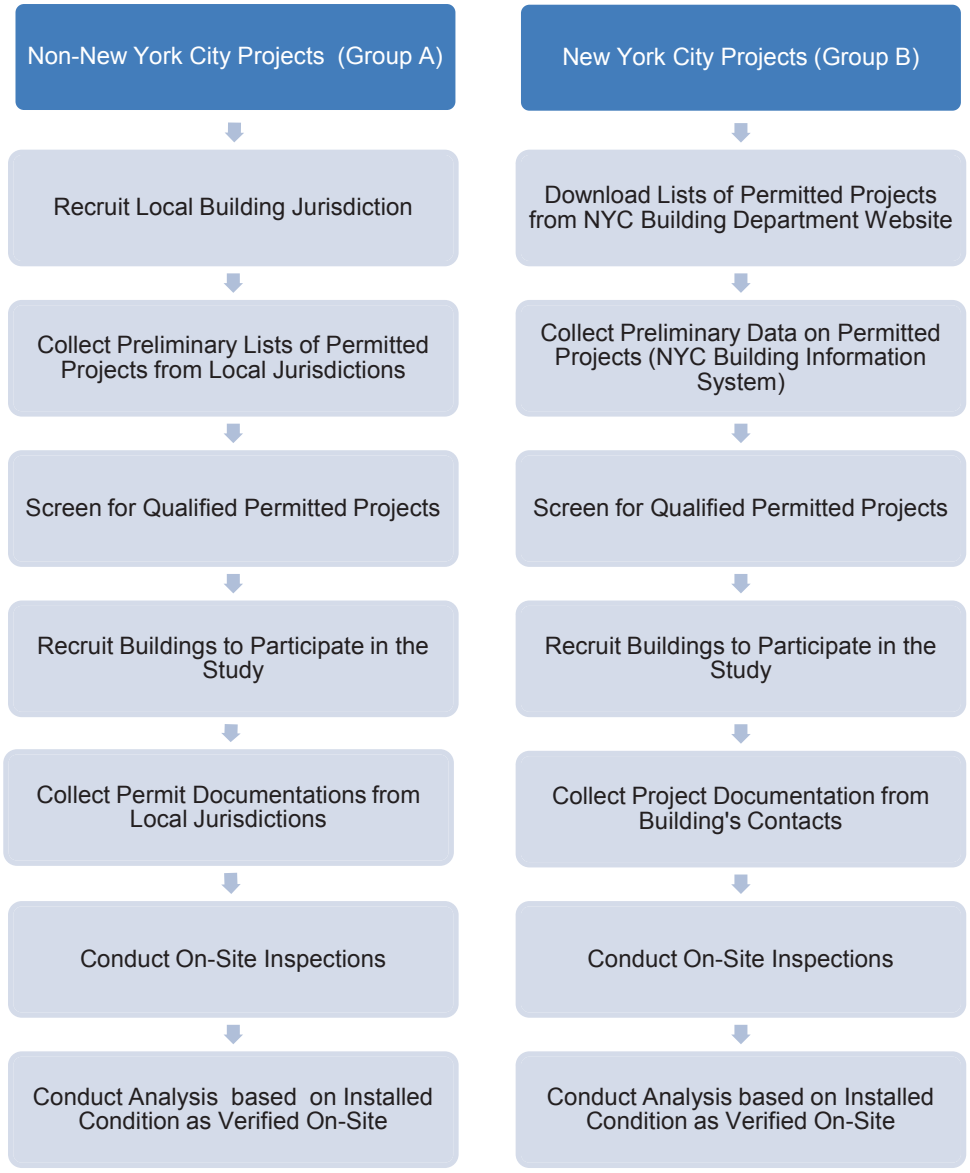
For this study, Cadmus created a framework to assess code compliance for commercial alterations in the state. Figure 1 illustrates the generic steps of the framework that Cadmus took to implement this project.

[6] ASHRAE Standard 90.1-2007 Energy Standard for Buildings Except for Low-Rise Residential Buildings (ASHRAE 90.1-2007)

[7] Comprised of the ECCCNYS-2010, Local Law 85 of 2009, Local Law 48 of 2010 and Local Law 1 of 2011

[8] https://www.energycodes.gov/sites/default/files/documents/90-1_iecc_comparison_final_12-16-2009.pdf

Figure 1. Steps to Implementing the Code Compliance Study



Alteration projects that affect energy performance impact one or more of the building systems, including: envelope, lighting, service water heating and heating, ventilation and air-conditioning (HVAC). Cadmus targeted at least 76 permitted commercial building alterations projects throughout the state for the on-site data collection sample and completed the study with 78 permitted commercial building alterations projects including 15 non-New York City projects (Group A) and 63 New York City Projects (Group B). The project team recruited 27 non-New York City projects and 120 New York City projects for possible site visits. Data sources included a combination of permit data (where available), building documentation/drawings, on-site inspection and interviews with site contacts and architectural and engineering firms involved with the project.

Cadmus sought to collect project-specific data as follows:

1. Pre-Site Visits: For sites located outside of NYC, referred to as Group A, permit documentation was sought from local building jurisdictions offices. For sites within NYC, referred to as Group B, project team obtained a list of permitted projects from the NYCDOB website9.
2. On-Site Inspections: Cadmus collected data to develop the inputs for energy models and engineering calculations to estimate the energy impacts from projects in the sample from on-site inspections and telephone interviews with owners and/or site contacts, and involved architectural and engineering firms.

The requirements stipulated in the energy codes (ECCCNYS-2010, ASHRAE 90.1-2007, or NYCECC-2011) outline the efficiency standards for the systems in the scope of alteration projects, including the following characteristics for each system:

- Envelope systems: insulation *R*-values; fenestration *U*-factors; solar heat gain coefficients (SHGC); moisture control; air barrier; and sealing and air tightness.
- HVAC and service hot water systems: equipment sizing; equipment efficiencies; controls requirements; air and water-side economizers; energy recovery controls; duct sealing; and duct and piping insulation.
- Lighting and power systems: allowable interior and exterior lighting wattage; fixtures; lamp, ballast and transformer efficiencies; lighting controls systems; and dwelling unit meters.

Compliance with energy codes is demonstrated by choosing a compliance path, although this selection is not always documented in building permit application materials. For Group A projects, the project team determined the compliance path by referencing the building documentation collected during project site visits (if not obtained from the building department). For Group B projects, in the absence of code compliance documentation, the project team determined the compliance path by the scope of alteration and the requirements under ASHRAE 90.1-2007 unless another compliance path was otherwise identified. Compliance options included the following:

- Building envelope: mandatory plus prescriptive (*R*-value); mandatory plus prescriptive (*U*-factor); or mandatory plus envelope trade-off (used only if permit documentation identified the trade-off compliance path).
- HVAC: mandatory plus prescriptive (the simplified approach option was used only if permit documentation indicated it was used to demonstrate compliance).
- Service water heating: mandatory plus prescriptive.
- Lighting: mandatory plus space-by-space option.

[9] http://www.nyc.gov/html/dob//html/codes_and_reference_materials/foilmonthly.shtml#permit

The project team used the code requirements of each compliance path to determine if a system or multiple systems met the requisite efficiency standards. Subsequently, the project team determined the degree of compliance based on energy performance (expressed by an Energy Compliance Index (ECI) and Savings Compliance Margin (SCM)) by conducting energy modeling and/or engineering calculations to estimate the energy consumption and savings. The methodology selected for each project was based on the following considerations:

- **Energy Modeling:** Energy modeling, also referred to as whole-building modeling, was used to analyze alteration projects affecting lighting, building space heating, cooling, or water heating loads. These projects include envelope improvements, lighting and HVAC alterations and service water heater replacements. Additionally, if a project altered multiple building systems (e.g., envelope and HVAC), all altered building systems were included in the project's energy model. Energy models account for the interactive effects resulting from the installed measures and thus estimate fill effects on building loads.
- **Engineering Analysis:** Cadmus used engineering analysis to calculate the lighting power densities of altered lighting systems. Lighting power densities were input to the energy model to account for the interactive effects with other building systems in a building.

The details of energy modeling and engineering analysis are discussed in Chapter 2.6 - Compliance and Energy Analysis Methodology.

The analysis approach varied based on the alteration type, as illustrated in Table 1. For the majority of projects in the sample, analysis was based on the prescriptive compliance path, as required by ASHRAE 90.1-2007, unless indicated otherwise (e.g., ECCCNYS-2010 or NYCECC-2011) in the permit documentations.

Table 1. Summary of Analysis Methodology by Type of Alteration

Type of Alteration	Analysis Methodology
HVAC Only	Modeling
Service Water Heating Only	Modeling
Envelope Only	Modeling
Lighting Only	Modeling and Engineering Analysis
HVAC and Envelope	Modeling
Service Water Heating and Envelope	Modeling
HVAC and Lighting	Modeling and Engineering Analysis
Service Water Heating and Lighting	Modeling and Engineering Analysis
Envelope and Lighting	Modeling and Engineering Analysis
HVAC, Service Water Heating, Envelope and Lighting	Modeling and Engineering Analysis

2.1.1 Group A: Non-NYC Projects

Cadmus originally planned to analyze the three following cases for Group A projects:

1. As-permitted based on permit application;
2. As-installed based on on-site verification; and,
3. Baseline based on full compliance with code requirements.

Due to the small number of permit applications and documentation obtained for these projects, Cadmus and NYSERDA determined it was not worthwhile to perform the Case 1 analysis. Consequently, only Cases 2 and 3 were analyzed for Group A projects. Energy performance and the ECI and SCM were determined by comparing Case 2 to Case 3.

2.1.2 Group B: NYC Projects

Cadmus originally planned to analyze the three following cases also for Group B projects:

1. As-permitted based on permit application;
2. As-installed based on on-site verification; and,
3. Baseline based on full compliance with code requirements.

To perform the Case 1, NYSERDA and Cadmus collaborated in the beginning of study to get support from the NYC Department of Buildings to reduce the amount of time for permit data collection since NYC projects constitute the majority of the projects in this study. However, due to the work load of the NYC Department of Buildings and insufficient manpower at the time of the study, NYSERDA and Cadmus couldn't get the support of the NYC Department of Buildings. Therefore, for all Group B projects, Cadmus only analyzed Cases 2 and 3, and then assessed the energy performance and the ECI and SCM by comparing Case 2 to Case 3.

2.2 Code Context and Applicability

Cadmus developed a systematic approach for assessing commercial building alteration projects in the context of requirements established in the ECCCNYS-2010 and the EBCNYS.

According to the ECCCNYS-2010, new commercial buildings, including residential buildings over three stories, must be designed to meet the requirements of Chapter 5 of the ECCCNYS-2010. Section 501 allows use of ASHRAE 90.1-2007. According to Section 501.2 of the ECCCNYS-2010 (Application), the commercial building project shall entirely comply with the requirements in Sections: 502 (building envelope requirements), 503 (building mechanical systems), 504 (service water heating) and 505 (electrical power and lighting systems). As an alternative, the commercial building project shall comply with the requirements of ASHRAE 90.-2007 in its entirety. Therefore, as discussed before, Cadmus determined the compliance by the scope of alteration and the requirements under ASHRAE 90.1-2007 in absence of code compliance documentation.

Since all alteration applications filed in NYC on or after December 28, 2010, must comply with the 2011 NYCECC[10], the team determined the compliance by the scope of alteration and the requirements under NYCECC-2011 (comprised of the ECCCNYS-2010, Local Law 48 of 2010 and Local Law 1 of 2011) for the projects in which the code compliance documentation is available. For all other projects where the code compliance documentation is not available, the team determined the compliance by ASHRAE 90.1-2007. The specific requirements of ECCCNYS-2010, NYCECC-2011 and ASHRAE 90.1-2007 are studied in detail and summaries are provided in Appendix B: Code Context and Applicability.

2.3 Sampling Methodology

The project team drew a sample of commercial building alteration projects through a framework consistent with the methodology for code compliance evaluation developed by PNNL.[11] While the sample design maintains methodological consistency, it builds upon PNNL's approach by incorporating McGraw-Hill Dodge (Dodge) data specific to alterations and including a larger sample size to account for potentially high degrees of variation in alteration projects when compared to new construction.

2.3.1 Sample Size

The PNNL guideline require a minimum sample size of 44 sites. This sample size is based on a power calculation to test the hypothesis that the compliance rate is 90% or greater. The power calculation below assumes that compliance rates will have a standard deviation of 0.13 and is calculated to detect a difference of at least 5% with 80% power and 95% confidence.

[10] http://www.nyc.gov/html/dob/html/codes_and_reference_materials/nycecc_about.shtml

[11] http://www.energycodes.gov/sites/default/files/documents/MeasuringStateCompliance.pdf

Equation 1

$$n = \frac{s^2(Z_{1-\alpha} + Z_{1-\beta})^2}{\Delta^2} + 0.5Z_{1-\alpha}^2$$

Where:

n	=	the sample size for buildings evaluated
s^2	=	the sample variance
Z	=	the standard normal z-score
1-α	=	the confidence level
1-β	=	the power
Δ	=	the minimum detectable difference from 90% compliance

Identical parameters were used for the sample size calculations, except for the standard deviation. The assumed standard deviation was increased to 0.175 to account for potentially higher variation in alteration data results as compared to new construction (the primary basis for the PNNL guideline). This results in a final sample size of 78 sites[12].

2.3.2 Data Resources

The Dodge data was the primary data source for the sample design. This data includes project details and location for all permits issued for commercial alterations in the state for 2011 and 2012. The DOE sample generator uses Dodge data for commercial building starts to allocate sample sites between counties, as alteration data is not consistently available in all states. However, it was determined that the state's alteration data was sufficiently complete to justify using this data for the allocation.

For the Group B sample, a detailed permit database extract was available at the NYCDOB website.[13] This data was used to develop size allocations. However, for aggregation purposes, these project counts were adjusted proportional to the Dodge project counts to ensure consistency in the weighting scheme.

[12] Cadmus originally set an upper limit target sample size of 100 projects to be conservative relative to the PNNL assumptions; and established a limit on how many projects could be included, contingent on budget and the number requiring energy modeling rather than engineering analysis. Because the ultimate number of projects requiring energy modeling was much larger than originally anticipated, the number of projects sampled was limited to 78. This number of projects is consistent with the assumption that the standard deviation of the compliance rate is 0.175.

[13] http://www.nyc.gov/html/dob//html/codes_and_reference_materials/foilmonthly.shtml#permit

2.3.3 Sample Allocation

The PNNL guideline for sample design specifies a two-stage process. Counties are first selected proportional to the number of projects permitted during the study period and, subsequently, sites are selected from those counties using jurisdiction data. Although PNNL does not provide explicit guidelines on the site selection within counties, it does emphasize the need for representativeness.

The sample allocation follows the PNNL guideline, albeit with an expanded sample size. As is done with DOE's sample generator[14], a list was created containing one entry for each relevant project by county. This list was then randomly sorted and the first 100 entries selected, providing the allocation of site visits needed by county.

Building type and project size were intended to be stratified using commercial alteration permit data. However, upon review of initial project lists from jurisdictions, Cadmus determined that project details in the permit data were insufficiently reliable to form the basis of a stratification scheme. Instead, data was requested from all jurisdictions within each selected county, except the small jurisdictions where fewer than three projects took place over the study period. This removed the burden of data collection on small jurisdictions and is consistent with PNNL's guidance. The only exception was Seneca County, where Cadmus requested data from all jurisdictions because only nine projects applicable to the sample were issued county-wide. While jurisdictions could have been selected proportional to the number of projects permitted during the study period, nearly all jurisdictions were included to account for low response rates from many permitting offices.

Cadmus randomly sorted project lists and contacted project representatives in the resulting order. This random selection was intended to ensure a representative mix of projects within jurisdictions. The sample targets and achieved sample by county are shown in Table 2.

[14] https://energycode.pnl.gov/SampleGen/

Table 2. Initial and Final Sample Allocation by County

Climate Zone (CZ)	County (*NYC Borough*)	N (Population)	n (Sample Targets)	n (Achieved Sample)
4	Bronx (*The Bronx*)	778	6	7
	Kings *(Brooklyn)*	1,279	9	7
	New York (*Manhattan*)	6068	35	39
	Queens (*Queens*)	1051	9	9
	Richmond (*Staten Island*)	152	1	1
	Nassau	213	2	1
	Suffolk	321	1	1
	Westchester	221	1	1
Total for CZ 4		**10,083**	**64**	**66**
5	Albany	149	1	0
	Chemung	25	1	0
	Columbia	21	1	0
	Erie	247	4	3
	Monroe	214	1	3
	Orange	81	1	1
	Rockland	47	1	0
	Saratoga	65	0	1
	Seneca	9	1	1
	Wayne	16	2	0
Total for CZ 5		**809**	**13**	**9**
6	Cattaraugus	20	1	0
	Jefferson	30	1	0
	Oneida	67	2	3
	Steuben	27	1	0
	Tompkins	74	1	0
Total for CZ 6		**218**	**6**	**3**
GRAND TOTAL		**11,110**	**83**	**78**

Among 78 achieved samples, New York City constitutes the majority with 63 buildings and all the buildings in the five counties of New York City are located in Climate Zone 4. Our achieved sample includes three additional buildings outside of New York City that are also located in Climate Zone 4. For Climate Zone 4, the achieved sample exceeded our target by two project. On the other hand, Climate Zone 5 has nine in the achieved sample, four less than the target, and Climate Zone 6 has three in the achieved sample, three less than the target.

For buildings in New York City (Group B), detailed project data available from the NYCDOB permit database included project costs, enabling size-based stratification. The sample was stratified in four of the boroughs using optimal strata boundaries based on alteration project cost,[15] with a limit of five strata per borough and a minimum target of two sites per stratum as shown in Table 3. Only one site from Staten Island was allocated in the sample, negating the need for sub-stratification.

Table 3. Size Allocation for Group B

County (*Borough*)	Size Stratum	N (from NYCDOB Permit Database)	Total Cost	Average (Cost)	n (Sample Targets)	n (Achieved Sample)
Bronx (*The Bronx*)	1	529	$16,845,865	$31,845	2	2
	2	182	$21,496,326	$118,112	2	3
	3	67	$28,849,320	$430,587	2	2
Kings *(Brooklyn)*	1	892	$23,418,114	$26,253	3	0
	2	302	$30,480,135	$100,928	3	4
	3	85	$43,668,399	$513,746	3	3
New York (*Manhattan*)	1	3,713	$115,064,506	$30,990	7	8
	2	1,329	$146,299,639	$110,082	7	6
	3	637	$175,709,276	$275,839	7	9
	4	294	$212,960,157	$724,354	7	10
	5	95	$293,303,690	$3,087,407	7	6
Queens (*Queens*)	1	729	$21,629,500	$29,670	3	2
	2	240	$28,097,393	$117,072	3	4
	3	82	$38,264,390	$466,639	3	3
Richmond (*Staten Island*)	1	152	$11,084,623	$72,925	1	1

2.4 Sample Recruitment

Cadmus coordinated with the Department of State, Division of Building Standards and Codes (DOS) to issue an official letter to all jurisdictions included in the Sample Frame (See Appendix C: Recruitment Letter Sent to Jurisdictions by Department of State), requesting a list of all projects that met the following criteria:

- The project qualified as a commercial alteration.
- The project was permitted under the ECCCNYS-2010.
- The permit was approved with a permit application date between January 1, 2011 and December 31, 2012.

Different paths were followed for recruitment for Group A and Group B Projects.

[15] Cadmus calculated optimal boundaries using the algorithm found in Chapter 13 of the California Evaluation Framework: http://www.calmac.org/publications/California_Evaluation_Framework_June_2004.pdf

2.4.1 Group A: Non-NYC Projects

Cadmus subcontracted with T.Y. Lin International Group (T.Y.Lin) to support recruitment work for half of the jurisdictions. Recruiters at Cadmus and T.Y. Lin called sample jurisdictions and followed up with a letter describing study objectives and project selection criteria (See Appendix D: Recruitment Letter Sent to Jurisdictions by NYSERDA). Some jurisdictions declined to participate in the study for various reasons, such as high workload due to Hurricane Sandy and lack of qualified projects. When a jurisdiction declined to participate, the project team substituted a jurisdiction in an adjacent county in the same Climate Zone in order to maintain consistency in the sample. Preliminary lists of permitted projects were received from 32 local jurisdictions.

Permit lists were screened for qualified projects and qualified projects sorted randomly to assemble a representative mix. Based on the sample, a goal of recruiting 25 projects was established. Recruiters reached out to the project contacts in the resulting order, conducted phone interviews with building owners or tenants, and followed up with a letter describing the goal of the study and the criteria for the projects (See Appendix E: Follow-up E-Mail Sent to Jurisdictions by Cadmus and T.Y. Lin). Ultimately, 27 projects were recruited for possible site visits.

2.4.2 Group B: NYC Projects

Because NYCDOB was not able to collaborate due to high workload and could not participate in this study, an alternative process was used to obtain a list of projects that qualified under the project selection criteria. The NYCDOB website[16] provided monthly statistical reports for permitted projects, and additional project-level details for the permitted projects was available from the Building Information System website.[17] All projects were screened and a sample of qualifying projects created.

Cadmus subcontracted with Population Research Systems (PRS) to lead the recruitment effort. PRS recruiters conducted phone interviews with each potential project and followed up with a letter describing the objectives of the study and the criteria the projects were required to meet. Anticipating cancellation and rescheduling needs, 120 projects were recruited for possible site visits in order to reach the targeted 75 projects.

2.5 Data Collection

Site visits were made to each project in the sample to document alteration characteristics and assess compliance. Data collected from each site visit was used to determine if the alteration was code compliant. The following sections describe the data collection and site visit process.

[16] http://www.nyc.gov/html/dob//html/codes_and_reference_materials/foilmonthly.shtml#permit
[17] http://a810-bisweb.nyc.gov/bisweb/bsqpm01.jsp

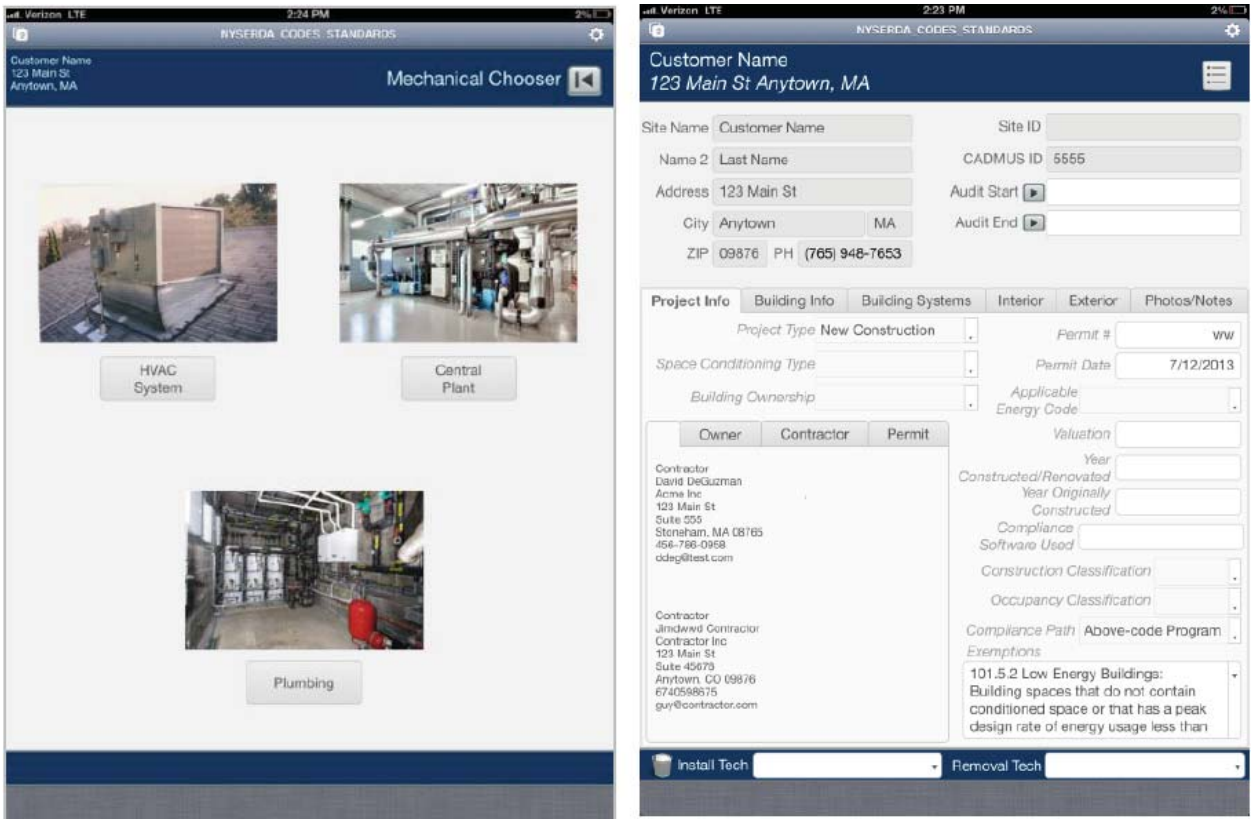
2.5.1 Development of Data Collection Tool

Cadmus developed commercial building data collection tablet-based software for site visits to collect all key data points necessary for verifying code compliance and conducting the energy analysis. This software is a front end for a File Maker Pro back-end database that allows field engineers to enter building and equipment characteristics directly into a database while on site. Collected data was synched to the master database, compiled and reviewed. Cadmus chose this software-based data collection tool, which results in more accurate data and cuts costs, for the following benefits:

- **Accuracy:** On-site data collected using paper forms must be transferred into a master database, thus requiring the field technician to enter data twice. Tablet-based software eliminates the second data-entry step.
- **Consistency:** Field technicians are forced to enter data a certain way, which ensures data is collected consistently for each site and reduces uncertainty and time to clean and analyze the data.
- **Photos and Voice Notes:** Field engineers can photograph equipment or appliances and save directly to the database. Engineers also can record notes and save to the database.
- **Data security:** No personal identification information, such as account numbers, is contained in the data. All tablets have two layers of password protection and are remote wipe enabled. If a tablet is lost, stolen or unaccounted for, staff remotely wipe the tablet clean within two-hours.

Figure 2 shows an example screen shot of the mechanical equipment and general sections of the data collection tool.

Figure 2. Commercial iPad-based Data Collection Tool



Early in the development of the data collection tool, Cadmus compiled a comprehensive list of the key building inputs and building system information that might be required as data collection points to assess compliance. The key inputs were organized by building system, and this structure served as the basis for the data collection tool's architecture. Data collection inputs were categorized into the following sections of the tool:

- **Project Information.** General project information such as building age, building owner or manager contact information, year constructed, year renovated and code compliance data are entered in this section. This data was collected for all projects and used during project analysis.
- **Building Information.** Building characteristics such as total building area, number of stories above grade, number of stories below grade and occupancy schedules are entered in this section. This data was collected for all projects and used during project analysis.
- **Building Systems.** Inputs related to mechanical systems, domestic hot water systems and the building envelope (insulation, roof construction, wall construction, window areas and characteristics) are entered into this section. High-level mechanical and envelope characteristic data for almost all projects was collected to generate an energy model. The team collected more detailed information for projects that underwent specific envelope and mechanical system alterations to determine code compliance.

- **Interior Spaces and Lighting.** Key interior space characteristics (e.g., space type, area, and occupancy schedules), lighting fixtures characteristics and lighting controls information are entered in this section. For lighting alteration projects, this data was analyzed to determine the installed lighting power density and lighting controls for comparison to energy code requirements.
- **Exterior Spaces and Lighting.** Inputs related to exterior spaces (e.g., space type, quantity or area of spaces), lighting fixture characteristics and lighting controls information are entered into this section. Data collected exterior lighting alteration projects was analyzed to determine code compliance.
- **General Building Notes.** Field engineers used this section to take building-specific notes to document additional on-site conditions and to photograph general building characteristics. This data was used to inform and support the analysis.

The data collection tool was put through beta testing before field work began to identify usability issues, to confirm there were no programming glitches, and to ensure that the tool was exporting data correctly. A half-day field engineer training conducted prior to assigning projects included an overview of project objectives, data collection tool training, a walk-through of example projects and safety training.

2.5.2 Data Collection and Document Review

The goal of the data collection process was to identify the scope of the alteration and to obtain site-specific information to analyze compliance and the energy-efficiency effects.

2.5.2.1 Pre-Site-Visit Document Review Activities

Wherever available, field engineers reviewed relevant documentation prior to the site visit. The project team obtained documentation as described in the section 2.4 Sample Recruitment.

Documentation often consisted of building code department forms, building plans obtained through e-mail from the recruitment phones calls and notes from recruitment phone calls. Field engineers used this data to identify the scope of the alteration project, resolve any technical issues relating to the project prior to the site visit, and begin pre-populating the data collection tool.

2.5.2.2 Site Visits

The purpose of the site visits was to confirm the scope of the alteration, verify installation and collect site-specific information to model the energy consumption of the alteration project.

Cadmus conducted 78 site visits, 19% in Group A (outside of New York City) counties and 81% in Group B (New York City) counties. Table 4 shows a breakout of site visits by location.

Table 4. Summary of Site Visits by County and Climate Zone

County (*NYC Borough*)	ASHRAE Climate Zone	Number of Site Visits included in the Analysis
Bronx (The Bronx)	4	7
Kings (Brooklyn)		7
New York (Manhattan)		39
Queens (Queens)		9
Richmond (Staten Island)		1
Nassau		1
Westchester		1
Suffolk		1
Erie	5	3
Monroe		3
Seneca		1
Orange		1
Saratoga		1
Oneida	6	3
TOTAL		78

On average, site visits took 30 minutes to two hours per site, excluding travel time. Audit time depends on the size and complexity of the alteration. Alterations such as installation of a new boiler are not complicated since nameplate and relevant information are readily available and with the help of tablet-based data collection software developed by Cadmus such site visits took shorter time. Moreover, for almost all envelope alterations, field engineers were not able to observe the actual insulation on site. In such cases, field engineers took photos of all relevant documents that are readily available via tablet-based data collection software which reduced audit time. Time availability of the facility staff in the building visited also impacted the audit time. In cases in which the facility staff had limited time, field engineers input the key data on the data collection software and again took the photos of relevant supportive via tablet-based data collection software. The following verification activities were undertaken at each site:

- **Facility staff interviews.** Facility staff or property managers were interviewed to discuss the alteration project scope and to gather key building characteristics (e.g., number of floors, age of building, date of alteration, occupancy schedule, etc.).
- **Drawings and code-related documentation review.** Documentation available on site was reviewed to collect relevant data on building characteristics, equipment specifications and code compliance. In most instances, electronic copies of this documentation were not available, and most of the documentation was collected through photographs of drawings.
- **Physical verification.** A walk-through of the building was conducted and data collected on any relevant equipment from nameplate information or building management systems (BMS), or through physical verification, counts and measurements.

The level of data collected and the time spent at each site varied based on the type of the Alteration. Types of alterations in the sample are listed in Table 5.

Table 5. Summary of Alteration Types in Sample

Alteration Type	Number of Alterations
Envelope	7
Lighting	30
Mechanical	63
Domestic Hot Water	17
Total Alterations for 78 sites	117

Alterations are categorized as: (1) envelope: glazing or insulation replacement; (2) lighting: interior or exterior lighting fixture and/or control replacement; (3) mechanical: HVAC system replacement; (4) domestic hot water system replacement; or (5) a combination of envelope, lighting, mechanical or domestic hot water system replacement.

2.5.2.3 Post-On-Site Documentation Review

After engineers completed each site visit and downloaded data from the data collection tool database, the project team reviewed the data for each site and checked for quality control. Site information was reviewed to determine: (1) if there was any missing data necessary to assess code compliance and (2) if photographs and documentation collected on site were consistent with the data obtained during recruitment.

All quality-control comments and questions from this review were recorded and circulated to field engineers responsible for providing clarification and missing information. In some instances, field engineers were required to check with building facility staff on key site characteristics that could not be determined during the site visit (See Appendix A: List of Site Visits).

Table 6 identifies the key data collected and sources for various projects.

Table 6. Summary of Site Visit Data Collected and Source by Alteration Type

Component	Data Collected	Source
General	Building address Building floor area Total conditioned area Number of floors above/below grade Building site type Building space types	Permit documentation Field verification
Envelope Alterations – Roof, Windows and Walls	*R*-Value, *U*-Factor, SHGC Window, wall, roof area Wall, window, roof assembly type	Permit documentation As-built architectural drawings Building floor schedules Field verification
Lighting – Interior/Exterior	Space and area type Fixture types and quantity Lighting fixture wattage consumption Renovated area Controls	Permit documentation Electrical drawings Lighting fixture specifications Floor plans Field verification
Mechanical – Heating, Ventilation, Air Conditioning	Nameplate information Equipment operating efficiency	Permit documentation Mechanical drawings
	HVAC configuration Controls Quantity Conditioned Area served	Equipment start-up tests Energy management system Field verification
Plumbing – Domestic Hot Water	Floor plan/space types Quantity Controls	Permit documentation Mechanical drawings Field verification

2.6 Compliance and Energy Analysis Methodology

2.6.1 Energy Compliance Index and Savings Compliance Margin

This study applied three metrics to assess how well alterations complied with code requirements in terms of their energy impacts. The first provided a measure of the absolute energy use of the altered space, as installed, compared to its use if the alteration had just complied with the energy code. The second and third provided a relative indicator of the space's energy use compared to its use if the alteration had just complied with the code. All three metrics required determining the energy performance of each building alteration under two conditions:

1. As-Installed Condition based on on-site verification and documentation of the alteration; and,
2. Code Baseline Condition ECCCNYS-2010/ASHRAE 90.1-2007 or NYCECC-2011 applied to the alteration.

The first metric calculates the annual energy ***savings*** by determining the difference between the As-Installed Condition energy performance to and the Code Baseline Condition performance to calculate annual energy savings relative to the code as shown in Equation 2:

Equation 2

$$Annual\ Energy\ \ Savings_i = (Code\ Baseline\ BTU_i\ -\ As - Installed\ BTU_i)$$

Where:

Annual Energy Savings$_i$ =Annual energy savings for buildings for site i;

$Code\ Baseline\ BTU_i$= Baseline building energy consumption for site i based on just meeting the applicable code in the ECCCNYS-2010/ASHRAE 90.1 2007 or NYCECC-2011 scenario: and

$As - Installed\ BTU_i$ = Installed building energy consumption for site i, based on actual alterations conditions determined from site verification.

The Energy Compliance Index (ECI) was developed as a consistent metric of the relative performance of the alterations' As-Installed Condition energy savings. It can be expressed as a ratio or percentage. The metric is similar to the Home Energy Rating System (HERS)[18] Index and, when expressed as a percentage, indicates how much more (>100%) or less (<100%) energy the as-installed-alteration consumes relative to its consumption if it just met the code. For example, if the ECI is 0.3, the altered space uses 70% less energy than it would have if it just met the code. Equation 3 shows how the ECI is calculated.

[18] Note that the 2015 IECC has added a residential code compliance path referred to as Energy Rating Index, which is similar to the ECI.

Equation 3

$$Energy\ Compliance\ Index_i = \frac{Installed\ System\ BTU_i}{Code\ Baseline\ BTU_i}$$

The Savings Compliance Margin (SCM) is an alternative way of indicating the degree of code compliance based on relative energy use. It can be calculated as shown in Equation 4. The numerator is the energy savings of the Installed System relative to the Code Baseline, and dividing by the Code Baseline converts the value to a percentage saving relative to the Code Baseline. This metric has the intuitive appeal of being positive when the alteration Installed System saves energy compared to the Code Baseline. The SCM can also be expressed as one minus the ECI.

Equation 4

$$Savings\ Compliance\ Margin_i = \frac{Code\ Baseline\ BTU_i - Installed\ System\ BTU_i}{Code\ Baseline\ BTU_i}$$

2.6.2 Energy Analysis and Modeling

Cadmus used building energy simulations to analyze envelope alterations, lighting alterations, HVAC upgrades, and service water heating system replacements. If a project altered multiple building systems that have interactive effects (e.g., envelope and HVAC), the altered building systems were included in the energy model. Energy models were built using eQUEST 3.64, a DOE-2-based whole-building energy analysis simulation tool that performs hourly analyses for 8,760 hours (annual simulation) using typical meteorological year (TMY-2) weather data to predict energy demand and consumption.

To develop the energy models, Cadmus used the following two categories of model inputs:

1. **Altered building systems**. These are building systems that are directly related to the alteration project. All relevant data such as system types, efficiencies and operating characteristics was collected during the site visit.[19]
2. **Non-altered building systems**. These refer to building systems that impact the energy consumption, but were not replaced or altered as part of the scope of the project. During on-site verification, as much information as possible was collected pertaining to these non-altered building systems.

[19] Three out of 78 analyzed projects included envelope alterations with components modified in the building walls or roof. Field engineers could not directly observe those modifications on-site for these 3 projects so relied instead on relevant plans and project documents for the analysis of these alterations.

Because building alteration documentation, drawings and records often are not maintained on site, collecting data on all characteristics was challenging. Furthermore, it was not feasible to access and observe the details for all non-altered building systems (such as wall insulation). When details for non-altered building systems were not available, default values found in widely used references were used to provide the energy model inputs for these systems. Sources used were developed by PNNL, ASHRAE and National Renewable Energy Laboratory (NREL), as further described in Appendix F: Sources of Energy Modeling Inputs and Modeling Protocols.

Using assumptions from these sources provides a systematic and standardized approach to model the building energy consumption based on typical building construction characteristics by vintage. The energy models were developed such that assumptions pertaining to non-altered building systems were consistent between the Code Baseline Condition and As-Installed Condition, resulting in estimates from the simulations that were affected only by measures modified by the alteration.

Figure 3 through Figure 7 illustrate the steps taken to develop the energy models for HVAC alterations, lighting alterations, envelope alterations, domestic hot water (DHW) system alterations and combination HVAC, service water heating system and envelope alterations, respectively. Data collected on-site was used for altered and non-altered building systems. When non-altered systems were unverifiable during field verification, the above-noted references were used to fill gaps in data. ASHRAE 90.1-2007 served as the assumed code unless project documentation clearly demonstrated compliance using ECCCNYS-2010 or NYCECC-2011.

Figure 3. Development of Energy Model for HVAC Alterations

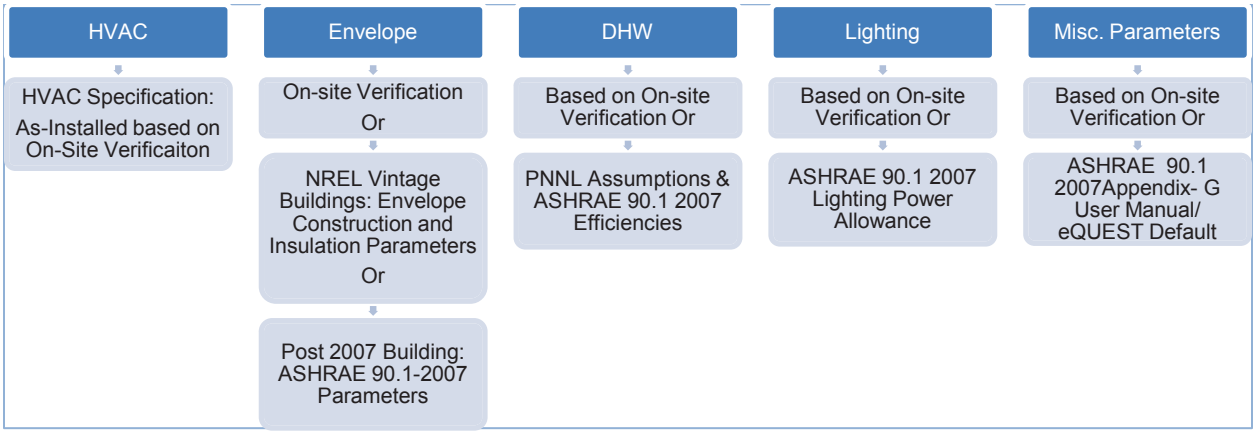


Figure 4. Development of Energy Model for Lighting Alterations

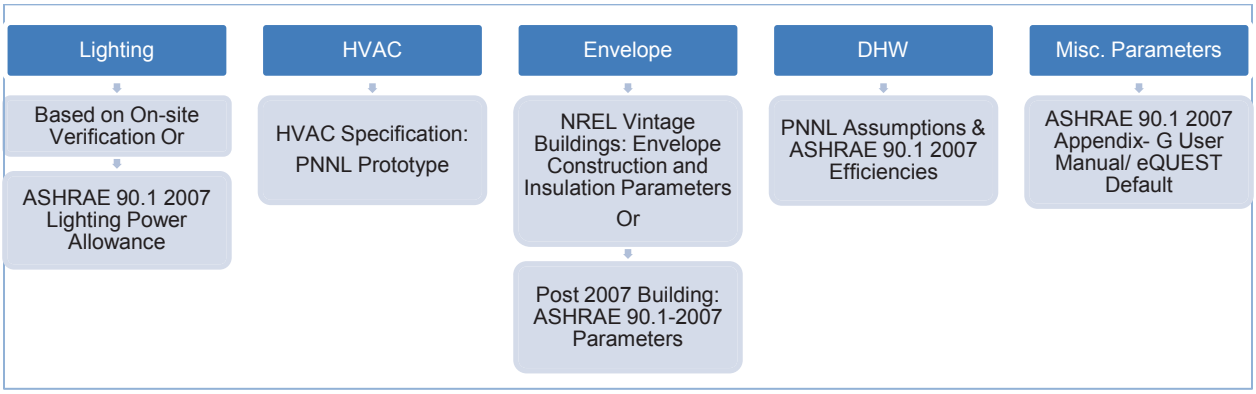


Figure 5. Development of Energy Model for Envelope Alterations

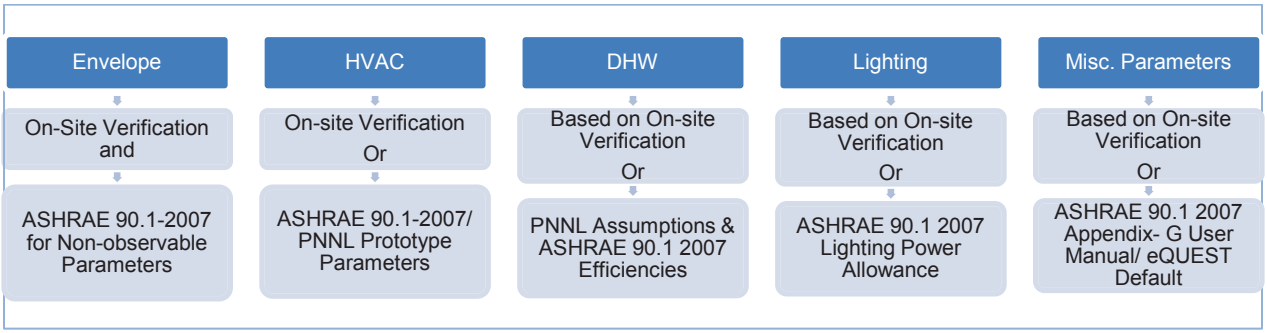


Figure 6. Development of Energy Model for Domestic Hot Water Alterations

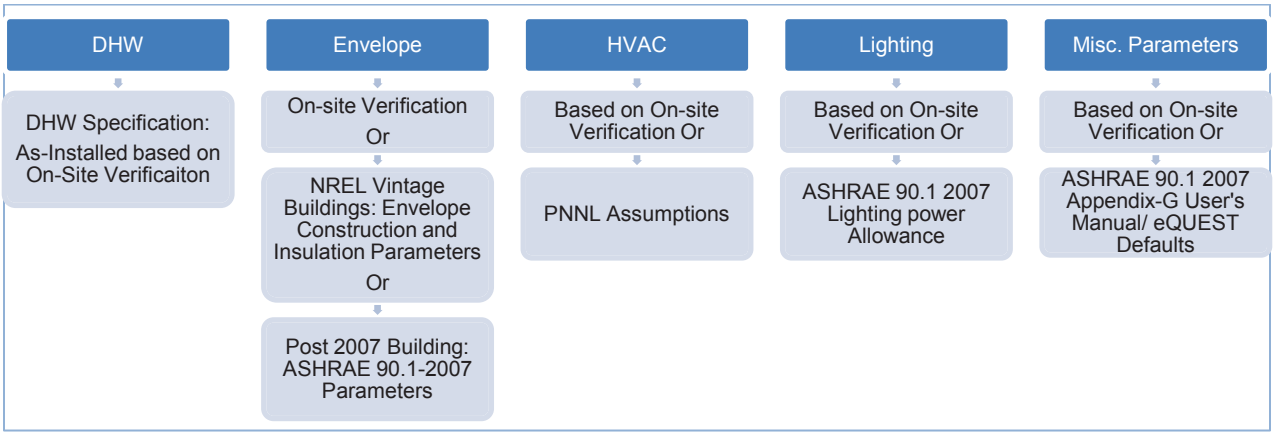
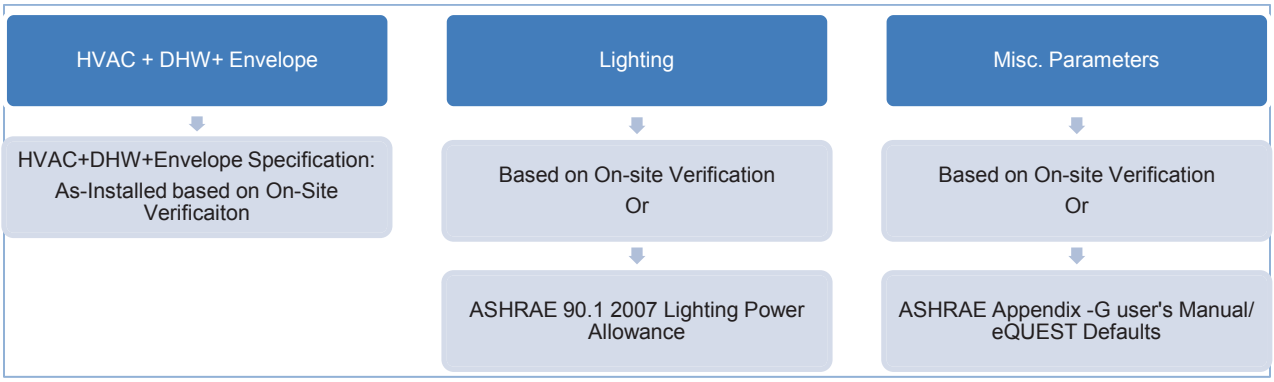


Figure 7. Development of Energy Model for HVAC, Domestic Hot Water, Lighting and Envelope Alterations



As described earlier, the analysis compared the As-Installed Condition and Code Baseline Condition (ASHRAE 90.1 2007 or ECCCNYS-2010 or NYCECC-2011). The following steps were followed to estimate the energy impacts and ECIs for each project:

1. Review permit documentation.[20]
2. Review site verification[21] documentation.
3. Define project scope and parameters to include inputs for energy model or engineering calculations.
4. Identify code applicability, exemptions, exceptions, additional NYC local laws (where applicable), compliance paths and ECCCNYS-2010 or ASHRAE 90.1-2007 requirements. As previously described, ASHRAE 90.1-2007 was the assumed code unless a project's permit documentation reflected ECCCNYS-2010 or NYCECC-2011.
5. Develop detailed calculation models (either spreadsheet calculations or energy simulation models) using prototypical and site-verified data that reflect the facility type and scope of the alteration. With the exception of one site, eQUEST models were generated for all projects. For sites that underwent lighting alterations, engineering calculations were performed to determine the code allowed lighting power density and the post alteration lighting power density. These lighting power densities were then incorporated into whole building simulation models to account for the interactive effect of lighting systems on HVAC systems and to calculate a resultant compliance index.
6. Generate parametric runs using an incremental analysis method to compare the independent impacts associated with each alteration measure.
7. Calculate and report the energy savings and ECI and SCM.
8. Conduct quality control checks (ongoing throughout process).
9. Report the final results for energy savings and the ECI and the SCM.

[20] Permit documentation includes any code-related documentation for an alteration project. Some permit documentation was collected from local jurisdictions' building departments in Group A. Preliminary project information (including scope of work) was collected from the NYC Building Information System database for projects located in NYC (Group B). More detailed permit documentations (e.g., building drawings) were collected when available during on-site inspections.

[21] This included as-built drawings, project specifications, equipment cut sheets, code compliance forms in drawings, site visit photographs of nameplate information, equipment setpoints and building characteristics, and site visit notes.

2.6.3 Parametric Models Approach

In addition to reporting aggregate energy impacts of each alteration project, energy impacts associated with each measure were assessed independently for projects that underwent alterations involving multiple building systems. Individual measures in an alteration that incorporates multiple energy-efficiency improvement measures often influence the same end uses and, therefore, it is important to understand the *net impact* pertaining to energy consumption per end use. For example, a project that has undergone a lighting retrofit as well as high-efficiency boiler replacement will produce savings from both the efficient lighting and the efficient boiler. However, when these measures are applied together, the lighting-related heating penalty will be diminished by the improved boiler efficiency.

To estimate these effects, parametric measure scenarios were run starting with the Code Baseline Condition and modifying incrementally. Incremental modifications were made in the following order:

Baseline ⟶ Envelope ⟶ Lighting ⟶ Mechanical ⟶ DHW

These incremental runs were organized to prioritize any alterations that impact changes in heating and cooling loads first (envelope and lighting alteration projects). After these parametric runs were completed, any alterations relating to changes in equipment (mechanical and domestic hot water) were modeled. Accounting for load changing alteration projects first is common industry practice to better account for interactive effects.

A subtractive analysis approach was used to calculate savings associated with any single measure in isolation. For example, to calculate savings associated with lighting alone, the Envelope Interactive model consumption was subtracted from the Lighting Interactive model consumption.

2.6.4 Energy Analysis for Lighting Alterations

The project team used engineering calculations to estimate the energy impacts from lighting alteration projects by applying the ASHRAE 90.1-2007 Space by Space Method or the ASHRAE 90.1-2007 Building Area Method (unless a different compliance path was indicated in the permit documentation). The lighting allowances prescribed by the two methods are shown in Figure 8 (ASHRAE 90.1-2007 Table 9.6.1 Lighting Power Densities (LPD)) and Figure 9 (ASHRAE 90.1-2007 Table 9.5.1 Lighting Power Densities Using the Building Area Method).

The project team verified LPDs through a combination of the following methods:

1. Lighting inventory during a building on-site verification.
2. COM*Check* report documenting lighting inventory and lighting code compliance.
3. Documentation provided by the site representative during on-site verification (e.g., floor plan, lighting fixture diagram, lighting schedule, etc.).

Both the lighting inventory performed during an on-site verification and the COM*Check* report provided granular lighting data for individual spaces within the site. Documentation (plans, fixture schedules, and fixture cut sheets) did not always present information at this level of granularity. Two different methodologies were used for the lighting analysis, depending on the availability of data for each site, as shown in Table 7 and described in the following sections.

Figure 8. ASHRAE 90.1-2007 Space-By-Space Lighting Allowances

TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method

Common Space Types[a]	*LPD*, W/ft^2	Building-Specific Space Types	*LPD*, W/ft^2
Office—Enclosed	1.1	Gymnasium/Exercise Center	
Office—Open Plan	1.1	Playing Area	1.4
Conference/Meeting/Multipurpose	1.3	Exercise Area	0.9
Classroom/Lecture/Training	1.4	Courthouse/Police Station/Penitentiary	
For Penitentiary	1.3	Courtroom	1.9
Lobby	1.3	Confinement Cells	0.9
For Hotel	1.1	Judges' Chambers	1.3
For Performing Arts Theater	3.3	Fire Stations	
For Motion Picture Theater	1.1	Engine Room	0.8
Audience/Seating Area	0.9	Sleeping Quarters	0.3
For Gymnasium	0.4	Post Office—Sorting Area	1.2
For Exercise Center	0.3	Convention Center—Exhibit Space	1.3

Figure 9. ASHRAE 90.1-2007 Building Area Method Lighting Allowances

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	*LPD* (W/ft^2)
Automotive facility	0.9
Convention center	1.2
Courthouse	1.2
Dining: bar lounge/leisure	1.3
Dining: cafeteria/fast food	1.4
Dining: family	1.6
Dormitory	1.0
Exercise center	1.0
Gymnasium	1.1
Health-care clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing facility	1.3
Motel	1.0
Motion picture theater	1.2
Multifamily	0.7
Museum	1.1
Office	1.0
Parking garage	0.3
Penitentiary	1.0
Performing arts theater	1.6
Police/fire station	1.0
Post office	1.1
Religious building	1.3
Retail	1.5
School/university	1.2
Sports arena	1.1
Town hall	1.1
Transportation	1.0
Warehouse	0.8
Workshop	1.4

[a] In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Table 7. Lighting Analysis Methodology Depending on Data Available

Data Source	Data Type	Methodology Applied
Lighting inventory (walk-through audit)	Full lighting inventory by space	Methodology A: Space-by-Space LPD
COM*check* Report	Full lighting inventory by space	Methodology A: Space-by-Space LPD
Other Documentations Provided on Site	Full lighting inventory by site	Methodology B: Building Area Method

2.6.4.1 Methodology A: Space-by-Space LPD

When sufficient data was available on a room-by-room basis, the project team calculated Lighting Power Density (LPD) of each space within the altered portion of the site by dividing the total installed lighting wattage in the space by the square footage (area) of the space. Further, the LPDs of the individual spaces were aggregated into an overall LPD for the as-installed condition.

The project team then compared the site-level overall LPD to the Allowed Lighting Power Density (ALPD), calculated based on the allowed LPD for different space types. The weighted average LPD allowed for each space type, per ASHRAE 90.1-2007 Table 9.6.1, was used to provide As-Installed average LPD.

Comparing the As-Installed LPD against the Code Baseline LPD, an ECI was calculated as a percentage value. ECI values less than or equal to 100% correspond to verified LPDs that meet or are less than the allowed LPD, indicating that the site is compliant with the requirements set by ASHRAE 90.1-2007. The equations we used were the following:

Equation 5

$$LPD_x = Watts_x / SF_x$$

Equation 6

$$LPD_{site} = \sum(LPD_x * SF_x) / \sum(SF_x)$$

Equation 7

$$ALPD_{site} = \sum(ALPD_x * SF_x) / \sum(SF_x)$$

Equation 8

$$\%Compliance = LPD_{site} / ALPD_{site}$$

Where:

LPD_x	=	Lighting Power Density of space *x*, in watts per square foot
$Watts_x$	=	Total installed lighting wattage of space *x*, in watts
SF_x	=	Area of space *x*, in square feet
LPD_{site}	=	Overall aggregated Lighting Power Density of the site, in watts per square foot
$ALPD_x$	=	Allowed Lighting Power Density of the space, from ASHRAE 90.1-2007 Table 9.6.1, based on space type, in watts per square foot
$ALPD_{site}$	=	Allowed overall Lighting Power Density of the site, in watts per square foot
% Compliance	=	ECI, in %

2.6.4.2 Methodology B: Building Area Method

Methodology B was used for projects that lacked sufficient data to carry out Methodology A. A common data gap that prevented the use of Methodology A was the lack of square footage breakout by space type within the project. This occurred when either (1) the square footage could not be confidently estimated by the engineer at the site or (2) the space types could not be clearly delineated and determined from the provided documentations, such as building floor plans or lighting schedules. For these projects, Methodology B: Building Area Method was applied to bypass the calculation of individual space-level LPD. Within the Building Area Method, ASHRAE defines the maximum allowable (site-level) LPD based on the general occupancy type of the building (e.g., office, school, hospital, etc.)

In Methodology B, the As-Installed LPD was calculated by dividing the sum of the installed lighting wattage at the site, rather than at each space within the site, by the total square footage of the site. The site-level LPD was then compared against the site-level LPD allowed by ASHRAE 90.1-2007 Table 9.5.1 for the Building Area Method using the following equations:

Equation 9

$$LPD_{site} = Watts_{site} / SF_{site}$$

Equation 10

$$\%Compliance = LPD_{site} / ALPD_{site}$$

Where:

$Watts_{site}$	=	Total installed lighting wattage of the site, in watts
SF_{site}	=	Area of the site, in square feet
LPD_{site}	=	Overall aggregated Lighting Power Density of the site, in watts per square foot
$ALPD_{site}$	=	Allowed overall Lighting Power Density of the site, from ASHRAE 90.1-2007 Table 9.5.1, in watts per square foot
%Compliance	=	ECI, in %

Upon comparing the lighting compliance in isolation, the project team investigated the resulting overall ECI of post-lighting retrofits. Scaled versions of prototypical models were generated based on building types, maximum allowable LPD, and As-Installed LPD in the Code Baseline and As-Installed Conditions, respectively. The scaled models only cover the area affected by lighting alterations.

This resulted in accounting for the interactive effects of lighting alterations on HVAC consumption. Comparison of the overall building level consumption between both Code Baseline and As-Installed Conditions present the net energy savings associated with lighting alterations.

Table 8 summarizes the number of sites verified using each of the two methodologies.

Table 8. Number of Sites using Methodology A and Methodology B

Methodology Used	Number of Sites	% of Sites
Methodology A	22	71%
Methodology B	9	29%
Total	31	100%

2.6.5 Quality Control

A senior engineer assessed the completed energy models and calculations to verify consistency between modeling inputs and site-verified data, applicability of assumptions and prototypical data, scoping of altered area, and representation of accurate climate data. The analysis summary results were compared to Commercial Buildings Energy Consumption Survey (CBECS) energy use intensity (EUI) to benchmark the total energy consumption of the baseline and proposed models. EUI comparisons were conducted by fuel type to determine the accuracy of the magnitude of savings resulting from the alteration projects. Discrepancies were resolved by an energy modeler and, upon resolution, the modeler provided a brief explanation of the issue and its resolution.

2.6.6 Aggregating Results

To aggregate As-Installed estimates of the ECI for each project site to a statewide level, the project team used the following formula:

Equation 11

$$Energy\ Compliance\ Index = \frac{\sum w_i * Installed\ System\ BTU_i}{\sum w_i * Code\ Baseline\ BTU_i}$$

$$w_i = \left(\frac{M_j}{\sum N_{hj}}\right) * \frac{N_{hj}}{n_{hj}}$$

Where:

$\boldsymbol{w_i}$ = The sampling weight for site, i, in stratum, h, and Climate Zone, j;

$\boldsymbol{N_{hj}}$ = The population size for stratum, h, in Climate Zone, j;

$\boldsymbol{n_{hj}}$ = The sample size for stratum, h, in Climate Zone, j; and

$\boldsymbol{M_j}$ = The population size for Climate Zone, j.

Equation 11 (summing across all sites and strata) was used to aggregate As-Installed estimates of energy savings compared to the Code Baseline Condition up to the statewide level.

Equation 12

$$Annual\ Energy\ Savings = \sum w_i * Sampled\ Project\ Savings\ BTU_i$$

This aggregation approach uses sampling weights that account for the proportional allocation of sites within and between Climate Zones. The weights are nested, where extrapolation is first performed at the Climate Zone level by taking the ratio of stratum population size to stratum sample size.[22] This weight is then multiplied by the ratio of the total population of the Climate Zone to the sum of the population sizes for all strata sampled within that Climate Zone to provide a weight to aggregate the results for each sampled site to the statewide level.

The population sizes for each stratum are defined according to the data source used to draw the sample for that particular region. For instance, sites outside NYC, population sizes are defined by Dodge data. Sites within NYC are defined by the detailed permitting data.

This formula differs from the simple average of an ECI because the ECI is treated as a ratio estimator and, hence, weights are applied to the ECI for each site. The weights are used to account for the relative frequency of sites of a given type in the population. The final estimates of the ECI and savings, therefore, robustly account for differences in compliance due to both region (in the weights) and total energy use (in the use of the ratio estimator for ECI).

For sites in NYC, adjusted values for N_{hj} proportional to the counts in the Dodge data to ensure that weighting between counties was consistent for all Climate Zones. This preserved between-county/borough consistency while maintaining within-borough size allocation found in the detailed NYC permit data. Table 9 and Table 10 show the calculated adjustment factors for each borough.

[22] For Climate Zones 5 and 6, and Climate Zone 4 outside of New York City, a stratum is defined as a county. In the case of New York City, we also accounted for anticipated project size in our stratification (as this data was available for the region). This helped to improve the overall precision and representativeness of the sample.

Table 9. NYC Population Weighting Adjustment Factors

Borough	NYC Projects in MH	NYC Projects in Code Data	NYC Adjustment Factor
Bronx	565	778	0.73
Brooklyn	1,120	1,279	0.88
Manhattan	5,938	6,068	0.98
Queens	688	1,051	0.65
Staten Island	144	152	0.95

Table 10. Adjusted NYC Population Sizes by Stratum

Borough-Stratum	NYC Permit Data Project Count	Adjusted NYC Project Count (Final N_{hj})
Bronx-1	529	384
Bronx-2	182	132
Bronx-3	67	49
Brooklyn-1	892	781
Brooklyn-2	302	264
Brooklyn-3	85	74
Manhattan-1	3,713	3,633
Manhattan-2	1,329	1,301
Manhattan-3	637	623
Manhattan-4	294	288
Manhattan-5	95	93
Queens-1	729	477
Queens-2	240	157
Queens-3	82	54
Staten Island-1	152	144

After adjusting the population values, weights were calculated for each stratum. These calculations are shown in Table 11.

Table 11. Final Statewide Weighting Calculations

CZ	Stratum	Stratum Population		Sample		Weights		
		Number of Projects	Percent of CZ	Number of Projects	Percent of CZ	Within CZ (N/n)	Between CZ (M/ΣN)	Overall (w)
4	Bronx-1	384	5%	2	3%	192.1	1.1	209.9
4	Bronx-2	132	2%	3	5%	44.1	1.1	48.1
4	Bronx-3	49	1%	2	3%	24.3	1.1	26.6
4	Brooklyn-2	264	3%	4	6%	66.1	1.1	72.2
4	Brooklyn-3	74	1%	3	5%	24.8	1.1	27.1
4	Manhattan-1	3,633	43%	8	12%	454.2	1.1	496.3
4	Manhattan-2	1,301	15%	6	9%	216.8	1.1	236.9
4	Manhattan-3	623	7%	10	15%	62.3	1.1	68.1
4	Manhattan-4	288	3%	10	15%	28.8	1.1	31.4
4	Manhattan-5	93	1%	6	9%	15.5	1.1	16.9
4	Nassau	213	3%	1	2%	213.0	1.1	232.8
4	Queens-1	477	6%	2	3%	238.6	1.1	260.7
4	Queens-2	157	2%	3	5%	52.4	1.1	57.2
4	Queens-3	54	1%	3	5%	17.9	1.1	19.6
4	Staten Is.-1	144	2%	1	2%	144.0	1.1	157.4
4	Suffolk	321	4%	1	2%	321.0	1.1	350.8
4	Westchester	221	3%	1	2%	221.0	1.1	241.5
5	Erie	247	40%	3	33%	82.3	2.5	205.8
5	Monroe	214	35%	3	33%	71.3	2.5	178.3
5	Orange	81	13%	1	11%	81.0	2.5	202.5
5	Saratoga	65	11%	1	11%	65.0	2.5	162.5
5	Seneca	9	1%	1	11%	9.0	2.5	22.5
6	Oneida	67	100%	3	100%	22.3	9.8	218.0

2.6.7 Precision

Cadmus calculated precision around the ECI using the formula (see Equation 12) for a stratified ratio estimator as found in DOE's Uniform Methods Project Sample Design Cross-Cutting Protocols[23], estimating the standard error of the weighted total for As-Installed Conditions.

[23] https://www1.eere.energy.gov/wip/pdfs/53827-11.pdf

Equation 13

$$SE(\ Total\ Installed\ System\ BTU) = \sqrt{\sum w_i * (w_i - 1) * (Code\ Baseline\ BTU_i - \ Installed\ System\ BTU_i * Energy\ Compliance\ Index)^2}$$

Where:

$Energy\ Compliance\ Index$= the population-weighted ECI.

We then calculated the sample standard error and precision about the ECI as:

Equation 14

$$SE(Energy\ Compliance\ Index) = \frac{SE(\ Total\ Installed\ System\ BTU)}{Total\ Code\ Baseline\ BTU}$$

$$Precision(Energy\ Compliance\ Index) = 1.645 * SE(Compliance\ Index)$$

The precision calculation for savings differed slightly, as here a simple mean estimate is taken. Therefore, we used the following calculations:

Equation 15

$$SE(Annual\ Energy\ Savings) = \sqrt{\sum w_i * (w_i - 1) * (Project\ Savings\ BTU_i - \ \overline{Savings\ BTU})^2}$$

$$Relative\ Precision(Annual\ Energy\ Savings) = 1.645 * SE(Annual\ Energy\ Savings)$$

Where:

$\overline{Savings\ BTU}$ = The weighted average annual energy savings in Btu across all observed projects.

3 Compliance Assessment and Findings

3.1 Compliance Results for Sample Commercial Alteration Projects

Because this study focused on code compliance, the primary outcomes of interest for this study are (1) the statewide ECI, defined as the ratio of As-Installed Condition energy consumption to Code-Baseline Condition energy consumption and (2) the SCM, defined as the percentage savings of the alteration relative to energy use if the alteration just met the code. ECI values less than 100% indicate that the As-Installed Condition uses less energy than it would if it just met the code and energy performance is better than if the projects were minimally code compliant. SCM values greater than zero indicate the project saves energy compared to what it would have used if it just met the code. The table below shows the final ECI results for commercial alterations by Climate Zone and statewide. The table also shows the Savings Compliance Margin, which is the energy savings relative to the Code Baseline Condition; the Savings Compliance Margin is positive when a project performs better than code requires and negative when it does not perform as well as code requires. Table 12. Energy Compliance Index and Savings Compliance Margin Results by Climate Zone

Climate Zone	Energy Compliance Index			Relative Precision (90% confidence level)		
	Electric	Gas	Total	Electric	Gas	Total
4	99%	98%	99%	±0.6%	±0.9%	±0.5%
5	92%	104%	97%	±2.3%	±2.7%	±0.9%
6	91%	91%	91%	±1.7%	±3.1%	±2.0%
Statewide	**99%**	**98%**	**98%**	**±0.5%**	**±0.8%**	**±0.6%**

Climate Zone	Savings Compliance Margin*		
	Electric	Gas	Total
4	**1%**	**2%**	**1%**
5	**8%**	**-4%**	**3%**
6	**9%**	**9%**	**9%**
Statewide	**1%**	**2%**	**2%**

***The same precision values apply to the ECI and SCM estimates.**

The statewide code Savings Compliance Margin indicates alteration projects, on the average, use 1% less electricity, 2% less gas, and 2% less energy overall than the maximum allowed under the code. Although most SCM values showed the compliance margin was positive, the value for gas in Climate Zone 5 was negative, indicating alterations used more gas than the maximum allowed under the code. The average ECI based on total energy associated with sampled commercial building alteration projects (electricity plus natural gas) is less than 100% for all Climate Zones and for the state overall, indicating that energy efficiency of alterations exceeded the minimum level required by code overall. The results in all cases are estimated well within a sampling error of 10% relative precision at the 90% confidence level, largely due to a very low level of variation in the data.

Performance in Climate Zone 4, which includes NYC and adjoining areas, has an overall ECI of 99%. The SCM of 1% indicates, on average, commercial alterations in Climate Zone 4 consume 1% less energy than would be expected if they just met code. Climate Zones 5 and 6 demonstrate better average compliance in terms of energy consumption. Except for gas consumption, the energy compliance indices are lower, and the SCMs are larger, in these Climate Zones than in Climate Zone 4 (that is, the alterations performed better relative to code in terms of energy usage than s in Climate Zone 4).

Despite these positive findings regarding code compliance, it is necessary to qualify these results. The main caveat is that the sample sizes in Climate Zones 5 and 6 were so small (9 and 3, respectively) that the compliance results are not likely to be as accurate as the calculated precision suggests. The precision is determined based on appropriate statistical calculations, but it is valid only if the projects in the sample are truly representative of the entire population of alterations in these climate zones and the population is very homogeneous. In Climate Zone 6, we tried to recruit projects from several counties, but all three projects we were able to analyze were from a single county. Because the SCM and ECI compliance results for the projects sampled in Climate Zones 5 and 6 fell in a narrow range, the calculated precision was small. But given the small sample sizes in these climate zones, we believe that the calculated precision understates how much compliance actually varies across all alterations in these areas and that there are likely to be locations or project types, not captured in the samples we studied, that have less favorable compliance.

Table 13 shows ECIs by system, aggregated across Climate Zones. The results do not differ significantly among systems, with all ECIs between 96% and 100%. The estimates for both the water heating (DHW) and mechanical systems, however, are relatively imprecise because the results vary significantly by project.

Table 13. Energy Compliance Index Results by System

System	Energy Compliance Index	Precision (90%)
Envelope	100%	±3.1%
Lighting	98%	±6.2%
Mechanical	96%	±11.3%
DHW	96%	±21.9%

Overall, these findings indicated that, from an energy perspective, commercial alterations in the state met or exceeded minimum compliance levels, on the average. This finding was consistent across climate zones and major systems. However, as noted above, these findings must be caveated in Climate Zones 5 and 6 because of the small samples studied.

3.2 Energy Impact Analysis Results

As previously stated, the primary objective of this study is to assess statewide commercial building alteration energy code compliance in terms of energy impacts. Additionally, this study assessed how much the degree to which commercial alteration projects complied with the code affected building energy consumption.

The project team calculated the energy impact of each project as the difference between Code Baseline Condition energy consumption and the As-Installed Condition energy consumption. In alterations affecting only one fuel type (electricity or gas), the analysis considers only the affected energy type. In alterations comprising multiple systems, our approach analyzes the alterations sequentially to show incremental and interactive impacts. For projects with multiple alterations affecting different electric and gas end uses, the combined energy (electric and gas) impacts were accounted for.

The results shown in Table 14 indicate that overall substantial savings are realized due to alterations exceeding the energy code. It is estimated that alterations conducted over the study period saved a total of 807,823 MMBtu per year more than they would have if they just met the energy code, equivalent to approximately 0.07% of total energy consumption in the state's commercial building sector.[24]

[24] This is based on a value of 1,099.9 trillion Btu per year consumption in the commercial building sector, per EIA: http://www.eia.gov/state/?sid=NY

Table 14. Total Energy Savings over Minimum Code Compliance by Climate Zone

Climate Zone	Total Savings (MMBtu)			Relative Precision (90%)		
	Electric	Gas	Total	Electric	Gas	Total
4	117,507	562,945	680,452	±112.3%	±83.9%	±83.9%
5	113,906	-35,730	78,177	±60.6%	±422.5%	±160.7%
6	19,407	29,788	49,194	±148.2%	±338.9%	±236.4%
Statewide	**250,820**	**557,003**	**807,823**	**±58.4%**	**±88.6%**	**±72.3%**

The relative precision of the estimates in Table 14 is large because energy savings vary dramatically by building type, size and nature of alteration. Given the large variation in energy impacts across alterations, a study estimating these savings with 10% relative precision would require many more sites than the 78 visited. Given the sample size for this study and variation in the savings estimates, the study estimates that commercial building alterations produce energy savings between approximately 223,000 and 1.4 million MMBtu per year (with 90% confidence) more than they would have if all alterations just met the energy code requirements.

4 Conclusions and Recommendations

4.1 Major Conclusions

The results of this study show that alteration projects statewide typically deliver energy performance slightly better than required by the code. The statewide average ECI is 98%, indicating that alteration projects use 2% less total energy than if implemented to code minimum.

ARRA established a minimum code compliance threshold for states to meet by 2017. PNNL and DOE developed a checklist code verification method to determine code compliance, and the minimum statewide compliance required using this method is 90%. This method, unlike the analysis conducted for the current report, does not directly relate to energy use and, given that the PNNL-DOE method determines compliance based on what percentage of specific code requirements are met, their compliance level cannot exceed 100%. In contrast, the compliance estimates provided by this study account for projects performing better than they would if they just met the code minimum.

Although overall *energy* compliance exceeds code requirements, quantification of the percentage of each system type that complies provides useful information. Table 15 summarizes compliance by system type in terms of the percentage of projects in the study that meet or exceed the energy efficiency requirements of the code.

Table 15. Compliance Percentages by System Type

All Projects	Number of Alterations	Number of Alterations Compliant	Number of Alterations not Compliant	% of Alterations Compliant
Envelope	7	7	0	100%
Lighting	30	25	5	83%
Mechanical	63	63	0	100%
DHW	17	17	0	100%
Total	117	112	5	96%

4.2 Challenges with Sampling, Recruiting, and Data Collection

Challenges encountered in conducting this study are presented to inform future studies. Some of the challenges also represent opportunities for improving the code enforcement process.

4.2.1 Sampling Challenges

Sampling relied heavily on Dodge data to determine project distribution statewide. However, Dodge data contains no consistent information on project size or type that can be reliably tied to jurisdiction data. Building types were often incorrectly identified, and projects listed in the Dodge data were sometimes not found in the jurisdiction data. Absent this information, it was difficult to sample efficiently for more variable estimates, such as total savings.

The NYC permit database used for Group B projects also posed challenges. While this data was more detailed than Dodge data, it lacked a critical variable: the square footage of space affected. This variable would have helped to determine project size and efficiently extrapolate savings results to the sample population.

4.2.2 Recruiting Challenges

Difficulties recruiting projects to participate in the study included the following:

- **Low response rates of jurisdictions**. Local building jurisdictions (outside of NYC) vary in terms of workload and staff availability. The jurisdictions in rural areas typically have only one or two code enforcement officers (CEO). Due to high workload and/or limited working hours, many CEOs were difficult to reach. Several indicated they did not have time to assist with the study. Jurisdictions in areas affected by Hurricane Sandy had particular difficulty providing permit lists in a timely manner due to the high volume of reconstruction work.
- **Issues with contact information in permit lists.** During phone interviews, recruiters often had difficulty reaching contacts for buildings in the recruitment sample because the contact information provided by jurisdictions was out-of-date or incomplete. In such cases, recruiters were required to undertake online research to identify accurate contact information for each project.
- **Resistance of some building contacts to participate in the study**. During phone interviews, some building contacts indicated they had previously worked with NYSERDA on a similar effort and could not again dedicate time for another study.

4.2.3 Data Collection Challenges

Some challenges with the data collection process resulted in uncertainty around key data points. These challenges are summarized below.

- **The energy code used for compliance could not be determined**. For some projects, code compliance documentation such as COM*check* files could not be obtained from the site. Because of this issue, it could not be determined with certainty if code compliance was based on ECCCNYS-2010 or ASHRAE 90.1-2007. Whenever the energy code could not be determined, the energy code was assumed to be ASHRAE 90.1-2007.
- **Some key code compliance variables could not be determined**. For a couple of sites, key inputs required for the code compliance analysis could not be determined through the documentation review or observed at the site. Eleven sites were eliminated from the site visits due to a high level of uncertainty around key code requirements and were replaced with back-up sites.
- **Key building staff involved in the project no longer worked at the site**. In a few instances, field engineers reported that building staff interviewed during the site visit were not familiar with the project, making it difficult to determine the scope of the alteration.
- **Permit documents for Group A could not be collected for each project in the sample**. Cadmus was unable to collect permit documents for some of the projects in Group A. Some jurisdictions did not provide permit documents for federal buildings.
- **Issues with identifying occupancy and alteration types**. Cadmus intended to collect data for occupancy and alteration types for each project in the sample. For NYC, permit documents obtained from NYCDOB's website were used to identify alteration and occupancy types. However, permit documentation, and complete data for occupancy and alteration type was not available for all Group A projects. The alteration and occupancy types identified are summarized in project summaries in Appendix H and Appendix I.
- **Facility staff were often unfamiliar with system controls**. In several projects, project team engineers found that facility staff were not sufficiently knowledgeable about proper settings and operation of system controls.

4.3 Recommendations

Two sets of recommendations are provided. The first set applies to the process of conducting future studies; the second applies to ways in which the code enforcement and compliance processes can be improved. Since the study scope focuses on commercial building alterations, some of the recommendations may not be applicable to other code focus areas, such as new residential buildings.

4.3.1 Recommendations for Future Studies

These recommendations will help inform future studies to assess energy code compliance and energy impacts in the state.

- **Target the study to emphasize the most critical research needs:** Assessing code compliance comprehensively is a complex, resource-intensive process. Decisions must be made about where to focus limited resources. For example, consideration could be given to limiting the scope of a study to focus on elements of the code that have changed from one cycle to the next, or to emphasizing code requirements or energy measures documented to have low compliance.
- **Work closely with Department of State (DOS) to plan and conduct the study:** DOS has contact information for building departments statewide and can help inform and recruit local building departments.
- **Engage the NYCDOB in the study:** This department has extensive building information and that could help conduct future studies. NYCDOB was unable to help in the current study because of timing; early contact in future studies is essential. NYCDOB's building permit data is essential, although limited.
- **Engage municipalities in the study:** Cooperation and assistance from municipal building departments are critical. It is important to communicate the purpose of the study and the utility of the information it will provide, and to reinforce the confidentiality (to the extent permitted by law) of all collected information. If possible, researchers should attend meetings and make personal contact with CEOs and municipal leadership to communicate the study's objectives. It is very beneficial to have a former CEO with a strong network as a member of the study team. The study team should find ways to minimize the burden on the building departments, including visiting the department to compile data, providing prepaid mailers to submit information, and timing visits to be as convenient as possible.
- **Obtain the best possible data on building starts throughout the state:** While Dodge data was found to be incomplete and inconsistent with jurisdictional project information, the NYC permit data website was invaluable. The best data sources are permit lists from jurisdictions coordinated by DOS, or utility new building connection data.
- **Develop an electronic data collection tool, leveraging existing tools or instruments:** The tablet-based data collection tool developed for this study, based on information collected to run COM*check*, and/or the PNNL-DOE checklists are good starting points for designing a data collection tool that provides efficiencies and increases accuracy.
- **Select an oversample of jurisdictions and building projects:** Because attrition is common in these studies, it is important to design a sample that allows for substitution of jurisdictions and buildings as needed. An oversample of at least 50% is recommended.
- **Minimize self-selection bias:** A common concern is the likelihood that both jurisdictions and building owners willing to participate may not be representative of the population and thus bias results. This is less a problem with building departments than with owners and contractors for the actual projects recruited. One means to encourage diverse participation is to offer financial or other incentives to participants, such as a brief summary of findings on their project. The researchers should identify what factors might distinguish unique characteristics that would undermine representativeness and review the sample of projects as they are recruited to detect any bias in its makeup. One such characteristic in the residential market is the proportion of custom-built homes.

- **Engage the building industry in the study:** If buildings are studied before occupancy, owners and contractors must be engaged to allow site visits. The researchers should reach out to market actor organizations to explain the study, encourage cooperation and participation, minimize concerns and identify ways to reduce the burden on participants. The study team should identify incentives to encourage participation, such as a commitment to share the study findings or a financial incentive.
- **Engage building owners/occupants in the study:** In most similar studies, it is important to visit buildings with key systems installed and some completed buildings to get the most thorough data. In cases requiring owner or occupant recruitment, most of the tactics identified to recruit other market actors should be considered. For commercial buildings, it is critical to involve a facility manager or someone most familiar with the energy aspects of the building.
- **Include qualitative data collection from market actors:** For such research to be most useful to the industry and to inform efforts to enhance compliance and enforcement, it is important to include a research component that gathers qualitative information from key market actors. For example, interviews with CEOs can identify what enforcement issues are most challenging and where training or tools could most improve enforcement.
- **Schedule data collection to take into account industry cycles:** If the study needs to collect information during construction phases, data collection should be planned during the most active months of the construction season.
- **Use prototypical building simulation models when desirable:** Simulation models of prototype buildings were used to minimize the effort required to model energy use in each project in this study. This approach can reduce the resources required to estimate the energy effects of building characteristics.
- **Examine options for integrating building code compliance characteristics, billing data, and modeled energy impacts:** Developing predictive relationships of actual energy impacts of various degrees of code compliance based on billing data and simulation models could provide a cost-effective means to minimize the amount of building modeling required. Such approaches are still in the concept stage and would require research such as simulation model analyses of a range of building characteristics that affect energy use and calibrated building simulations to adjust simulation model estimates.
- **Disseminate findings from future studies:** Sharing the findings of code studies with market actors could induce participation and help advance the state of both code enforcement and compliance. The information could be disseminated through code enforcement organizations, designer and architect groups, and other relevant organizations.

4.3.2 Recommendations for Improving Code Enforcement and Compliance

These recommendations are intended to suggest ways to enhance the code enforcement and compliance processes in New York State. Since this study addresses commercial building alterations only, the recommendations focus on alterations and may be less applicable to new commercial and residential construction. Since only limited data collection was available for this study from the building departments, most of these recommendations focus on the project site.

- **Establish a statewide, consistently formatted database of permit information:** Some states (for example, California and Rhode Island) are moving to create a statewide database where jurisdictions will enter their permit data. Because determining code compliance, trends, and impacts is likely to become increasingly important, the state should investigate ways to establish such a database with consistent data fields.

- **Commercial alteration projects should be required to maintain code compliance information on site:** While new commercial buildings typically have key information (plans and specifications) on site, there was no such information at the smaller commercial projects visited. For larger projects, envelope specifications were not available. For all projects, including alterations, information about the project should be required to be retained on site.
- **CEOs should scrutinize lighting alterations more in areas that are not regularly occupied:** Non-compliance in lighting projects was only found in areas generally not consistently occupied, such as lobbies, corridors, storage areas and basements.
- **More emphasis should be placed on increasing enforcement and compliance related to controls:** Gaps exist at the facilities in knowledge and understanding of controls for mechanical systems and lighting. Facility staff often had little familiarity with HVAC controls or could not explain energy management system functionality. Facility staff should be more fully trained on requirements for controls, including exemptions, and require that proper documentation is maintained on site.

Appendix A: List of Site Visits

This study examines 78 permitted commercial building alterations projects including 15 non-New York City projects (Group A) and 63 New York City Projects (Group B). Alteration types, codes used for the code compliance analysis and data verified on-site for each project are listed below:

Table 16. List of Site Visits

Project ID	Envelope alteration	Lighting alteration	Mechanical alteration	Code compliance analysis was based on	Site engineer was able to verify which code was used for compliance?	Permit data for alteration was verified by site engineer during site visit?
A2		X	X	ECCCNYS-2010	Yes	Yes
A3		X	X	ECCCNYS-2010	Yes	Yes
A4		X	X	ASHRAE 90.1-2007	No	Yes
A5		X	X	ASHRAE 90.1-2007	No	Yes
A6		X	X	ASHRAE 90.1-2007	Yes	Yes
A7		X		ASHRAE 90.1-2007	Yes	Yes
A8	X	X	X	ASHRAE 90.1-2007	No	Yes
A9	X		X	ASHRAE 90.1-2007	No	Yes
A13			X	ASHRAE 90.1-2007	No	Yes
A14		X	X	ASHRAE 90.1-2007	Yes	Yes
A15			X	ASHRAE 90.1-2007	No	Yes
A17	X		X	ASHRAE 90.1-2007	No	Yes
A18			X	ASHRAE 90.1-2007	No	Yes
A23	X		X	ASHRAE 90.1-2007	No	No - Measure data for exterior doors could not be verified
A25		X	X	ASHRAE 90.1-2007	No	Yes
B1			X	ASHRAE 90.1-2007	No	Yes
B2			X	ASHRAE 90.1-2007	No	Yes
B4			X	ASHRAE 90.1-2007	No	Yes
B6	X	X	X	ECCCNYS-2010	Yes	Yes
B12			X	ASHRAE 90.1-2007	No	Yes
B14			X	ASHRAE 90.1-2007	No	Yes
B15	X	X	X	ECCCNYS-2010	Yes	Yes
B16			X	ASHRAE 90.1-2007	No	Yes
B18			X	ASHRAE 90.1-2007	No	Yes
B19			X	ASHRAE 90.1-2007	No	Yes
B20			X	ASHRAE 90.1-2007	No	Yes
B21			X	ASHRAE 90.1-2007	No	Yes

B22			X	ASHRAE 90.1-2007	Yes	Yes
B23			X	ASHRAE 90.1-2007	Yes	Yes
B28			X	ASHRAE 90.1-2007	No	Yes
B29			X	ASHRAE 90.1-2007	No	Yes
B30			X	ASHRAE 90.1-2007	No	Yes
B32			X	ASHRAE 90.1-2007	No	Yes
B33			X	ECCCNYS-2010	Yes	Yes
B37			X	ASHRAE 90.1-2007	No	Yes
B38			X	ASHRAE 90.1-2007	No	Yes
B40			X	ASHRAE 90.1-2007	No	Yes
B41			X	ASHRAE 90.1-2007	No	Yes
B42			X	ASHRAE 90.1-2007	No	Yes
B46			X	ASHRAE 90.1-2007	No	Yes
B47			X	ASHRAE 90.1-2007	No	Yes
B51			X	ASHRAE 90.1-2007	No	Yes
B52			X	ASHRAE 90.1-2007	Yes	Yes
B53			X	ASHRAE 90.1-2007	No	Yes
B59			X	ASHRAE 90.1-2007	No	Yes
B60			X	ASHRAE 90.1-2007	No	Yes
B64		X		ASHRAE 90.1-2007	No	Yes
B65			X	ASHRAE 90.1-2007	No	Yes
B66		X		ASHRAE 90.1-2007	No	Yes
B68			X	ASHRAE 90.1-2007	No	Yes
B69			X	ASHRAE 90.1-2007	No	Yes
B70		X		ASHRAE 90.1-2007	No	Yes
B71			X	ASHRAE 90.1-2007	No	Yes
B72			X	ASHRAE 90.1-2007	No	Yes
B73			X	ASHRAE 90.1-2007	No	Yes
B75			X	ECCCNYS-2010	Yes	Yes
B77		X		ASHRAE 90.1-2007	No	Yes
B78			X	ASHRAE 90.1-2007	No	Yes
B79			X	ASHRAE 90.1-2007	No	Yes
B80			X	ASHRAE 90.1-2007	No	Yes
B81			X	ASHRAE 90.1-2007	No	Yes
B82			X	ASHRAE 90.1-2007	No	Yes
B83			X	ASHRAE 90.1-2007	No	Yes
B85			X	ASHRAE 90.1-2007	No	Yes
B88	X			ECCCNYS-2010	Yes	Yes
B89	X			ASHRAE 90.1-2007	No	Yes
B93			X	ASHRAE 90.1-2007	No	Yes

B94		X	X	ASHRAE 90.1-2007	No	No - Name plate for HVAC could not be accessed
B95		X	X	ASHRAE 90.1-2007	No	Yes
B96			X	ASHRAE 90.1-2007	No	Yes
B97			X	ASHRAE 90.1-2007	No	Yes
B98			X	ASHRAE 90.1-2007	No	Yes
B99			X	ASHRAE 90.1-2007	No	Yes
B100			X	ASHRAE 90.1-2007	No	Yes
B101		X		ASHRAE 90.1-2007	No	Yes
B102		X		ASHRAE 90.1-2007	No	Yes
B103		X		ASHRAE 90.1-2007	No	Yes
B104		X		ASHRAE 90.1-2007	No	Yes

Appendix B: Code Context and Applicability

Code Context and Applicability of Cadmus' code compliance project with NYSERDA is a systematic approach for assessing commercial alterations building projects in the context of requirements established in the 2010 Energy Conservation Construction Code of New York State (ECCCNYS-2010) and the Existing Building Code of New York State (EBCNYS).

This document includes the following sections:

- Section 1: Code Applicability
- Section 2: Exemptions
- Section 3: Exceptions
- Section 4: Additional NYC Local Laws
- Section 5: Compliance Paths
- Section 6: EBCNYS Code Requirements

Section 1: Code Applicability

The ECCCNYS-2010 has an effective date of December 28, 2010. Commercial buildings, including buildings over three stories, must be designed by Chapter 5 of the ECCCNYS-2010. Section 501 allows alternative design by ASHRAE 90.1-2007, Energy Standards for Buildings Except for Low-Rise Residential Buildings. According to Section 501.2 of the ECCCNYS-2010 (Application), the commercial building project shall comply with the requirements in Sections: 502 (Building envelope requirements), 503 (Building mechanical systems), 504 (Service water heating) and 505 (Electrical power and lighting systems) in its entirety. As an alternative the commercial building project shall comply with the requirements of ASHRAE/IESNA 90.1 in its entirety.

The ECCCNYS-2010 as it pertains to alteration, renovation or repair of an existing building is subject to New York State Energy Law Section 11-103(b), which provides that in the case of the renovation of an existing building, this code:

(1) shall apply only if the renovation is a "substantial renovation" (i.e., only if more than 50% of any "building subsystem" is replaced), and
(2) shall apply only to that portion of the "building subsystem" which is being replaced.

The New York City Energy Conservation Code (NYCECC), which went into effect July 1, 2010, includes Local Law 85, stating that the 50% rule no longer applies. All new modifications now need to comply with NYCECC.

Section 2: Exemptions

Cadmus examined the exemptions in ECCCNYS-2010 and put emphasis on these exemptions during the recruitment of buildings to avoid recruiting any non-eligible buildings for the study. The exemptions in ECCCNYS-2010 include:

- **Historic Buildings & Low Energy Buildings:** According to the ECCCNYS-2010 specific historic buildings (Section 101.4.2) and specific low energy buildings (Section 101.5.2) are exempt from meeting the code.
- **Additional Exemptions for NYC:** In addition to the above exemptions (Historic and Low Energy Buildings), the NYCECC outlines additional exemption for categories of work not affecting energy use, including:
    - Temporary structures (as described in Administrative Code 28-111 and BC 3203) are exempt from compliance with the Energy Code. In addition, the following work types are exempt:
        - FA (fire alarm); (B) FP (fire suppression in a range hood); (C) SD (standpipe); (D) SP (sprinklers); (E) FS (fuel storage); (F) EQ (construction equipment); (G) CC (curb cut); (H) OT/BPP (builder's pavement plan); and (I) OT/FPP (fire protection plan).

Section 3: Exceptions

According to Section 101.4.3 of the ECCCNYS-2010, this code applies to alterations and renovations to existing commercial buildings, in all cases where ASHRAE 90.1-2007 applies; however, there are eight exceptions to these code requirements, six of which apply to building envelope and two to lighting code requirements.

The general provisions of the ECCCNYS-2010 and ASHRAE 90.1-2007 code applicability and exceptions are summarized below:

Table 17. ECCCNYS-2010 Code Applicability and Exceptions: General Provisions

	Applicability	Exceptions
Application (Section 501.2)	Application. The commercial building project shall comply with the requirements in Sections 502 (Building envelope requirements), 503 (Building mechanical systems), 504 (Service water heating) and 505 (Electrical power and lighting systems) in its entirety. As an alternative the commercial building project shall comply with the requirements of ASHRAE/IESNA 90.1 in its entirety.	
General (Chapter 1)	The ECCCNYS-2010 (Provisions of sections 101.4.1, 101.4.2, 101.4.4, 101.4.5 and 101.4.6) as it pertains to alteration, renovation or repair of an existing building is subject to New York State Energy Law section 11-103(b), as in effect at the time of adoption of this code, which provides that in the case of the renovation of an existing building, this code:	Historic buildings are exempt from meeting the code if the building is: (a) listed in the New York State Register of Historic Places, either individually or as a contributing building to a historic district, or (b) listed in the National Register of Historic Places, either individually or as a contributing building to a

	(a) shall apply only if the renovation is a "substantial renovation" (i.e., only if more than 50% of any "building subsystem" is replaced), (*NYC removed this rule*) and (b) shall apply only to that portion of the "building subsystem" which is being replaced.	historic district, or (c) Eligible for listing in either the New York State or National Register of Historic Places, either individually or as a contributing building to a historic district, by the New York State Commissioner of Parks, Recreation and Historic Preservation, or (d) Eligible for listing in the National Register of Historic Places, either individually or as a contributing building to a historic district, by the U.S. Secretary of the Interior, need not comply with this code. (Section 101.4.2)
	Spaces undergoing a change in occupancy that would result in an increase in demand for either fossil fuel or electrical energy shall comply with this code; and where the use in a space changes from one use to another (in Table 505.5.2), the installed lighting wattage shall comply with Section 505.5. (Section 101.4.4)	Low Energy Buildings or portions of a building separated from the reminder of the building by building thermal envelop assemblies complying with the code, shall be exempt from the building thermal envelope provisions of the code (Section 101.5.2): (a) Building spaces with a peak design rate of energy usage less than 3.4 Btu/h per square foot or 1.0 watt per square foot (10.7 W/m2) of floor area for space conditioning purposes; (b)Building spaces that do not contain conditioned space
	Any non-conditioned space that is altered to become conditioned space shall be required to be brought into full compliance with this code (Section 101.4.5).	In addition to the above exemptions (Historic and Low Energy Buildings), the NYCECC outlines additional exemption for Categories of work not affecting energy use, including temporary structures (as described in Administrative Code 28-111 and BC 3203) are exempt from compliance with the Energy Code. In addition, the following work types are exempt: (a) FA (fire alarm), (b) FP (fire suppression in a range hood), (c) SD (standpipe), (d) SP (sprinklers), (e) FS (fuel storage), (f) EQ (construction equipment), (g) CC (curb cut), (h) OT/BPP (builder's pavement plan), (i) OT/FPP (fire protection plan)
	Commercial buildings shall meet the provisions of Chapter 5; where a building includes both residential and commercial occupancies, each occupancy shall be separately considered and meet the applicable provisions of Chapter 4 for residential and Chapter 5 for commercial (Section 101.5)	
	Compliance can be determined through the use of software developed by the U.S. DOE including COM*check*. In the case of energy modeling, the code official shall be permitted to accept an energy cost budget worksheet based on AHRAE 90.1 or Section 506 and any information and reports showing acceptable results of the energy modeling. When using software approach to show compliance, mandatory provisions of Chapter 5 must be complied with.	

Table 18. ECCCNYS-2010 Code Applicability and Exceptions: Envelope & HVAC Systems

	Applicability	Exceptions
Envelope Alterations (Sect. 502)	Alterations to building envelope shall comply with the Building Envelope Mandatory Provisions: Air Leakage (Section 502.4), Vapor Retarders (Section 502.5) *NYCESS does not mandate vapor barriers as they are not required for CZ 4A*	Exceptions to building envelope requirements include : (a) Storm windows installed over existing fenestration.
		(b) Glass only replacements in an existing sash and frame provided the *U*-factor and the solar heat gain coefficient (SHGC) will be equal to or lower than before the glass replacement.
		(c) Alterations, renovations or repairs to roof/ceiling, wall or floor cavities which are insulated to full depth with insulation having a minimal nominal value of R-3.0/inch.
		(d) Alterations, renovations or repairs to walls and floors, where the existing structure is without framing cavities and no new framing cavities are created.
		(e) Reroofing where neither the sheathing nor the insulation is exposed. Roofs without insulation in the cavity and where the sheathing or insulation is exposed during reroofing shall be insulated either above or below the sheathing.
		(f) Replacement of existing doors that separate conditioned space from the exterior shall not require the installation of a vestibule or revolving door, provided, however, that an existing vestibule that separates a conditioned space from the exterior shall not be removed.
HVAC (Section 503)	Alterations with HVAC systems in existing building must comply with the Mandatory Provisions in Section 502, including: Calculation of heating and cooling loads (Section 503.2.1); Equipment and system sizing (Section 503.2.2): Heating and cooling equipment and systems capacity shall not exceed the loads calculated in accordance with Section 503.2.1; HVAC equipment performance requirements (503.2.3); HVAC System Controls (503.2.4); Ventilation (Section 503.2.5); Demand controlled ventilation (Section 503.2.3.1); Energy recovery ventilation systems (Section 503.2.6); Duct and plenum insulation and sealing (Section 503.2.7); Duct Construction (Section 503.2.7.1); Piping Insulation (Section 503.2.8)	
	Buildings using the Simple HVAC prescriptive approach must comply with Section 503.3: This section applies to buildings served by unitary or packaged HVAC equipment listed in Tables 503.2.3(1) through 503.2.3(5), each serving one zone and controlled by a single thermostat in the zone served. It also applies to two-pipe heating systems serving one or more zones, where no cooling system is installed. This section does not apply to fan systems serving multiple zones, non-unitary or non-packaged HVAC equipment and systems or hydronic or steam heating and hydronic cooling equipment and distribution systems that provide cooling or cooling and heating which are covered by Section 503.4.	

	Buildings using the Complex HVAC prescriptive approach must comply with Section 503.4: This section applies to buildings served by HVAC equipment and systems not covered in Section 503.3

Table 19. ECCCNYS-2010 Code Applicability and Exceptions: Service Water Heating & Electrical Power and Lighting Systems

	Applicability	Exceptions
Service Water Heating (Section 504)	Alteration to building service water heating equipment must comply with the Mandatory provisions under Section 504, including: Service water heating equipment performance efficiency (Section 504.2); Temperature controls (Section 504.3); Heat traps (Section 504.4); Pipe insulation (Section 504.4); and Hot water system controls (Section 505.5)	
Electrical Power and Lighting Systems (Section 505)		The following need not comply with the provisions of this code, provided the energy use of the building is not increased (Section 101.4.3): (a) An alteration that replaces less than 50 percent of the luminaires in a space, provided that such alteration does not increase the installed interior lighting power; (b) An alteration that replaces only the bulb and ballast within the existing luminaires in a space, provided that such alteration does not increase the installed interior lighting power.
	Lighting Controls Mandatory Provisions (Section 502.2)	Exceptions to Section 502.2: lighting within dwelling units may have a minimum of 50 percent of the permanently installed interior light fixtures fitted with high-efficacy lamps as an alternative to Section 502.5.2 (Section 505.5.3)
	Tandem Wiring Mandatory Provisions (505.3)	Exceptions to Section 505.3: 1. Where electronic high-frequency ballasts are used. 2. Luminaires on emergency circuits. 3. Luminaires with no available pair in the same area.
	Exit Signs Mandatory Provisions (Section 505.4)	
	Exterior Lighting Mandatory Provisions (Section 505.5)	Exception to Section 505.5: Low-voltage landscape lighting; where approved because of historical, safety, signage or emergency considerations
	Electrical Energy Consumption (Section 505.6) In buildings having individual dwelling units, provisions shall be made to determine the electrical energy consumed by each tenant by separately metering individual dwelling units.	

Table 20. ASHRAE-90.1 2007 Code Applicability and Exceptions: General, Envelope & HVAC Systems

	Applicability	Exceptions
General (Section 4.2)	Alterations of existing buildings shall comply with the provisions of Sections 5, 6, 7, 8, 9, and 10, provided, however, that nothing in this standard shall require compliance with any provision of this standard if such compliance will result in the increase of energy consumption of the building. (Section 4.2.1.3)	a. A building that has been specifically designated as historically significant by the adopting authority or is listed in The National Register of Historic Places or has been determined to be eligible for listing by the US Secretary of the Interior need not comply with these requirements
		b. Where one or more components of an existing building or portions thereof are being replaced, the annual energy consumption of the comprehensive design shall not be greater than the annual energy consumption of a substantially identical design, using the same energy types, in which the applicable requirements of Sections 5, 6, 7, 8, 9, and 10, as provided in Section 4.2.1.3, and such compliance is verified by a design professional, by the use of any calculation methods acceptable to the authority having jurisdiction
Envelope Alterations (Section 5.1)	Alterations to the building envelope shall comply with the requirements of Section 5 for insulation, air leakage, and fenestration applicable to those specific portions of the building that are being altered. (Section 5.1.3)	a. Installation of storm windows over existing glazing
		b. Replacement of glazing in existing sash and frame provided the *U*-factor and SHGC will be equal to or lower than before the glass replacement
		c. Alterations to roof/ceiling, wall, or floor cavities, which are insulated to full depth with insulation having a minimum nominal value of R- 3.0/in
		d. Alterations to walls and floors, where the existing structure is without framing cavities and no new framing cavities are created
		e. Replacement of a roof membrane where either the roof sheathing or roof insulation is not exposed or, if there is existing roof insulation, below the roof deck
		f. Replacement of existing doors that separate conditioned space from the exterior shall not require the installation of a vestibule or revolving door, provided, however, that an existing vestibule that separates a conditioned space

		from the exterior shall not be removed
		g. Replacement of existing fenestration, provided, however, that the area of the replacement fenestration does not exceed 25% of the total fenestration area of an existing building and that the *U*-factor and SHGC will be equal to or lower than before the fenestration replacement
Alterations to HVAC in Existing Buildings Exceptions (Section 6.1)	New HVAC equipment as a direct replacement of existing HVAC equipment shall comply with the specific minimum efficiency requirements applicable to that equipment (Section 6.1.1.3)	a. For equipment that is being modified or repaired but not replaced, provided that such modifications and/or repairs will not result in an increase in the annual energy consumption of the equipment using the same energy type;
	New cooling systems installed to serve previously uncooled spaces shall comply with this section as described in Section 6.2	b. Where a replacement or alteration of equipment requires extensive revisions to other systems, equipment, or elements of a building, and such replaced or altered equipment is a like-for-like replacement;
	Alterations to existing cooling systems shall not decrease economizer capability unless the system complies with Section 6.5.1	c. For a refrigerant change of existing equipment;
	New and replacement ductwork shall comply with Sections 6.4.4.1 and 6.4.4.2	d. For the relocation of existing equipment; or
	New and replacement piping shall comply with Section 6.4.4.1	e. For ducts and pipes where there is insufficient space or access to meet these requirements.

Table 21. ASHRAE-90.1 2007 Code Applicability and Exceptions: Service Water Heating, Power & Lighting Systems

	Applicability	Exceptions
Service Water Heating (Section 7.1)	Alterations to Existing Buildings. Building service water heating equipment installed as a direct replacement for existing building service water heating equipment shall comply with the requirements of Section 7 applicable to the equipment being replaced. New and replacement piping shall comply with Section 7.4.3. (Section 7.1.1.3)	Compliance shall not be required where there is insufficient space or access to meet these requirements.
Power (Section 8.2)	Power distribution systems in all projects shall comply with the requirements of Section 8.1, General; Section 8.4, Mandatory Provisions; and Section 8.7, submittals. (Section 8.2.1)	
Lighting (Section 9.1)	Section 9.1.1 General Scope a. interior spaces of buildings	a. emergency lighting that is automatically off during normal

	b. exterior building features, including facades, illuminated roofs, architectural features, entrances, exits, loading docks, and illuminated canopies c. exterior building grounds lighting provided through the building's electrical service	building operation b. lighting within dwelling units c. lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation d. decorative gas lighting systems
	Section 9.1.2 Lighting Alterations The replacement of lighting systems in any building space shall comply with the LPD requirements of Section 9 applicable to that space. New lighting systems shall comply with the applicable LPD requirements of Section 9. Any new control devices as a direct replacement of existing control devices shall comply with the specific requirements of Section 9.4.1.2(b).	Alterations that replace less than 50% of the luminaires in a space need not comply with these requirements provided that such alterations do not increase the installed interior lighting power.
	Section 9.1.3 Installed Interior Lighting Power Installed Interior Lighting Power. The installed interior lighting power shall include all power used by the luminaires, including lamps, ballasts, transformers, and control devices except as specifically exempted in Section 9.2.2.3.	If two or more independently operating lighting systems in a space are capable of being controlled to prevent simultaneous user operation, the installed interior lighting power shall be based solely on the lighting system with the highest wattage.
	Section 9.1.4 Luminaire Wattage Luminaire Wattage. Luminaire wattage incorporated into the installed interior lighting power shall be determined in accordance with the following criteria: a. The wattage of incandescent or tungsten-halogen luminaires with medium screw base sockets and not containing permanently installed ballasts shall be the maximum labeled wattage of the luminaire. b. The wattage of luminaires with permanently installed or remote ballasts or transformers shall be the operating input wattage of the maximum lamp/auxiliary combination based on values from the auxiliary manufacturers' literature or recognized testing laboratories or shall be the maximum labeled wattage of the luminaire. c. For line-voltage lighting track and plug-in bus-way, designed to allow the addition and/or relocation of luminaires without altering the wiring of the system, the wattage shall be 1. the specified wattage of the luminaires included in the system with a minimum of 30 W/lin ft or 2. the wattage limit of the system's circuit breaker or 3. the wattage limit of other permanent current-limiting device(s) on the system. d. The wattage of low-voltage lighting track, cable conductor, rail conductor, and other flexible lighting systems that allow the addition and/or relocation of luminaires without altering the wiring of the system shall be the specified wattage of the transformer supplying the system. e. The wattage of all other miscellaneous lighting equipment shall be the specified wattage of the lighting equipment.	

Section 4: Additional NYC Local Laws

- Local Law 1[25] (LL1) of 2011 which went into effect December 28, 2010, establishes the 2011 NYCECC based on the 2010 ECCCNYS.
- Local Law 85 of 2009, which went into effect July 1, 2010, removed the exemptions for envelope additions, alterations and repairs that affect less than 50% of a system.
- Local Law 48[26] of 2010 amends Section 5050 of the NYCECC, and adds Appendix A amending ASHRAE 90.1/2007, Section 9: Shutoff-only occupancy sensors are now required for:
    - Classrooms (excluding shop, laboratory, or preschool classrooms)
    - Conference/meeting rooms
    - Employee lunch break and break rooms
    - Offices smaller than 200 square feet (unless the offices have lighting controlled with photo-sensor)
- 1 Rules of the City of New York 5000-01[27] and 1 RCNY 101-07[28], define NYCECC submission and project progress inspection and verification procedures
- Building Bulletin 2010-031[29]: outlines conditions under which an addition, alteration, renovation or repair to an HVAC or service hot water system may not be required to comply with the Energy Code
- Building Bulletin 2010-032[30]: outlines conditions under which an addition, alteration, renovation or repair to a lighting or electrical power system, or control equipment may not be required to comply with the Energy Code
- Building Bulletin 2011-015[31]: outlines conditions under which an addition, alteration, renovation or repair to a building envelope may not be required to comply with the Energy Code.

Section 5: Compliance Paths

ECCCNYS-2010: Compliance with the ECCCNYS-2010 can be demonstrated by one of the following paths: The ECCCNYS-2010 allows compliance to be demonstrated by two main compliance paths:

1. **Prescriptive:** Provisions under the prescriptive path must be met by every building unless an approved tradeoff or performance approach is used or unless there is a specific exception in the code. This approach requires that every building component (e.g. fenestration, wall assemblies, lighting. mechanical equipment, etc.) must comply with the requirements in the ECCCNYS- 2010 code for the project to demonstrate code compliance. Additionally, the ECCCNYS - 2010 code makes provisions for the Envelope *R*-value to be used in place of *U*-values for each assembly component. It also makes provisions for trade-off between exterior lighting allowances in various exterior space types such that total installed exterior lighting power allowance for tradable surfaces collectively does not exceed the lighting power allowance.

[25] http://www.nyc.gov/html/dob/downloads/pdf/ll1of2011.pdf
[26] http://www.nyc.gov/html/dob/downloads/pdf/ll48of2010.pdf
[27] http://www.nyc.gov/html/dob/downloads/rules/1_RCNY_5000-01.pdf
[28] http://www.nyc.gov/html/dob/downloads/rules/1_RCNY_101-07.pdf
[29] http://www.nyc.gov/html/dob/downloads/bldgs_bulletins/bb_2010-031.pdf
[30] http://www.nyc.gov/html/dob/downloads/bldgs_bulletins/bb_2010-032.pdf
[31] http://www.nyc.gov/html/dob/downloads/bldgs_bulletins/bb_2011-015.pdf

2. **Performance**: provisions under the performance-based compliance path require that the proposed building be shown to have an annual energy cost that is less than or equal to the annual energy cost of the standard reference design (with the exception of jurisdictions that require site energy, in kWh or Btu, to be used rather than energy cost as the metric of comparison). This method is termed as the "Total Building Performance (modeling)"

Regardless of the compliance approach used, there are mandatory requirements in the ECCCNYS-2010 that must be met by every building unless there is a specific exception in the code. Compliance can be demonstrated through the use of computer software developed by the United States Department of Energy (DOE), including COM*check*. Compliance can alternatively be demonstrated by the approach specified in Chapter 5 of the ECCCNYS 2010. Section 501 of the ECCCNYS 2010 allows alternative design by ASHRAE 90.1-2007, *Energy Standard for Buildings, Except for Low Rise Residential Buildings*.

ASHRAE 90.1-2007: Compliance with the ASHRAE 90.1-2007 can be demonstrated by one of the following paths:

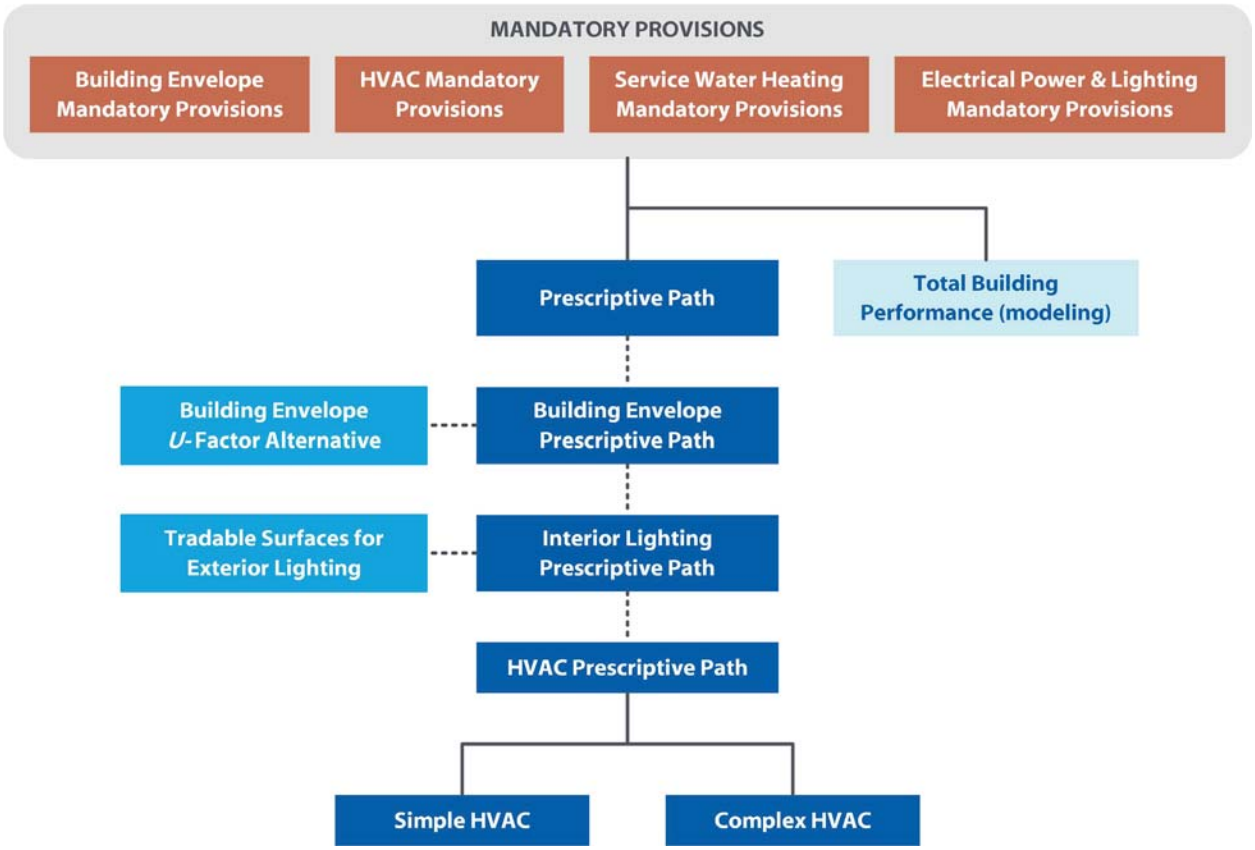
1. **Prescriptive:** Provisions under the prescriptive path must be met by every building unless an approved tradeoff or performance approach is used or unless there is a specific exception in the code. This approach requires that every building component (e.g.: fenestration, wall assemblies, lighting. mechanical equipment, etc.) must comply with the requirements in the ECCCNYS- 2010 code for the project to demonstrate code compliance. The ASHRAE 90.1 Standard allows envelope compliance using an alternate compliance option per Section 5.6 – Building Envelope Trade-off Option. This approach allows demonstrating envelope compliance through the "envelope performance factor" analysis. Similar to ECCCNYS -2010, the ASHRAE 90.1 Standard also identifies certain exterior building area categories wherein lighting power allowance can be traded as long as the collective connected exterior lighting power consumption is equal to or less than the allowable lighting consumption.
2. **Performance**: provisions under the performance-based compliance path require that the energy cost of the proposed building must be less than or equal to the annual energy cost of the baseline design. This method is termed as the "Total Building Performance (modeling)"

In the case of energy modeling, the code official shall be permitted to accept an energy cost budget worksheet based on ASHRAE 90.1 or Section 506 of the ECCCNYS-2010 and any information and reports showing acceptable results of the energy modeling. When using the software approach to show compliance, the mandatory code provisions of Chapter 5 must be complied with Section 101.5 of ECCCNYS-2010.

On the other hand, the NYCECC-2011 specifies that COM*check* software program can be used for alterations and repairs only when a Total Building Performance (modeling) is performed and where the COM*check* report states "alteration" as the project type[32].

Illustration of the compliance paths by building components and a summary of the code requirements as required in the ECCCNYS-2010 and ASHRAE-90.1-2007 code are shown below:

Figure 10. Illustration of ECCCNYS-2010 Compliance Paths



[32] http://www.nyc.gov/html/dob/downloads/rules/1_RCNY_5000-01.pdf

Figure 11. ECCCNYS-2010 Compliance Paths & Requirements

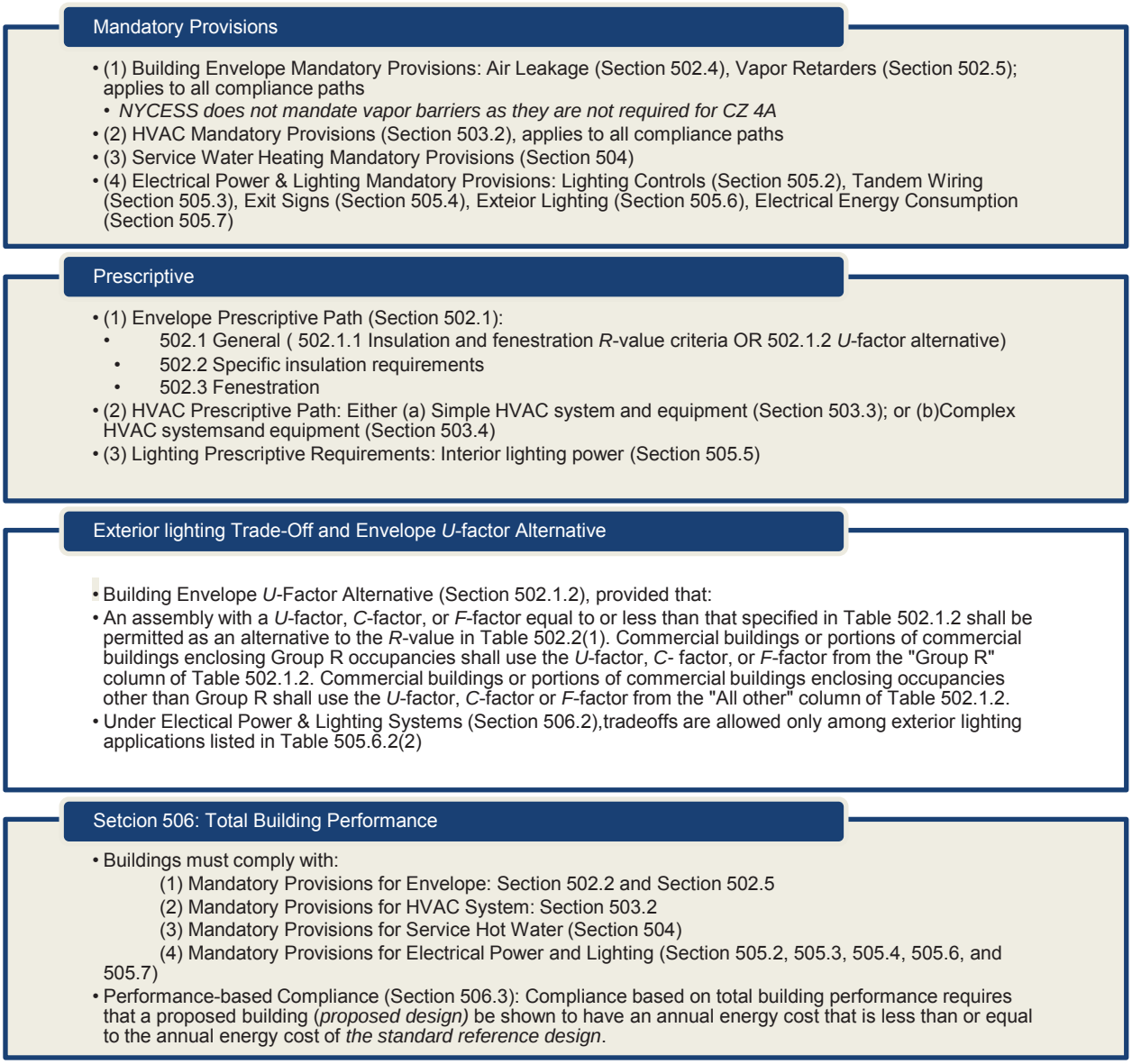


Figure 12. Illustration of ASHRAE 90.1-2007 Compliance Paths

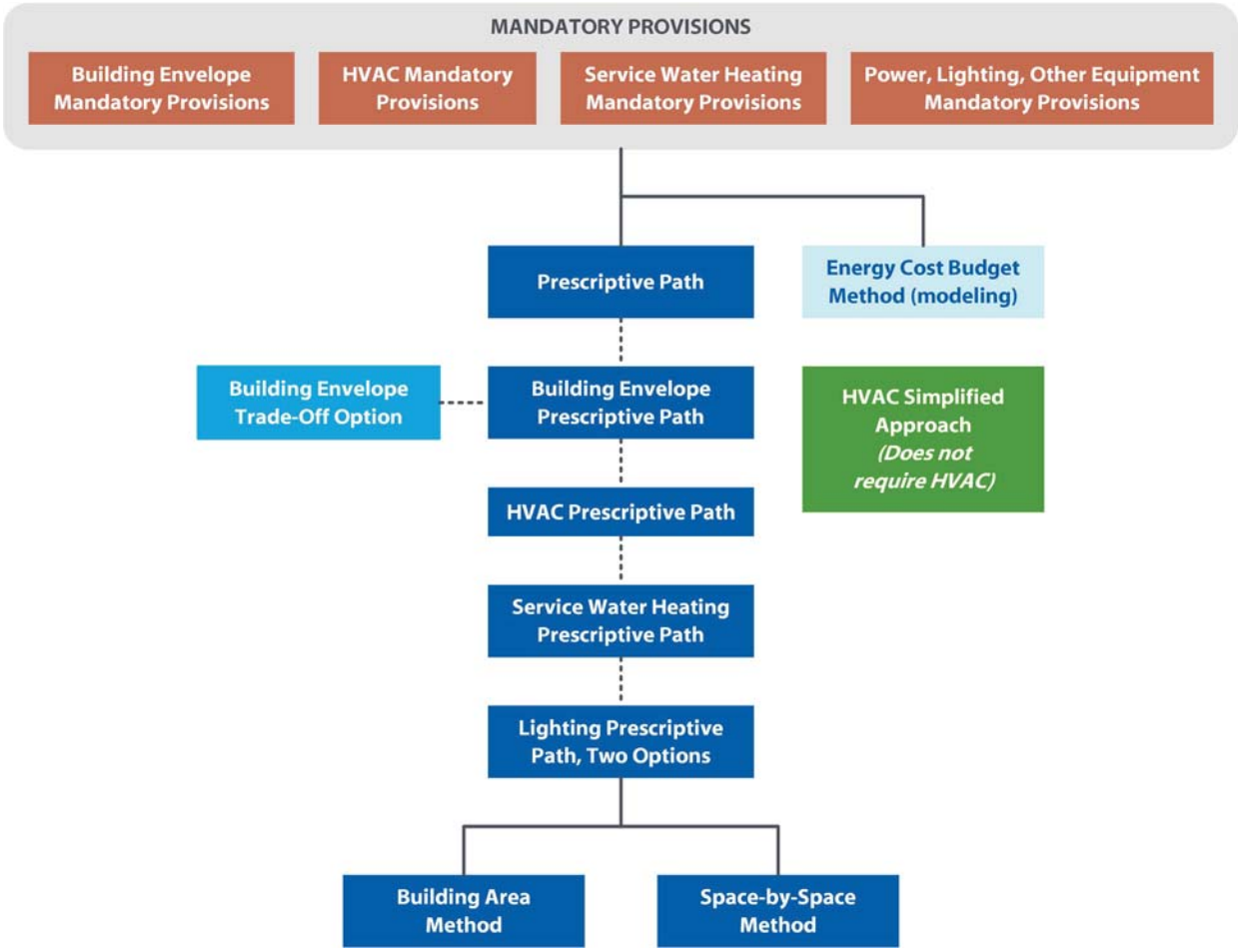
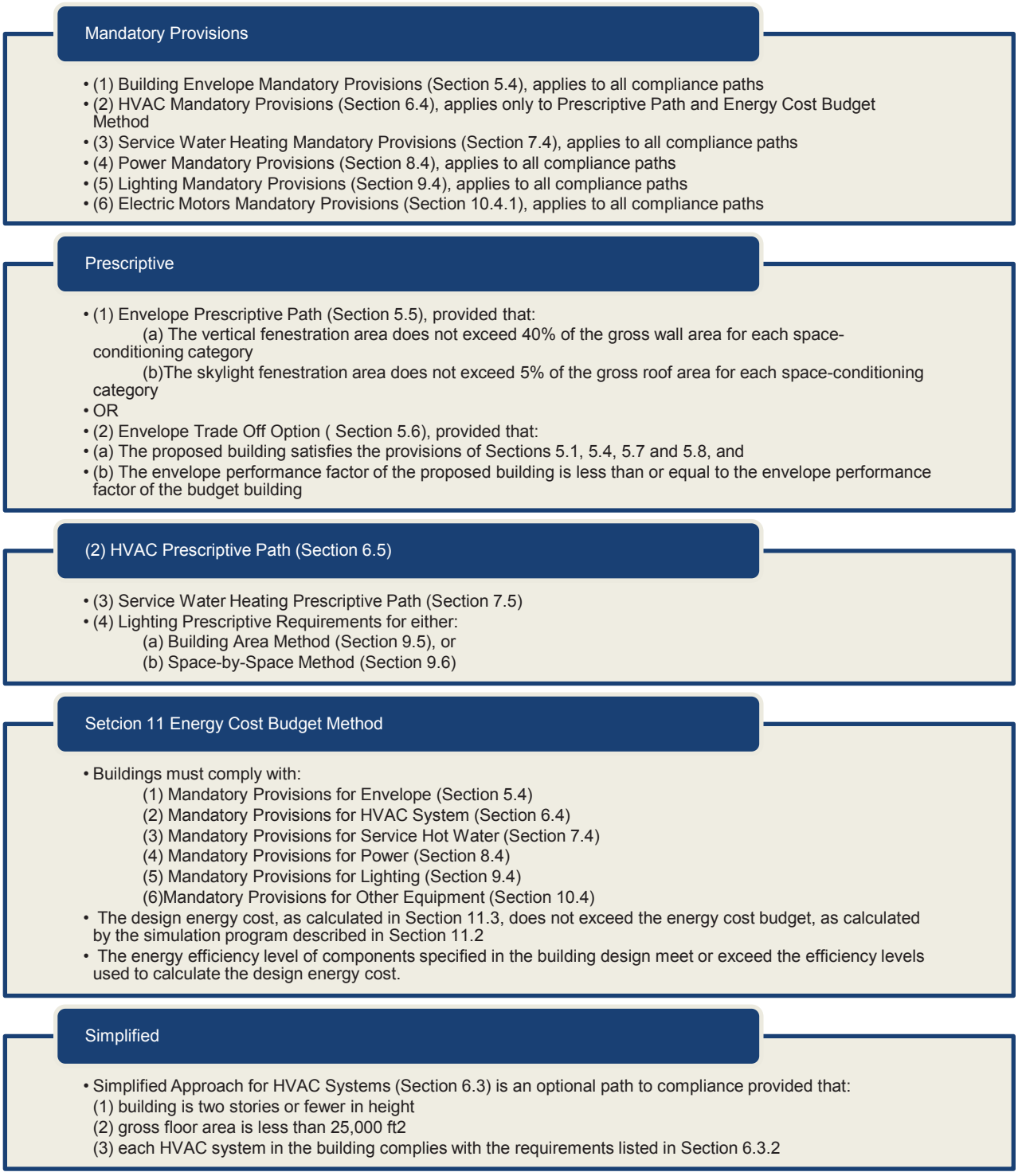


Figure 13. ASHRAE Compliance Paths & Requirements



Section 6: EBCNYS Code Requirements

The classification of work in existing buildings based on the EBCNYS-2010 is summarized below:

Table 22. Classification of Work in Existing Buildings (EBCNYS-2010)

Classification of work	Definition	Reference	
Repair	The restoration to good or sound condition of any part of an existing building for the purpose of its maintenance. Repairs include the patching or restoration or replacement of damaged materials, elements, equipment or fixtures for the purpose of maintaining such components in good or sound condition with respect to existing loads or performance requirements.	EBCNYS Section 202 General Definitions & Section 402.1 Scope	402.2 Application. Repairs shall comply with the provisions of Chapter 5. 402.3 Related work. Work on non-damaged components that is necessary for the required repair of damaged components shall be considered part of the repair and shall not be subject to the provisions of Chapter 6, 7, 8, 9 or 10.
Alteration	Any construction or renovation to an existing structure other than a repair or addition. Alterations are classified as Level 1, Level 2, and Level 3. Alterations also include converting an unconditioned or semi-heated space to a conditioned space.	EBCNYS Section 202 General Definitions	
Alteration - Level 1	Level 1 alterations include the removal and replacement or the covering of existing materials, elements, equipment, or fixtures using new materials, elements, equipment, or fixtures that serve the same purpose.	EBCNYS Section 403.1 Scope	403.2 Application. Level 1 alterations shall comply with the provisions of Chapter 6.
Alteration - Level 2	Level 2 alterations include the reconfiguration of space, the addition or elimination of any door or window, the reconfiguration or extension of any system, or the installation of any additional equipment.	EBCNYS Section 404.1 Scope	404.2 Application. Level 2 alterations shall comply with the provisions of Chapter 6 for Level 1 alterations as well as the provisions of Chapter 7.
Alteration - Level 3	Level 3 alterations apply where the work area exceeds 50 percent of the aggregate area of the building.	EBCNYS Section 405.1 Scope	Level 3 alterations shall comply with the provisions of Chapters 6 and 7 for Level 1 and 2 alterations, respectively, as well as the provisions of Chapter 8.
Change Of Occupancy	A change in the purpose or level of activity within a building that involves a change in application of the requirements of this code.	EBCNYS Section 202 General Definitions	406.1 Scope. Change of occupancy provisions apply where the activity is classified as a change of occupancy as defined in Chapter 2. 406.2 Application. Changes of occupancy shall comply with the provisions of Chapter 9.

Classification of work	Definition	Reference	
Additions	An extension or increase in floor area, number of stories, or height of a building or structure. Additions, even if in conjunction with existing building alterations or New Construction, must be shown to comply in separate compliance runs	EBCNYS Section 202 General Definitions	407.1 Scope. Provisions for additions shall apply where work is classified as an addition as defined in Chapter 2. 407.2 Application. Additions to existing buildings shall comply with the provisions of Chapter 10.
Historic Buildings	Any building or structure that is listed in the State or National Register of Historic Places; designated as a historic property under local or state designation law or survey; certified as a contributing resource within a National Register listed or locally designated historic district; or with an opinion or certification that the property is eligible to be listed on the National or State Register of Historic Places either individually or as a contributing building to a historic district by the State Historic Preservation Officer or the Keeper of the National Register of Historic Places.	EBCNYS Section 202 General Definitions	408.1 Scope. Historic buildings provisions shall apply to buildings classified as historic as defined in Chapter 2. 408.2 Application. Except as specifically provided for in Chapter 11, historic buildings shall comply with applicable provisions of this code for the type of work being performed. 501.1 Scope Repairs to historic buildings shall comply with Chapter 5, except as modified in Chapter 11.
Relocated Buildings	Relocated buildings provisions shall apply to relocated or moved buildings.	EBCNYS Section 409.1 Scope	409.2 Application. Relocated buildings shall comply with the provisions of Chapter 12.

Appendix C: Recruitment Letter Sent to Jurisdictions by Department of State

Re: Request for Participation with Energy Efficiency Study for Commercial Alteration Projects

Dear [contact name and address]:

The New York State Energy Research and Development Authority (NYSERDA) is conducting a study of the energy efficiency of commercial alteration projects throughout New York State. The first component of this study will begin mid-2013 and we are seeking your cooperation to access specific building information for commercial alteration projects permitted under the 2010 Energy Conservation Construction Code of New York State (ECCCNYS).

This Study was developed in response to recent changes to the New York State Energy Law (§ 11-110), which requires the Secretary of State to "*report yearly to the legislature and the governor as to the operation and effectiveness of the state energy conservation construction code*" and to oblige municipalities to assist, as necessary, the Secretary in meeting these requirements. This survey is being undertaken in fulfillment of this obligation.

NYSERDA has contracted with the independent research firms, The Cadmus Group, Inc. (Cadmus) and T.Y. Lin International Group (T.Y. Lin), to conduct the Study. Cadmus has selected a random sample of jurisdictions and projects within those jurisdictions to analyze. Cadmus or T.Y Lin staff will contact you for assistance in obtaining project permit information. Where available, the information that Cadmus and T.Y Lin will seek to obtain from the building departments includes:

- Building Permits, including permits number, issue dates
- Building Plans and/or Design and Construction Documents, including plans submittal dates
- Compliance Software Documentation, including input and output files
- Project contact information for the building owner/manager and Designer/Contractor
- COMCheck Reports, COMCheck data files including Commercial Building Data Checklist

The study team of Cadmus and T.Y. Lin, as an independent research firms, will keep the information collected private to the extent permitted by law. NYSERDA's analysis will only use summary level data and will not identify individual projects or organizations.

Should you have any questions about this study, please feel free to contact (NYSERDA Project Manager). If you would like more information about Cadmus or T.Y. Lin, please visit their websites at www.cadmusgroup.com or www.tylin.com.

Thank you in advance for your interest and cooperation.

Sincerely:

[Name]

Appendix D: Recruitment Letter Sent to Jurisdictions by NYSERDA

Dear [contact name]:

The New York State Energy Research and Development Authority (NYSERDA) is conducting a study of the energy efficiency of commercial building alteration projects throughout the state of New York, in order to estimate the energy impacts associated with the state's energy code, the 2010 Energy Conservation Construction Code of New York State (ECCCNYS).

NYSERDA has contracted with the independent research firm, Cadmus, to conduct the study. With your participation and assistance, Cadmus will perform a site visit to gather information on the specifics of your building alteration. Analysis of the information collected from your building will be recorded at an aggregated level across all buildings included in this study and will give NYSERDA a comprehensive look at energy use among commercial building alteration projects in the context of the ECCCNYS.

If you agree to help us with this study, a Cadmus engineer will visit your building at a time that is convenient for you. Please be assured that the engineer will carry proper ID at all times and will be respectful of your property, tenants and patrons. He or she will also gladly answer any questions that you may have.

The success of this important study depends largely on your participation. If you have questions regarding the evaluation process, please contact:

- NYSERDA Project Manager: Name, E-mail, Phone Number
- Cadmus Project Manager: Name, E-mail, Phone Number

Thank you in advance for your interest and cooperation.

Sincerely,

[Name]

Appendix E: Follow-up E-Mail Sent to Jurisdictions by Cadmus and T.Y. Lin

SUBJECT: Follow-up on Department of State's Request for Participation with Energy Efficiency Study for Commercial Alteration Projects in New York State
[Name]
[Contact Info]

We are writing you to follow-up on the letter that has recently been sent by the Department of State (DOS) regarding the energy-efficiency study currently being conducted by The New York State Energy Research and Development Authority (NYSERDA).

Cadmus, an employee-owned consulting and research firm delivering energy-efficiency services, is working with NYSERDA as a contractor to conduct this study to assess the energy efficiency of commercial alteration projects throughout New York State. For this study, Cadmus is seeking your cooperation to obtain a list of all the commercial alteration projects that meet the following criteria:

- The project is qualified as a Commercial Alteration
- The project is permitted under the 2010 Energy Conservation Construction Code of New York State (ECCCNYS)
- The permit was approved and the permit application dates are between 01/01/2011 and 12/31/2012.

The data for each commercial (non-residential) building permit should include:

- Building address
- Building type (office, retail, etc.)
- Owner's name and contact information (business phone, e-mail, address)
- Other contact information (such as building operators and/or other main contacts)
- Date of permit application
- The scope of the alteration.

After reviewing the list of projects that we receive from you, we will follow up with you to obtain permit documentations for a sample of projects from that list.

Any questions concerning this request may be directed to [Name] from Cadmus. The requested documents can be delivered to [Name] via his e-mail or fax, and any hard-copy documents can be mailed to our Portland office, Attn: [Name]. We would be happy to provide prepaid mailers and cover reproduction costs, if any. If you would like more information about Cadmus, please visit our website at www.cadmusgroup.com. Should you have any questions about this study, please feel free to contact [Name] from NYSERDA at [Contact Info].

Thank you in advance for your cooperation. We would appreciate it if you would provide your response by August 20, 2013. If you do not have any project that meets the criteria for this study, please confirm it via e-mail.

Sincerely,

[Name]

Appendix F: Sources of Energy Modeling Inputs and Modeling Protocols

For *non-altered* building components that are not accessible during the on-site verification and/or not available in projects' documentation, Cadmus used the following references as the primary sources for developing the energy models:

1. **ASHRAE 90.1-Appendix G- Building Performance Rating Method**. This is currently the most widely used energy modeling guideline, and it provides general guidance on equipment sizing and selection, equipment controls, typical baseline operating conditions, setpoints, and other assumptions. This guideline was most recently updated in 2007 and is adopted by the U.S. Green Building Council (USGBC) for Leadership in Energy and Environmental Design (LEED) certification, utility programs, and some states for energy code models. *Cadmus used this reference to establish general model inputs for the baseline case.*
2. **ASHRAE 90.1-Appendix G User Manual**. This is a supplement to Appendix G that contains general guidance on modeling unusual building systems; it provides examples of different modeling techniques and contains data on typical occupancy hour and load assumptions based on building type. This manual is referenced as needed. *Cadmus used this reference to establish assumptions associated with non-altered systems. These assumptions represent typical industry standards.*
3. **National Renewable Energy Laboratory's (NREL)** *DOE Commercial Reference Building Models of the National Building Stock Report*[33]**:** DOE partnered with the national energy laboratories to develop a report that details the development of energy models for typical commercial buildings and mid-rise multifamily buildings. The report presents typical characteristics of buildings across all climate zones in the United States. The input parameters for NREL's models are derived from numerous sources including ASHRAE 90.1 2004, ASHRAE 62.1 2004, and ASHRAE 62 – 1999 and 90.1 – 1989 for post- 1980 buildings. The report also provides assumptions for vintage (pre-1980 and post-1980) buildings. *Cadmus used this reference to obtain the specifications for the model inputs for envelope construction type and envelope insulation parameters (U-values and R-values) for vintage buildings (built either pre- or post- 1980). If a building was built after 2007, we obtained these envelope parameters from ASHRAE 90.1-2007.*

[33] http://www.nrel.gov/docs/fy11osti/46861.pdf

4. **DOE Prototype Energy Inputs**[34]**.** The U.S. DOE supports the development of commercial building energy codes and standards by participating in review processes and providing analyses that are available for public review and use. To calculate the impact of ASHRAE Standard 90.1, researchers at PNNL created a suite of 16 prototype buildings covering 80% of the commercial building floor area in the U.S. for new construction, including both commercial buildings and mid- to high-rise multifamily buildings. As ASHRAE Standard 90.1 evolved, PNNL also made substantial modifications to the commercial reference building inputs, with extensive inputs from ASHRAE 90.1 Standing Standards Project Committee members and other building industry experts. The prototype models include specifications for the 16 building types in 17 climate locations. *Cadmus used the specifications of the relevant PNNL prototypical models as starting points in developing our energy models.* Specifically, we used PNNL prototypical model specifications to obtain the energy model inputs for building parameters including: aspect ratios, window glazing, window locations, zoning, floor-ceiling heights, floor-floor heights, wall construction types, envelope construction types, infiltration ratios (building leakage rate), thermostat set-point, set-back, loop supply temperatures, service water tank volumes, occupancy and equipment (HVAC and miscellaneous equipment) operating schedules, lighting and infiltration schedules, in absence of verifiable data.

[34] http://www.energycodes.gov/development/commercial/90.1_models

Appendix G: Summary of Projects

Among the various commercial building and alteration types studied, the most common alteration type were mechanical renovations followed by lighting, domestic hot water, and envelope. Envelope alterations were the least common alteration measure, likely due to implementation logistics, length of payback, and regulatory requirements for safety during construction.

Table G-1 shows the compliant vs. non-compliant alterations for all altered equipment in the project sample that are required to comply with ASHRAE 90.1 and ECCCNYS-2010. This data shows the frequency of altered equipment among the 78 sites sampled in the study. It should be noted that Table 5 lists 63 mechanical alterations whereas in Table G-1 lists a total of 80 mechanical alterations. The difference in the two values is that Table 6 was inclusive of all mechanical alterations for a particular site. 63 of the 78 sites sampled underwent at least one mechanical alteration. The most common altered equipment was air conditioners and condensing units (21% of altered equipment), followed by lighting (19%) and hot water boiler alterations (18%).

With the exception of 5 projects that did not meet lighting power densities requirements, all alterations were verified to be code compliant.

Table 23. Compliant vs. Non-Compliant Alterations

All Facility Types							
Altered Component	Altered Equipment	Code Requirement Category	Total Projects				
			Compliant	Non-Compliant	% Compliant	% of All Measures	% based on Alteration Type
Envelope	Roof	Assembly/Insulation Efficiency Standard	2	0	100%	2%	7%
	Wall	Assembly/Insulation Efficiency Standard	2	0	100%	2%	
	Doors	Assembly Efficiency Standard	1	0	100%	1%	
	Windows	Assembly Efficiency Standard	4	0	100%	3%	
Mechanical	Air Conditioners and Condensing Units	Cooling Equipment Efficiency Standard	27	0	100%	21%	61%
	Heat Pumps	Heating/Cooling Equipment Standard	4	0	100%	3%	
	Water Chilling Packages	Cooling Equipment Efficiency Standard	3	0	100%	2%	
	Furnaces, Duct Furnaces, and Unit Heaters	Heating Equipment Efficiency Standard	18	0	100%	14%	
	Boilers	Heating Equipment Efficiency Standard	24	0	100%	18%	
	Heat Rejection Equipment	Fan Speed Control	4	0	100%	3%	
DHW	Water Heating Equipment	Equipment Efficiency	17	0	100%	13%	13%
Lighting	Interior Lighting	Lighting Power Density (LPD)	25	5	83%	19%	19%
Overall: All Measures			131	5	96%	100%	

Overall, all alteration groupings demonstrate compliance with the energy code. Mechanical alterations demonstrated the best overall ECI when considering all fuel sources impacted. Lighting showed the best electricity ECI as a result of the interactive effect with cooling. However, when considering the associated heating impacts from reduced heat load from reduced light fixtures, the lighting alteration group is just compliant when all fuel sources (electricity and gas) are considered. Table G-2 describes the average overall compliance index based on alteration types considering impacted fuels only. These results do not adjust for climate, population or sample size for each stratum as described in the compliance and energy analysis methodology described in section 2.6 of this report. But is the overall ECI for each alteration grouping for the sample projects analyzed.

Table 24. Weighted ECI Based on Alteration Type

	Envelope	Lighting	Mechanical	DHW
Average Overall Electric ECI	99.76%	94.66%	99.14%	n/a
Average Overall Gas ECI	100.27%	103.04%	97.14%	96.22%
Average Overall ECI	99.83%	99.70%	97.38%	97.49%

The following sections highlight energy code findings and issues for each building and alteration type. The statistics are an observation about what kind of alteration projects are occurring for the sites sampled. The compliance rate shown in these tables should not be viewed as an extrapolation of the compliance index for alteration types for the given facility, but what was observed through verification of altered equipment in our sample and energy modeling.

G.1 Multifamily Buildings

The sample included 27 mid-and high-rise multi-family buildings. The projects consisted of the following system alterations and several involved multiple systems:

Table 25. Summary of Multifamily Buildings

Multifamily					
Altered Component	**Altered Equipment**	**Code Requirement Category**	**Total Projects**		
			Compliant	**Non-Compliant**	**% Compliant**
Envelope	Roof	Assembly/Insulation Efficiency Standard	0	0	N/A
	Wall	Assembly/Insulation Efficiency Standard	0	0	N/A
	Doors	Assembly Efficiency Standard	0	0	N/A
	Windows	Assembly Efficiency Standard	0	0	N/A
Mechanical	Air Conditioners and Condensing Units	Cooling Equipment Efficiency Standard	2	0	100%
	Heat Pumps	Heating/Cooling Equipment Standard	1	0	100%
	Water Chilling Packages	Cooling Equipment Efficiency Standard	2	0	100%
	Furnaces, Duct Furnaces, and Unit Heaters	Heating Equipment Efficiency Standard	4	0	100%
	Boilers	Heating Equipment Efficiency Standard	16	0	100%
	Heat Rejection Equipment	Fan Speed Control	1	0	100%
DHW	Water Heating Equipment	Equipment Efficiency	13	0	100%
Lighting	Interior Lighting	Lighting Power Density (LPD)	2	1	67%
Overall: All Measures			41	1	98%

Mechanical alterations account for 63% of all alterations for multifamily buildings. Three-fourths of the mechanical system alterations were boiler or DHW replacements. Generally speaking, all alterations were for the replacement of outdated equipment that passed its useful service life. Findings for multifamily building alterations included the following:

- The availability of code compliance documentation (COM*check* reports, building plans, etc.) that defines the scope of the project and performance specifications to assess the alteration was limited onsite. When this information was not available, the site contact was relied upon to define the alteration project and equipment specifications had to be researched online. For NYC however, on-line information permit documentation for boiler or water heater combustion efficiency and size was available.
- Information on boiler settings and controls was limited overall. In some instances, pressure gauges or time-clock information were observable during the site visit but in many cases set-point, outdoor air reset and/or lockout control was not identified. This is the result of a lack of an energy management system, or the site contact not having access to or know where to locate this information.
- Information on boiler controls was often unavailable because facility staff could not provide access to control rooms or maintenance was contracted out.

G.2 Office Buildings

The sample includes 33 office buildings. The projects consisted of the following system alterations and several involved multiple systems:

Table 26. Summary of Office Buildings

Office					
Altered Component	**Altered Equipment**	**Code Requirement Category**	**Total Projects**		
			Compliant	**Non-Compliant**	**% Compliant**
Envelope	Roof	Assembly/Insulation Efficiency Standard	2	0	100%
	Wall	Assembly/Insulation Efficiency Standard	1	0	0%
	Doors	Assembly Efficiency Standard	1	0	100%
	Windows	Assembly Efficiency Standard	3	0	100%
Mechanical	Air Conditioners and Condensing Units	Cooling Equipment Efficiency Standard	16	0	100%
	Heat Pumps	Heating/Cooling Equipment Standard	2	0	100%
	Water Chilling Packages	Cooling Equipment Efficiency Standard	1	0	100%
	Furnaces, Duct Furnaces, and Unit Heaters	Heating Equipment Efficiency Standard	6	0	100%
	Boilers	Heating Equipment Efficiency Standard	2	0	100%
	Heat Rejection Equipment	Fan Speed Control	2	0	100%
DHW	Water Heating Equipment	Equipment Efficiency	4	0	100%
Lighting	Interior Lighting	Lighting Power Density (LPD)	17	3	85%
Overall: All Measures			57	3	95%

Mechanical alterations accounted for 51% of all alterations where each component required efficiency standards to meet code. The next largest alteration grouping was lighting (30%), envelope (12%), and domestic hot water (7%) alterations. 77% of all envelope alterations occurred in office spaces. Findings for office building alterations included the following:

- Documentation (i.e. equipment specifications, mechanical drawing) for office building alteration projects, regardless of size, couldn't be found for most of the envelope alterations in smaller office buildings. Facility staff at these buildings was more aware of and involved in the alteration projects, so was able to provide necessary background information on the scope of the alteration project. Equipment nameplate information was always collected to confirm minimum equipment efficiencies.
- Roughly half of the 33 office alteration projects impacted only a small portion of the overall building area. Overall, it is estimated that the alteration impact is in the magnitude of 30-40% of the buildings total conditioned space.
- Approximately half of projects that completed a mechanical alteration also completed a lighting retrofit. Because of the negative heating energy penalty associated with more efficient lighting, the overall ECI tends to be higher (less efficient) than where mechanical alteration was implemented alone.
- Three of the seventeen lighting alterations projects are not compliant. Non-compliant lighting alterations occurred in non-occupied areas such as corridors, lobbies, and storage areas.
- Permit documentation that describes the alteration project and details to estimate the performance existed for most projects. Although in some instances the project scope had to be determined through an interview with the site contact.

G.3 Retail Buildings

The sample included five retail buildings that include the following individual measure alterations, with some projects including combinations of measures:

Table 27. Summary of Office Buildings

Retail					
Altered Component	**Altered Equipment**	**Code Requirement Category**	**Total Projects**		
			Compliant	**Non-Compliant**	**% Compliant**
Envelope	Roof	Assembly/Insulation Efficiency Standard	0	0	100%
	Wall	Assembly/Insulation Efficiency Standard	0	0	0%
	Doors	Assembly Efficiency Standard	0	0	N/A
	Windows	Assembly Efficiency Standard	0	0	N/A
Mechanical	Air Conditioners and Condensing Units	Cooling Equipment Efficiency Standard	3	0	100%
	Heat Pumps	Heating/Cooling Equipment Standard	0	0	N/A
	Water Chilling Packages	Cooling Equipment Efficiency Standard	0	0	N/A
	Furnaces, Duct Furnaces, and Unit Heaters	Heating Equipment Efficiency Standard	4	0	100%
	Boilers	Heating Equipment Efficiency Standard	0	0	N/A
	Heat Rejection Equipment	Fan Speed Control	0	0	N/A
DHW	Water Heating Equipment	Equipment Efficiency	0	0	N/A
Lighting	Interior Lighting	Lighting Power Density (LPD)	4	1	80%
Overall: All Measures			11	1	92%

Only mechanical and lighting alteration projects were identified through the sample of retail facilities. Findings for retail building alterations included the following:

- Plans were available for the projects but code compliance documentation was unavailable.
- All lighting alterations are compliant, with the exception of one exterior lighting alteration.
- All mechanical alterations are compliant.

    - Mechanical alterations are packaged roof top unit replacements
    - Confirming code compliance was facilitated by project documentation (describing the details of the alteration project) availability and the ability to verify equipment easily.
    - HVAC projects met but did not exceed code, primarily because these were smaller projects and installed by the owner at code minimum.

G.4 Education Buildings

The alteration sample includes six education buildings that involve the following specific system measures:

Table 28. Summary of Education Buildings

Education					
Altered Component	**Altered Equipment**	**Code Requirement Category**	**Total Projects**		
			Compliant	**Non-Compliant**	**% Compliant**
Envelope	Roof	Assembly/Insulation Efficiency Standard	0	0	100%
	Wall	Assembly/Insulation Efficiency Standard	1	0	0%
	Doors	Assembly Efficiency Standard	0	0	N/A
	Windows	Assembly Efficiency Standard	0	0	N/A
Mechanical	Air Conditioners and Condensing Units	Cooling Equipment Efficiency Standard	3	0	100%
	Heat Pumps	Heating/Cooling Equipment Standard	1	0	100%
	Water Chilling Packages	Cooling Equipment Efficiency Standard	0	0	N/A
	Furnaces, Duct Furnaces, and Unit Heaters	Heating Equipment Efficiency Standard	1	0	100%
	Boilers	Heating Equipment Efficiency Standard	4	0	100%
	Heat Rejection Equipment	Fan Speed Control	0	0	N/A
DHW	Water Heating Equipment	Equipment Efficiency	0	0	N/A
Lighting	Interior Lighting	Lighting Power Density (LPD)	1	0	100%
Overall: All Measures			11	0	100%

Mechanical alterations were the most common alteration project for education buildings accounting for 81% of all measures. Findings include the following:

- The one lighting project had an electrical ECI significantly better than code because the LPD was more efficient than required by code. Because due to the interactive effects, the highly efficient lighting resulted in increased natural gas consumption for heating, but overall complied with code.
- The mechanical alterations in all six projects were code compliant.
- Four projects include a boiler alteration; two involve packaged unit and heat pump alterations.
- The boilers installed meet code minimum, while the cooling unit replacements generally include units with above code efficiencies.
- HVAC control strategies were not verified during site visits because the facility contacts had little familiarity with these and no access was provided to the energy management systems in order to confirm operating points and parameters.

G.5 Hospital Buildings

Sample projects included three hospital buildings that involve the following specific system measures:

Table 29. Summary of Hospital Buildings

Hospital					
Altered Component	Altered Equipment	Code Requirement Category	Total Projects		
			Compliant	Non-Compliant	% Compliant
Envelope	Roof	Assembly/Insulation Efficiency Standard	0	0	100%
	Wall	Assembly/Insulation Efficiency Standard	0	0	0%
	Doors	Assembly Efficiency Standard	0	0	N/A
	Windows	Assembly Efficiency Standard	0	0	N/A
Mechanical	Air Conditioners and Condensing Units	Cooling Equipment Efficiency Standard	1	0	100%
	Heat Pumps	Heating/Cooling Equipment Standard	0	0	N/A
	Water Chilling Packages	Cooling Equipment Efficiency Standard	0	0	N/A
	Furnaces, Duct Furnaces, and Unit Heaters	Heating Equipment Efficiency Standard	0	0	N/A
	Boilers	Heating Equipment Efficiency Standard	1	0	100%
	Heat Rejection Equipment	Fan Speed Control	1	0	100%
DHW	Water Heating Equipment	Equipment Efficiency	0	0	N/A
Lighting	Interior Lighting	Lighting Power Density (LPD)	0	0	N/A
Overall: All Measures			3	0	100%

Only mechanical alterations occurred at the three hospitals sampled. These alterations impacted the central utility plant performance. Findings include:

- These three projects include mechanical system alterations for large hospital campuses targeting the central cooling and heating plant.
- Due to the overall impact these alterations have on utility bills, the projects typically installed very efficient technology and controls that exceed code minimum efficiencies. These include boiler stack economizers, oxygen trim and fan blower VSD controls, high efficiency chillers, and additional heat rejection equipment equipped with VSDs.
- All mechanical alteration projects are code compliant.

- The sites' facility staff and mechanical contractors provided excellent support. Staff and contractors were knowledgeable on project scope and able to provide supporting project documentation (such as buildings plans, COM*check* reports).

G.6 Other Buildings (Religious Worship, Warehouse)

The sample includes four religious worship and warehouse buildings classified as "other." Alterations in these building projects included the following:

Table 30. Summary of Other Buildings

Other (Religious Worship/Warehouse)					
Altered Component	**Altered Equipment**	**Code Requirement Category**	**Total Projects**		
			Compliant	**Non-Compliant**	**% Compliant**
Envelope	Roof	Assembly/Insulation Efficiency Standard	0	0	100%
	Wall	Assembly/Insulation Efficiency Standard	0	0	0%
	Doors	Assembly Efficiency Standard	0	0	N/A
	Windows	Assembly Efficiency Standard	1	0	100%
Mechanical	Air Conditioners and Condensing Units	Cooling Equipment Efficiency Standard	2	0	100%
	Heat Pumps	Heating/Cooling Equipment Standard	0	0	N/A
	Water Chilling Packages	Cooling Equipment Efficiency Standard	0	0	N/A
	Furnaces, Duct Furnaces, and Unit Heaters	Heating Equipment Efficiency Standard	3	0	100%
	Boilers	Heating Equipment Efficiency Standard	1	0	100%
	Heat Rejection Equipment	Fan Speed Control	0	0	N/A
DHW	Water Heating Equipment	Equipment Efficiency	0	0	N/A
Lighting	Interior Lighting	Lighting Power Density (LPD)	1	0	100%
Overall: All Measures			8	0	100%

Each site in this sample underwent a mechanical alteration. Only one site included a comprehensive alteration where the envelope, HVAC and lighting underwent upgrades. Findings include the following:

- All mechanical alterations projects met code.
- One project consists of an envelope, lighting and mechanical alteration. Although no permit documentation was available, the site contact provided supporting project documentation (such as buildings plans, COM*check* reports) on the project scope. This included facility layout, equipment performance sheets on lighting, windows, and unit heaters.
- The envelope and mechanical alterations meet code based on specifications provided by the point of contact.
- The lighting alteration exceeds code minimum.
- One project consists of a boiler alteration where permit documents describe thermal efficiencies above code.
- The remaining two mechanical alterations projects include replacing packaged rooftop units with gas furnaces. The cooling system has a slightly higher efficiency than required by code, and the furnace component of the packaged units meets code minimum. This was verified onsite through nameplate and equipment specifications.

Appendix H: Project Summaries for Group A

Table 31. Project Summaries for Group A

Building ID	A-2
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Lighting – 0.994; Mechanical 0.999
Building Type	Retail
Code Compliance	ECCCNYS-2010
Alteration	Alteration Level 3
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	14,496
Location	Cheektowaga, Erie County -Climate Zone 5A
Year Constructed	1990's
Project Description	Retail Space. 12,321 ft^2 of retail space, 2,175 ft^2 of storage. One floor building.
Renovated Equipment	Alteration includes interior lighting retrofit and replacement of six RTUs.
Cooling System	Air-cooled DX
Heating System	Natural Gas furnaces
Air Distribution System	Constant volume, single-zone RTUS
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for post-1980 constructed buildings. The auditor was not able to access the rooftop units, therefore all HVAC equipment has been modeled according to the mechanical schedule. Based on the model number in the schedule, the efficiency of RTU-6 does not comply with code, and has been modeled accordingly. There is no mention of RTU-6 in the permit documentation. Baseline, As Verified, and Permitted lighting power densities were modeled according to the lighting calculations. Weather file location used was Buffalo, NY.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	189,260	9,721	1,617,881,616	1,617,881,616
As Permitted	176,710	10,003	1,603,259,259	1,603,259,259
As Verified	181,040	9,902	1,607,913,826	1,607,913,826
Savings	8,220	(181)	9,967,790	9,967,790

Building ID	A-3
Overall Energy Compliance Index	0.97
Measure Energy Compliance Index	Lighting – 0.986; Mechanical 0.984
Building Type	Retail
Code Compliance	ECCCNYS-2010
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	18,750
Location	Cheektowaga, Erie County -Climate Zone 5A
Year Constructed	Post-1980
Project Description	Retail space in a single story building that contains three tenants. The Tile Shop tenant space consists of a main 18,750 sf sales floor, and also a storage area that is outside of the alteration scope.
Renovated Equipment	Four new RTUs serving the sales floor. Also interior lighting was renovated.
Cooling System	Air-cooled DX
Heating System	Natural Gas furnaces
Air Distribution System	Constant volume, single-zone RTUs
Major Modeling Assumptions	The shipping/receiving area was not modeled as part of the renovated area. The building vintage could not be confirmed, and therefore was assumed to be post-1980. All envelope properties were modeled per NREL document guidance for post-1980 constructed buildings. The tenant demising wall was modeled as an adiabatic surface. The auditor was not able to access the rooftop units, therefore all HVAC equipment properties have been modeled according to the model numbers in the mechanical schedule. Permit documentation was not available, therefore installed and permitted equipment are assumed to be identical. Baseline and As Verified/Permitted lighting power densities were modeled according to the lighting calculations. Weather file location used was Buffalo, NY.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	204,110	11,598	1,856,251,895	1,856,251,895
As Permitted	204,110	11,598	1,856,251,895	1,856,251,895
As Verified	176,660	11,989	1,801,688,652	1,801,688,652
Savings	27,450	(391)	54,563,243	54,563,243

Building ID	A-4
Overall Energy Compliance Index	0.94
Measure Energy Compliance Index	Lighting – 0.944; Mechanical 0.997
Building Type	Multifamily
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	32,632
Location	Erie County -Climate Zone 5A
Year Constructed	1973
Project Description	Retirement home containing 74 bedrooms. Single story. Alteration includes new split heat pumps that serve the corridors, as well as a lighting retrofit throughout the building.
Renovated Equipment	Split heat pumps, Lighting alteration in the corridors, dining, living quarters and other.
Cooling System	DX
Heating System	Heat Pump
Air Distribution System	Ductless
Major Modeling Assumptions	Building area and year of construction were obtained by a Google search of property records, as neither could be confirmed by the auditor. All envelope properties are modeled per NREL document guidance for Pre-1980 constructed buildings. Weather file used was Buffalo, NY. Economizer dry-bulb high limit set to 45F to represent no economizers. Alteration included two outdoor condensing units. Permit documentation indicates these two units are identical, but field verification photos show two units of different capacities and different HSPFs. Despite the differences, all units comply with code efficiencies. Unit-1 serves the north hallways and Unit-2 serves the south hallways. Residential units (outside of HVAC alteration scope) were modeled with PTHPs corresponding to ASHRAE 90.1 Appendix G. Baseline and As Verified LPD were determined from lighting power calculations. Permit documentation was not available for lighting; therefore the as-verified LPD was used in the Permitted model.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	694,630	-	2,370,174,808	2,370,174,808
As Permitted	654,100	-	2,231,880,774	2,231,880,774
As Verified	654,140	-	2,232,017,260	2,232,017,260
Savings	40,490		138,157,548	138,157,548

Building ID	A-5
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Lighting – 0.985; Mechanical 1.00
Building Type	Small Office
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	2,700
Location	Waterloo, Seneca County -Climate Zone 5A
Year Constructed	1974
Project Description	Single story physical therapy center that was converted from a house. Alteration included installing a new split AC unit for cooling only, serving the entire space. The furnace was not replaced. The alteration also included an interior lighting retrofit.
Renovated Equipment	Split AC unit, Interior lighting
Cooling System	Air cooled, DX split system
Heating System	Natural Gas furnace (existing)
Air Distribution System	Constant volume
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. Permit documentation was not available, therefore installed and permitted equipment are assumed to be identical. Code used for compliance was assumed to be ASHRAE 90.1 2007. Weather file location used was Rochester, NY. Year constructed obtained from internet search of property records. Baseline and As Verified/Permitted lighting power densities were modeled according to the lighting calculations.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	23,770	2,580	339,146,568	339,146,568
As Permitted	23,770	2,580	339,146,568	339,146,568
As Verified	19,900	2,662	334,061,586	334,061,586
Savings	3,870	(82)	5,084,982	5,084,982

Building ID	A-6
Overall Energy Compliance Index	0.95
Measure Energy Compliance Index	Lighting – 0.952; Mechanical 1.00
Building Type	Office Midrise
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	45,000
Location	Fairport, Monroe County - Climate Zone 5A
Year Constructed	1992
Project Description	Project is a three-story office building served by water source heat pumps throughout. The project underwent a cooling tower replacement used for heat rejection as the heat pump condenser. Interior lighting was also replaced.
Renovated Equipment	1 Cooling tower- axial fan with VFD, lighting retrofit
Cooling System	Heat Pumps with Water Cooled Condenser
Heating System	Heat Pumps/ Electric boiler to supplement heating
Air Distribution System	Single zone
Major Modeling Assumptions	Modeled envelope properties per NREL document guidance for post-1980 buildings located in Climate Zone 5A. Modeled an air-side economizer with a high-limit shut-off of 75F. Modeled a WLHP loop and assigned the electric supplemental boiler and cooling tower to this loop.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	727,440	943	2,576,437,122	2,482,127,122
Permitted	690,790	944	2,451,472,191	2,357,072,191
As Verified	690,790	944	2,451,472,191	2,357,072,191
Savings	36,650	(1)	124,964,931	125,054,931

Building ID	A-7
Overall Energy Compliance Index	0.97
Measure Energy Compliance Index	Lighting – 0.97
Building Type	Office
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Lighting
Impacted Area (ft^2)	22,500
Location	Monroe County -Climate Zone 5A
Year Constructed	1992
Project Description	Project installed new lighting fixtures in a manufacturing space.
Renovated Equipment	Lighting
Cooling System	Packaged DX
Heating System	Gas Boiler
Air Distribution System	Variable Air Volume
Major Modeling Assumptions	Baseline and installed lighting power densities were calculated from inspection findings. These lighting power densities were incorporated into eQUEST using proto-typical building models to estimate compliance index including interactive effects.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	238,360	13,299	2,143,217,690	813,317,690
Permitted				
As Verified	187,290	14,474	2,086,459,701	639,059,701
Savings	51,070	(1,175)	56,757,990	174,257,990

Building ID	A-8
Overall Energy Compliance Index	0.95
Measure Energy Compliance Index	Lighting – 0.955; Mechanical 0.994
Building Type	School
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	2,400
Location	Monroe County- Climate Zone 5A
Year Constructed	1930
Project Description	Two story, university building, religious center. First floor contains a kitchen, dining room, and meeting space. Second floor contains a library and living space. According to the site visit notes, the building underwent a full alteration including new RTUs as well as a lighting retrofit, and replacement of second floor windows plus three windows in the first floor dining hall.
Renovated Equipment	One packaged unit DX cooling w/ gas furnace, One split AC condensing unit, interior lighting.
Cooling System	DX
Heating System	Gas Furnace
Air Distribution System	Constant Volume
Major Modeling Assumptions	Permit documentation was not available, therefore installed and permitted equipment are assumed to be identical. Code used for compliance was assumed to be ASHRAE 90.1 2007. Year of construction was obtained from an internet search of property records, as it could not be confirmed by the field auditor. Building dimensions were based on architectural floor plans. The modeling starting point was the PNNL school prototype, changed to year-round occupancy. All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. New ACCU-1 provides cooling for the second floor living space. New RTU-1 serves 1,200 sf of dining room space on the first floor (based on an assumption of 400sf/ton). RTU-1 was modeled with a dry bulb economizer, as indicated by its model number. Only spaces served by new HVAC equipment were modeled - surfaces adjoining spaces served by existing equipment were modeled as adiabatic. As Verified LPD modeled according to lighting calculations. Windows in both cases were modeled as clear, dual pane, vinyl frame to reflect alterations as verified in field - no window specifications were available. Weather file used was Rochester, NY.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	30,130	940	196,757,778	196,757,778
As Permitted	-	-	-	-
As Verified	24,900	1,017	186,662,286	186,662,286
Savings	5,230	(77)	10,095,492	10,095,492

Building ID	A-9
Overall Energy Compliance Index	0.98
Measure Energy Compliance Index	Envelope – 1.00; Lighting – 0.983; Mechanical 0.998
Building Type	Warehouse
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Envelope, Lighting and Mechanical
Impacted Area (ft^2)	25,000
Location	Saratoga County - Climate Zone 5A
Year Constructed	Assumed post-1980
Project Description	Single story auto repair shop with retail/office space. Alteration included window replacement, new unit heaters in the shop/warehouse, and a lighting retrofit. Retail/office space served by existing air-cooled AC/gas furnace unit.
Renovated Equipment	Storefront Windows Unit Heaters Interior Lighting
Cooling System	Packaged DX - Air Cooled (office)
Heating System	Gas Furnace (office), Radiant Heaters (warehouse)
Air Distribution System	Packaged CV (office)
Major Modeling Assumptions	Year of construction was not confirmed by field auditor, therefore was assumed to be post-1980. The envelope is modeled based on NREL Document for post-1980 construction values. No code compliance documentation was available; therefore ASHRAE 90.1-2007 was assumed, and As Permitted/As Verified conditions are assumed to be the same (As Permitted model includes all measures). Weather file used was Albany, NY.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	108,270	3,301	699,542,398	699,542,398
As Permitted	101,840	3,392	686,682,338	686,682,338
As Verified	101,850	3,389	686,406,459	686,406,459
Savings	6,420	(88)	13,135,939	13,135,939

Building ID	A-13
Overall Energy Compliance Index	0.95
Measure Energy Compliance Index	Mechanical 0.95
Building Type	Office
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Mechanical
Impacted Area (ft^2)	2,576
Location	Utica, Oneida County -Climate Zone 6A
Year Constructed	1900
Project Description	Two story house converted into office space. Alteration included replacing a furnace for the top floor and installing new condensing units for the 1st and 2nd floor. Windows were replaced on the second floor, however no specifications on the installed windows were available, therefore, and window replacements were not modeled.
Renovated Equipment	One furnace serving second floor (first floor furnace was existing). Two split AC units (one per floor).
Cooling System	Air cooled, DX split systems
Heating System	Natural Gas furnaces
Air Distribution System	Ducted, constant volume, no reheat
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. Economizer shut-off limit is set at 45F to represent that an economizer is not installed. Permit documentation was not available, therefore installed and permitted equipment are assumed to be identical. Code used for compliance was assumed to be ASHRAE 90.1 2007. Baseline and As Verified/Permitted lighting power densities were modeled according to the lighting calculations. Weather file location used was Syracuse, NY.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	25,150	2,743	360,075,321	360,075,321
As Permitted				
As Verified	25,150	2,555	341,335,321	341,335,321
Savings	-	187	18,740,000	18,740,000

Building ID	A-14
Overall Energy Compliance Index	0.87
Measure Energy Compliance Index	Lighting – 0.99; Mechanical 0.881
Building Type	Office
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	10,500
Location	Genesee, Allegany County -Climate Zone 6A
Year Constructed	1900
Project Description	Office building, three stories above-grade plus basement. Alteration included installing new furnace/AC units and interior lighting. Alteration impacted entire building area.
Renovated Equipment	Split AC units with gas furnaces (4 total - one per floor)
Cooling System	Air cooled, DX split systems
Heating System	Natural Gas furnaces
Air Distribution System	Ducted
Major Modeling Assumptions	Building floor area was assumed based on lighting plans. All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. The north and south walls are tenant demising walls, and were modeled as adiabatic surfaces to represent the connection to the adjoining spaces on either side. Economizer shut-off limit is set at 45F to represent that an economizer is not installed. Permit documentation was not available, therefore installed and permitted equipment are assumed to be identical. Weather file location used was Buffalo, NY. Baseline and As Verified lighting power densities were modeled according to the lighting savings calculations. Window replacements were not modeled due to lack of available specifications on the retrofit windows.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	102,410	8,077	1,157,167,257	1,157,167,257
As Permitted	102,410	8,077	1,157,167,257	1,157,167,257
As Verified	92,430	6,946	1,010,014,100	1,010,014,100
Savings	9,980	1,131	147,153,157	147,153,157

Building ID	A-15
Overall Energy Compliance Index	0.97
Measure Energy Compliance Index	Lighting - 0.988; Mechanical – 0.929
Building Type	Office
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	17,000
Location	Utica, Oneida County - Climate Zone 6A
Year Constructed	1956
Project Description	Two story medical office building. Alteration included installing new furnace/AC units, windows, and interior lighting. Alteration impacted entire building area. Window replacement was not modeled based on lack of adequate documentation.
Renovated Equipment	Split AC units with gas furnaces (8 total - one per building quadrant/floor), mini-splits provide cooling only to procedure rooms (first floor NW zone).
Cooling System	Air cooled, DX split systems
Heating System	Natural Gas furnaces
Air Distribution System	Ducted, constant volume, no reheat
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. Economizer shut-off limit is set at 45F to represent that an economizer is not installed. Permit documentation was not available, therefore installed and permitted equipment are assumed to be identical. Code used for compliance was assumed to be ASHRAE 90.1 2007. Weather file location used was Syracuse, NY.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	161,290	15,275	2,077,844,061	2,077,844,061
As Permitted	-	-	-	-
As Verified	145,180	15,227	2,018,074,485	2,018,074,485
Savings	16,110	48	59,769,576	59,769,576

Building ID	A-17
Overall Energy Compliance Index	0.84
Measure Energy Compliance Index	Envelope – 1.00; Lighting - 1.00; Mechanical – 0.841; DHW – 1.00
Building Type	Office (Medical)
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Envelope, Lighting, Mechanical, DHW
Impacted Area (ft^2)	4,600
Location	Ossining, Westchester County - Climate Zone 4A
Year Constructed	1878
Project Description	The project is a restaurant spanning across three stories and a basement. The building is located in a strip mall where two walls are adjacent to neighboring shops. The project underwent window replacement, HVAC, boiler and DHW heater replacement.
Renovated Equipment	Unitary AC (3 qty) - 13 SEER Gas Furnace (3 qty) - 95.6 AFUE Windows - Anderson Series 400 (U-value 0.29/ SHGC 0.27) DHW Water Heater (1 qty) - 80% Et HW Boiler (1 qty) - 95% Et
Cooling System	Packaged DX - Air Cooled.
Heating System	Gas furnace/ hw boiler
Air Distribution System	Packaged VAV/ CV for top two levels
Major Modeling Assumptions	Since only one of the two DHW heaters was replaced, modeled the second DHW heater with existing efficiency recorded to be 75%. The envelope is modeled based on NREL Document per pre-1980 envelope insulation values. Window properties for the baseline case have been modeled as per ASHRAE 90.1 in the Baseline case and per verified conditions in the As-verified case.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	50,300	3,243	495,910,642	495,910,642
As Permitted	-	-	-	-
As Verified	50,930	2,431	416,850,290	416,850,290
Savings	(630)	812	79,060,352	79,060,352

Building ID	A-18
Overall Energy Compliance Index	0.97
Measure Energy Compliance Index	Lighting - 0.990; Mechanical – 0.992; DHW – 0.987
Building Type	Small Office
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Lighting, Mechanical, and DHW
Impacted Area (ft^2)	4,950
Location	Nassau County - Climate Zone 4A
Year Constructed	1985
Project Description	Single story tutoring facility consisting of mainly office space. Alteration scope was HVAC, DHW, and lighting.
Renovated Equipment	(3) Packaged RTUs, (1) gas-fired storage tank DHW heater; lighting
Cooling System	Air cooled, DX
Heating System	Natural Gas furnace
Air Distribution System	Constant volume
Major Modeling Assumptions	Building area and year of construction could not be confirmed by the field auditor; therefore, this information was obtained via an internet search of property records. All envelope properties were modeled per NREL document guidance for post-1980 constructed buildings. Permit documentation was not available, therefore installed and permitted equipment are assumed to be identical. Code used for compliance was assumed to be ASHRAE 90.1 2007. Weather file location used was New York City. Economizer dry bulb high limit set to 45F to represent no economizers. Two 7.5-ton RTUs and one 5-ton RTU serve the space - exact zoning was unknown, so it was assumed that the larger RTUS serve the perimeter zones and the smaller RTU serves the core zone. Lighting power densities in the Baseline and As Verified/Permitted cases were modeled according to the lighting savings calculations.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	44,660	2,534	405,766,172	405,766,172
As Permitted	44,660	2,534	405,766,172	405,766,172
As Verified	41,890	2,523	395,264,545	395,264,545
Savings	2,770	11	10,501,627	10,501,627

Building ID	A-23
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Envelope – 1.00
Building Type	Small Office
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Envelope
Impacted Area (ft^2)	3,296
Location	Orange County - Climate Zone 5A
Year Constructed	2003
Project Description	Single story bank office. Alteration scope was two new exterior doors. (Envelope)
Renovated Equipment	Glazed Exterior Doors
Cooling System	Air cooled, DX (assumed)
Heating System	Natural Gas furnace (assumed)
Air Distribution System	Constant volume (assumed)
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for new construction buildings. West wall was modeled as an adiabatic surface to represent the adjoining space. Permit documentation was not available, therefore installed and permitted equipment are assumed to be identical. Code used for compliance was assumed to be ASHRAE 90.1 2007. Weather file location used was New York City. New doors were modeled as dual pane, clear, insulated metal frame, with specific U-value and SHGC determined by eQUEST. Doors were modeled identically in the Baseline and As Verified models.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	28,980	1,980	296,833,817	296,833,817
As Permitted				
As Verified	28,980	1,980	296,833,817	296,833,817
Savings	-	-	-	-

Building ID	A-25
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Lighting - 0.999; Mechanical – 0.991
Building Type	Office (Medical)
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	8,240
Location	Patchogue, Suffolk County - Climate Zone 4A
Year Constructed	1980
Project Description	Project is a dental office/training school originally constructed in 1980 and underwent complete lighting retrofit and a mini split system (cooling only) replacement for the storage space. The remaining space is served by an existing RTU (DX cooling, gas furnace heating). Interior lighting was also replaced in the corridors, offices, classrooms, restrooms, and active storage spaces.
Renovated Equipment	1 split system DX cooling unit.
Cooling System	Packaged DX - Air Cooled.
Heating System	gas furnace
Air Distribution System	Packaged VAV/ CV for storage room
Major Modeling Assumptions	Modeled efficiency of replaced unit to be SEER 18 based on manufacturer data. Mechanical equipment was auto-sized in the simulation model. Mechanical alteration only. Applied NREL Assumptions for roof, wall, window construction and specifications based on vintage and building type. Mechanic system modeled as observed. "As Permitted" model includes as-permitted lighting and as-verified HVAC, as no mechanical permit was available.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	63,670	3,351	552,350,954	552,350,954
As Permitted	63,100	3,351	550,406,034	550,406,034
As Verified	62,840	3,354	549,818,878	549,818,878
Savings	830	(3)	2,532,076	2,532,076

Appendix I: Project Summaries for Group B

Table 32. Project Summaries for Group B

Building ID	B-1
Overall Energy Compliance Index	0.97
Measure Energy Compliance Index	Mechanical – 0.97
Building Type	Mid-Rise Multifamily
Alteration	Alteration Type 2
Code Compliance	ASHRAE 90.1 2007
Alteration Type	Mechanical
Impacted Area (ft^2)	39,095
Location	Bronx County - Climate Zone 4A
Year Constructed	1920
Project Description	Project is a 5 story mid-rise apartment building and a basement floor with apartments on each floor including the basement and common area on first floor. Building underwent replacement of steam gas boiler.
Renovated Equipment	Steam Gas Boiler (1) - 80% thermal efficiency
Cooling System	No cooling
Heating System	Gas Steam Boiler
Air Distribution System	Baseboard heat only
Major Modeling Assumptions	Modeled Unit heater with no fan power to represent no active conditioning. Baseboard heating is provided through steam loop connected to the new gas steam boiler. One gas domestic hot water heater has been modeled that supplies DHW for all the apartments. Since the efficiency rating for the DHW heaters is expressed in Energy Factor, EF, , for modeling purposes, all stand by losses were ignored and the thermal efficiency was assumed to be equal to the EF. All envelope properties have been modeled per NREL document guidance per the building's vintage.

Analysis Results Summary	Electric (kWh/yr)	Gas (therms/yr)	Total Energy (Btu/yr)	Total Energy for Impacts (Btu/yr)
Code Baseline	119,640	30,789	3,487,128,430	3,078,900,000
As Verified	119,640	29,930	3,401,228,430	2,993,000,000
Savings	-	859	85,900,000	85,900,000

Building ID	B-2
Overall Energy Compliance Index	0.95
Measure Energy Compliance Index	Mechanical – 0.95
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	35,646
Location	Bronx County - Climate Zone 4A
Year Constructed	1913
Project Description	Project is a 5 story mid-rise apartment building and a basement floor with apartments on each floor including the basement and common area on first floor. Building underwent replacement of steam gas boiler.
Renovated Equipment	Steam Gas Boiler (1 qty) - 83.1% thermal efficiency
Cooling System	No cooling
Heating System	Gas Steam Boiler
Air Distribution System	Baseboard heat only
Major Modeling Assumptions	Modeled Unit heater with no fan power to represent no active conditioning. Baseboard heating is provided through steam loop connected to the new gas steam boiler. One gas domestic hot water heater has been modeled that supplies DHW for all the apartments. Since the efficiency rating for the DHW heaters is expressed in Energy Factor, EF, for modeling purposes, all stand by losses were ignored and the thermal efficiency was assumed to be equal to the EF. All envelope properties have been modeled per NREL document guidance per the building's vintage.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	108,640	20,859	2,456,594,890	2,085,900,000
As Verified	108,640	19,765	2,347,194,890	1,976,500,000
Savings	-	1,094	109,400,000	109,400,000

Building ID	B-4
Overall Energy Compliance Index	0.96
Measure Energy Compliance Index	Mechanical – 0.96; DHW – 0.99
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical & DHW
Impacted Area (ft^2)	65,000
Location	Bronx County - Climate Zone 4A
Year Constructed	1897
Project Description	Project is a seven story mid-rise apartment building with apartments on each floor including the basement. Building underwent boiler and domestic hot water heater replacement.
Renovated Equipment	Gas Boiler (1 qty) - 81% thermal efficiency Gas SHW Heater / SHW Storage tank - 82.3% thermal efficiency
Cooling System	No cooling
Heating System	Natural Draft Gas Steam Boiler serving baseboards
Air Distribution System	Baseboard heat only
Major Modeling Assumptions	The boiler shut-off is set at 55F per the auditor's observation. All envelope properties are modeled per the Pre-1980 vintage data per NREL.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	197,730	29,213	3,595,982,442	2,921,300,000
As Verified	197,730	27,924	3,467,082,442	2,792,400,000
Savings	-	1,289	128,900,000	128,900,000

Building ID	B-6
Overall Energy Compliance Index	0.95
Measure Energy Compliance Index	Envelope – 0.99 ; Lighting – 1.00 ; Mechanical – 0.95 ; DHW – 1.00
Building Type	Office (24*7) Emergency/ Warehouse
Code Compliance	ECCCNYS-2010
Alteration	Alteration Type 3
Alteration Type	Envelope, Lighting, Mechanical, DHW
Impacted Area (ft^2)	33,665
Location	Bronx County - Climate Zone 4A
Year Constructed	1970
Project Description	The project is an office and call center for medical emergency helpline for senior citizens. The building also has an adjacent warehouse/ enclosed parking area for ambulances/ emergency service vehicles. The office space is conditioned while the warehouse portion of the building is heated by unit heaters and air-curtains with an indoor design temperature set to 60F. Originally constructed in 1970, the project underwent envelope, lighting, mechanical, and DHW alteration.
Renovated Equipment	Replaced windows with U-0.37 and SHGC of 0.23. Replaced existing HVAC system with Mitsubishi City Multi Variable refrigerant flow system (EER 12.4 and SEER 17) Furred insulation in internal office walls with R-5 insulation. Domestic Hot water - 80% Thermal Efficiency Gas Furnaces and Unit Heater - 80% Thermal Efficiency
Cooling System	Split DX heat pumps
Heating System	Heat Pumps , Gas Furnace and Gas Unit heaters
Air Distribution System	Single Zone -Constant Volume
Major Modeling Assumptions	Modeled MAU per design/ Mech Plans, and assigned all HVAC systems to draw OA from the MAU unit. Modeled Electric resistance supplemental heat only on the baseline case. Modeled roof insulation and existing exterior walls per NREL documentation.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	562,380	5,375	2,456,399,293	2,456,399,293
As Verified	522,100	5,419	2,323,408,294	2,323,408,294
Savings	40,280	(44)	132,990,999	132,990,999

Building ID	B-12
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Mechanical – 0.99
Building Type	School
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	45,000
Location	Kings County (Brooklyn) - Climate Zone 4A
Year Constructed	1980
Project Description	Project is a five story elementary and middle school located in Brooklyn. The project underwent replacement of hot water boilers.
Renovated Equipment	Gas HW Boiler (2 qty) - 81% thermal efficiency
Cooling System	Air Cooled Chiller
Heating System	HW Loops with Baseboards
Air Distribution System	VAV throughout / CAV for kitchen zones.
Major Modeling Assumptions	The boiler shut-off is set at 55F. All envelope properties are modeled per the Post-1980 vintage data per NREL. Modeled kitchen systems to have constant volume packaged systems while the rest of the space is served by VAV - chiller -boiler configuration.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	524,460	17,434	3,532,930,944	1,743,400,000
As Verified	524,460	17,256	3,515,130,944	1,725,600,000
Savings	-	178	17,800,000	17,800,000

Building ID	B-14
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Mechanical – 1.00
Building Type	Hospital
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	750,000 ft^2 (entire building)
Location	Kings County (Brooklyn) - Climate Zone 4A
Year Constructed	1960
Project Description	The project is a collective 750,000 SF hospital buildings with 1 story below ground and 9 stories above ground. The hospitals are served by a central plant that provides chilled water and steam for cooling and heating spaces. Air is distributed through VAVs. Perimeter zones have Reheat. The project installed a new chiller and added controls.
Alteration Details	Project replaced the chiller, installed VFDs on existing chillers and CW. CHW pumps
Cooling System	Hydronic- CHW loop
Heating System	Steam Loop
Air Distribution System	Std VAV with perimeter reheat
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. The building has VAV boxes with perimeter reheat. Fans are variable speed. Fan powers were calculated per section G3.1.2.9 of ASHRAE 90.1 2007. Chillers, have a lock-out temp of 50. Economizer shut-off limit is set at 65F to represent economizer. Systems modeled with 100% OA.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	14,740,000	657,600	116,054,943,600	50,294,943,600
As Verified	14,740,000	657,600	116,054,943,600	50,294,943,600
Savings	-	-	-	-

Building ID	B-15
Overall Energy Compliance Index	0.87
Measure Energy Compliance Index	Envelope - 1.00; Lighting – 0.88, Mechanical – 0.98
Building Type	Office High-rise
Code Compliance	ECCCNYS-2010
Alteration	Alteration Type 2
Alteration Type	Envelope, Lighting and Mechanical
Impacted Area (ft^2)	17,000
Location	Kings County (Brooklyn) - Climate Zone 4A
Year Constructed	1955
Project Description	Project was an alteration of the basement and first floor - which were converted into administrative offices and conference areas. The project was a complete TI which included renovating: windows, installing a VRF heat pump HVAC system, and installing new lighting.
Renovated Equipment	FCU (8 qty), VRF HP (2 qty)
Cooling System	FCU and VRF HP
Heating System	Steam Radiator (along perimeter)
Air Distribution System	Ductless (HP and FCU)
Major Modeling Assumptions	Second story floor/first floor ceiling was modeled as adiabatic surfaces since the impacted space is located on the basement and 1st floor of a 12 story education building. The space only has two exterior wall exposures. Cooling capacity has been auto-sized to meet loads. Fans are constant volume. Heating source is modeled to be steam radiators in addition to heat pumps per site visit. The efficiency of the smaller condensing unit has been applied to all systems.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	174,860	569	653,556,800	653,556,800
As Verified	149,890	569	568,355,665	568,355,665
Savings	24,970	-	85,201,136	85,201,136

Building ID	B-16
Overall Energy Compliance Index	0.95
Measure Energy Compliance Index	Mechanical – 0.95
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1- 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	12,260 (Assumed 3.5 floors across both buildings)
Location	New York County (Manhattan) - Climate Zone 4A
Project Description	Project is a 4 story mid-rise apartment building with apartments on each floor. Building underwent replacement of steam gas boiler. The Gas boiler also serves space heating needs for the adj. 3 story apartment building.
Renovated Equipment	Steam Gas Boiler (1 qty) - 83% thermal efficiency
Cooling System	No cooling
Heating System	Gas Steam Boiler
Air Distribution System	Baseboard heat only
Major Modeling Assumptions	Project underwent replacement of Steam Boiler for heating. Baseboard heating is provided through steam loop connected to the new gas steam boiler. A gas Domestic hot water heater has been assumed that supplies DHW for all the apartments. Since the efficiency rating for the DHW heater is expressed in Energy Factor, for modeling purposes, all stand by losses were ignored and the thermal efficiency was assumed to be equal to the Baseline Energy Factor per ASHRAE 90.1 and kept constant across both models. Boiler capacity were hard-coated per permit docs and verified data and baseline efficiency was assigned per the Table6.8.1F. Apartments have been modeled to be conditioned with PTACs per verified data. PTAC efficiencies are modeled identical in both models and are based on ASHRAE 90.1 requirements. Fan Power calculated per G3.1.2.9

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	64,040	8,038	1,022,313,446	803,800,000
As Verified	64,040	7,600	978,463,446	759,950,000
Savings	-	439	43,850,000	43,850,000

Building ID	B-18
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Mechanical - 0.99
Building Type	Office High-rise
Code Compliance	ASHRAE 90.1 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	3750 ft^2 (server room on the 14th floor)
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1964
Project Description	Project replaced a DX split system with electric resistance heating serving accounting office's server room located on the 14th floor of a 20 story building with an 11.7 EER Skymark unit.
Renovated Equipment	1 Split system (DX cooling) - 11.7 EER
Cooling System	Split DX Unit
Heating System	None
Air Distribution System	Ducted - constant volume
Major Modeling Assumptions	Walls in two orientations, floor, and roof were modeled as adiabatic surfaces since the impacted space is a core zone located on the 12th floor of a 23 story office tower. Cooling capacity has been autosized to meet loads. The space has been modeled to operate after regular office hours. Fans are constant volume. Heating source is modeled to be electric resistance as per verified data. Economizer shut-off limit is set at 45F to represent economizer is not installed.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	68,440	97.50	233,527,837	233,526,862
As Verified	67,940	97.50	231,821,767	231,820,792
Savings	500	-	1,706,070	1,706,070

Building ID	B-19
Overall Energy Compliance Index	0.97
Measure Energy Compliance Index	Mechanical – 0.99; DHW – 0.97
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical and DHW
Impacted Area (ft^2)	10,080
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1940
Project Description	Project is a 4 story mid-rise apartment building and a basement floor with apartments on each floor including the basement and common area on first floor. Building underwent replacement of steam gas boiler, and DHW water heaters (2 qty).
Renovated Equipment	HW Gas Boiler (1 qty) - 81% thermal efficiency DHW Res Heater (2 qty) - 0.58 ENERGY FACTOR
Cooling System	No cooling
Heating System	Gas Steam Boiler
Air Distribution System	Baseboard heat only
Major Modeling Assumptions	Modeled Unit heater with no fan power to represent no active conditioning. Small exhaust for unconditioned space. Baseboard heating is provided through steam loop connected to the new gas steam boiler. Two new gas domestic hot water heaters have been installed that supplies DHW for all the apartments. Since the efficiency rating for the DHW heaters is expressed in ENERGY FACTOR, for modeling purposes, all stand by losses were ignored and the thermal efficiency was assumed to be equal to the ENERGY FACTOR. Domestic hot water heaters are modeled to be equally sized as verified through permit docs and are modeled to operate in sequence. Equipment capacities were hard-coated per permit docs and verified data.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	31,010	8,338	939,560,461	833,750,000
As Verified	31,010	8,052	911,020,461	805,210,000
Savings	-	285	28,540,000	28,540,000

Building ID	B-20
Overall Energy Compliance Index	0.97
Measure Energy Compliance Index	Mechanical - 0.97
Building Type	High rise Multifamily
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	1,000
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1998
Project Description	Project is a 7 story mid-rise senior housing apartment building that underwent a DX split cooling system replacement for its lobby, hallway and office on the first floor. The building is approximately 41,040 SF but the impacted area only accounts for 1,000 SF.
Renovated Equipment	Split DX Cooling system SEER - 16.5
Cooling System	Cooling only
Heating System	None
Air Distribution System	Ducted
Major Modeling Assumptions	Modeled a cooling only packaged AC unit for all three spaces. (lobby, hallway and office). Since this was the only impacted area, the apartment s and associated systems were not modeled. The envelope was modeled per the NREL document guidance for projects constructed post 1980s and is specific to the Climate zone 4A. Roof surface are considered to be adiabatic.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	10,730	16	38,231,362	36,612,262
As Verified	10,390	16	37,071,235	35,452,135
Savings	340	-	1,160,128	1,160,128

Building ID	B-21
Overall Energy Compliance Index	0.88
Measure Energy Compliance Index	Mechanical – 0.88; DHW – 1.00
Building Type	Office
Code Compliance	ASHRAE 90.1 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical and DHW
Impacted Area (ft^2)	36,000
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1988
Project Description	Medical office building. Six floors above grade and one floor below grade. Building site was originally a garage.
Renovated Equipment	Boiler and DHW heater
Cooling System	Screw chillers, water cooled
Heating System	Hot water boilers
Air Distribution System	Fan coils with DOAS on all floors, except second floor is VAV w/reheat, AHU w/preheat coils
Major Modeling Assumptions	Year constructed could not be obtained by field auditor; therefore was obtained via internet search. All envelope properties were modeled per NREL document guidance for post-1980 constructed buildings. Basement assumed to be unconditioned, but was included in the total floor area. Modeled system was simplified to be VAV with reheat throughout the building. Boiler hot water reset based on OAT was modeled, as verified in field. Economizers were not indicated in field data collection, therefore none have been modeled - economizer shut-off limit is set at 45F to represent that an economizer is not installed. No code documentation was available, therefore code used for compliance was assumed to be ASHRAE 90.1-2007

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	318,550	14,447	2,531,637,197	1,444,700,000
As Verified	318,550	12,765	2,363,437,197	1,276,500,000
Savings	-	1,682	168,200,000	168,200,000

Building ID	B-22
Overall Energy Compliance Index	0.93
Measure Energy Compliance Index	Mechanical – 0.93
Building Type	Religious Worship
Code Compliance	ASHRAE 90.1 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	18430 ft^2 (6939 ft^2 is unconditioned, 6840 ft^2 is radiator heating only, rest is conditioned with DX AC and radiator heating)
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1889
Project Description	Project replaced existing boiler with gas fired steam boilers (2 qty- each with 400 MBH). The project has an unconditioned basement mainly used for storage. The main floor has a large gathering hall which is conditioned by 8 Unitary AC units. The main floor is heating by steam loop radiators.
Renovated Equipment	2 Gas Fired- Steam Boilers - 400 MBH/ 82.39% Combustion Efficiency
Cooling System	DX
Heating System	Radiator only
Air Distribution System	Ducted - constant volume
Major Modeling Assumptions	Since PNNL does not have a prototype for religious facilities or public assembly buildings, the school prototype was used. For heating only space, a unit heater was modeled with no fan power, no heating system and baseboard heating. Since the combustion efficiency of the boilers is 82.39%, their thermal efficiency was assumed to be 81% (to account for losses).

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	84,600	4,430	731,637,044	442,970,000
As Verified	84,600	4,128	701,467,044	412,800,000
Savings	-	302	30,170,000	30,170,000

Building ID	B-23
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Mechanical 1.00
Building Type	Elementary School
Code Compliance	ASHRAE 90.1 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	14750 ft^2 (2950 ft^2 basement unconditioned floor, remaining area above ground and conditioned.)
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1938
Project Description	Project replaced existing boiler with gas fired steam boilers (1 qty- each with 400 MBH). The project has an unconditioned basement mainly used for storage. The 4 floors above ground are conditioned by heat pumps and radiator heating with steam loop.
Renovated Equipment	1 Gas Fired- Steam Boilers - 400 MBH/ 80% Combustion Efficiency
Cooling System	heat pump- DX
Heating System	Radiator only
Air Distribution System	VAV
Major Modeling Assumptions	School prototypical data was used for infiltration estimates, set points, glazing percentages, etc. NREL data was used to represent vintage envelope. A packaged VAV system was modeled to represent a heat pump (cooling Only) serving multiple zones. DHW water heater was assumed to be 80% efficient. Boiler shut-off set at 55F based on verified data. Schedules are based on actual hours of operation as per field verified data. Occupancy was modeled based on typical annual school schedules accounting for winter and summer breaks.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	104,180	6,060	961,516,745	606,040,000
As Verified	104,180	6,060	961,516,745	606,040,000
Savings	-	-	-	-

Building ID	B-28
Overall Energy Compliance Index	0.96
Measure Energy Compliance Index	Mechanical – 1.00; DHW – 0.96
Building Type	Mid-rise Multifamily/ Retail on first floor/ Unconditioned basement
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical and DHW
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1930
Project Description	Project is a 5 (above grade) story mid-rise apartment/mixed use building and an unconditioned basement floor. Building underwent boiler, pumps, boiler control and DHW water heater, pump and controls replacement.
Renovated Equipment	HW Gas Boiler (1 qty) - 93% thermal efficiency DHW Heater (1 qty) - 92% Combustion efficiency
Cooling System	Unitary AC units for retail spaces. No cooling for apartments.
Heating System	Natural Draft Gas HW Boiler
Air Distribution System	Baseboard heat only for residences and Unitary AC for retail spaces
Major Modeling Assumptions	Modeled Unit heater with no fan power to represent no active conditioning for residences. Baseboard heating is through hot water loop connected to the new gas HW boiler. A new domestic hot water heater has been installed that supplies all DHW for the apartments and retail spaces. Both the boilers have primary only pumps. Since the DHW heater has a combustion efficiency of 92%, the thermal efficiency was assumed to be 90% to account for standby losses.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	205,580	10,956	1,797,067,741	1,095,600,000
As Verified	205,580	10,499	1,751,367,741	1,049,900,000
Savings	-	457	45,700,000	45,700,000

Building ID	B-29
Overall Energy Compliance Index	0.96
Measure Energy Compliance Index	Mechanical – 0.97; DHW - 0.99
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical and DHW
Impacted Area (ft^2)	6,540
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1897
Project Description	Project is a four story mid-rise apartment building with two apartments on each floor including the basement. Building underwent boiler and boiler control replacement.
Renovated Equipment	Gas Boiler (1 qty) - 81% combustion efficiency/ SHW Storage tank
Cooling System	No cooling
Heating System	Natural Draft Gas HW Boiler
Air Distribution System	Baseboard heat only
Major Modeling Assumptions	Combined (indirect) hot water and heating system operation is modeled by applying the efficiency of the Steam Gas boiler and the Domestic hot water system. The boiler shut-off is set at 55F per the auditor's observation. All envelope properties are modeled per the Pre-1980 vintage data per NREL. Combustion efficiency of 81% therefore thermal efficiency of the verified case was modeled to be 80%

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	20,410	5,818	651,431,777	581,790,000
As Verified	20,410	5,603	629,911,777	560,270,000
Savings	-	215	21,520,000	21,520,000

Building ID	B-30
Overall Energy Compliance Index	0.96
Measure Energy Compliance Index	Mechanical – 0.97; DHW – 0.99
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical and DHW
Impacted Area (ft^2)	4,680
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1897
Project Description	Project is a five story mid-rise apartment building with two apartments on each floor. Building underwent boiler and boiler control replacement.
Renovated Equipment	Gas Boiler (1 qty) - 81% combustion efficiency, DHW alteration
Cooling System	No cooling
Heating System	Natural Draft Gas Steam Boiler
Air Distribution System	Baseboard heat only
Major Modeling Assumptions	Combined (indirect) hot water and heating system operation is modeled by applying the efficiency of the Steam Gas boiler and the Domestic hot water system. The boiler shut-off is set at 55F per the auditor's observation. All envelope properties are modeled per the Pre-1980 vintage data per NREL. Combustion efficiency of 81% therefore thermal efficiency of the verified case was modeled to be 80%
Compliance Notes	HW design supply temperature shall be modeled as 180 deg F and a design return temperature of 130 deg F.
	HWST shall be reset based on OSAT, Exception A Applies
	19W/GPM
	Boiler thermal efficiency at least 75%
	DHW storage tanks to have R12.5 insulation.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	14,790	4,473	497,775,551	447,310,000
As Verified	14,790	4,308	481,235,551	430,770,000
Savings	-	165	16,540,000	16,540,000

Building ID	B-32
Overall Energy Compliance Index	0.96
Measure Energy Compliance Index	Mechanical – 0.97; DHW – 0.99
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical and DHW
Impacted Area (ft^2)	20,570
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1905
Project Description	Project is a 7 story mid-rise apartment building and a basement floor with apartments on each floor including the basement and common area on first floor. Building underwent boiler, pumps, boiler control and DHW water heater, pumps and controls replacement.
Renovated Equipment	HW Gas Boiler (1 qty) - 84% thermal efficiency DHW Heater (1 qty) - 82% Thermal efficiency
Cooling System	No cooling
Heating System	Natural Draft Gas HW Boiler
Air Distribution System	Baseboard heat only
Major Modeling Assumptions	Modeled Unit heater with no fan power to represent no active conditioning. Baseboard heating is through hot water loop connected to the new gas HW boiler. A new domestic hot water heater has been installed that supplies al DHW for the apartments. Both the boilers have primary only pumps.
Compliance Notes	HW design supply temperature shall be modeled as 180 deg F and a design return temperature of 130 deg F.
	HWST shall be reset based on OSAT.
	19W/GPM
	HW Boiler efficiency and DHW heater efficiency should be at least 80%
	Area < 120,000 ft^2, pump curve.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	69,870	13,722	1,610,606,222	1,610,606,222
As Verified	69,870	13,119	1,550,306,222	1,550,306,222
Savings	-	603	60,300,000	60,300,000

Building ID	B-33
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Lighting – 0.99; Mechanical – 1.00
Building Type	Office
Code Compliance	ECCCNYS-2010
Alteration	Alteration Type 2
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	9,900
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1913
Project Description	14 story office building, alteration only impacts the third floor. Lighting retrofit throughout the space (9,000 ft^2). New split system AC unit serving one conference room (900 ft^2).
Renovated Equipment	Lighting, Split AC Unit
Cooling System	DX, air cooled
Heating System	Electric Resistance
Air Distribution System	CV
Major Modeling Assumptions	Only the conference room was modeled, as it was the only space served by the mechanical retrofit, and the lighting retrofit did not impact this space. The conference room east wall is exterior, and the other interior walls as well as the floor and ceiling were modeled as adiabatic surfaces. Envelope properties modeled per NREL document guidance for Pre-1980 constructed buildings. Code used for compliance was ECCCNYS 2010 based on COMCheck documentation

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	292,530	0	998,153,314	998,153,314
As Verified	290,980	0	992,864,497	992,864,497
Savings	1,550	-	5,288,817	5,288,817

Building ID	B-37
Overall Energy Compliance Index	0.98
Measure Energy Compliance Index	Mechanical – 0.98
Building Type	Office High-rise- Server room
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	65 ft^2 (server room on the 14th floor)
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1927
Project Description	Project replaced a split system cooling unit serving a small office's server room located on the 14th floor of a 20 story building with a 15.2 SEER Mitsubishi split system (cooling only).
Renovated Equipment	1 Split system (DX cooling) - 15.2 SEER
Cooling System	Split DX
Heating System	None
Air Distribution System	Ducted - constant volume
Major Modeling Assumptions	All walls, floor, and roof were modeled as adiabatic surfaces since the impacted space is a core zone located on the 14th floor of a 20 story office tower. Cooling capacity is based on the maximum output capacity of the equipment and is hard-coded in the model. The space has been modeled to operate 24X7. The miscellaneous equipment density has been assumed to be 10W/SF to represent average server technology loads. Fans are constant volume. No heating system/source has been modeled to represent the conditions as verified. Economizer shut-off limit is set at 45F to represent economizer is not installed.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	7,061	-	24,094,485	24,094,485
As Verified	6,923	-	23,623,610	23,623,610
Savings	138	-	470,875	470,875

Building ID	B-38
Overall Energy Compliance Index	0.93
Measure Energy Compliance Index	Mechanical – 0.93
Building Type	Office High-rise- Server room
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	208 ft^2 (server room on the 14th floor)
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1962
Project Description	Project replaced a split system cooling unit serving a switch room located on the 13th floor of a 15 story building with a 13.64 EER Liebert split water cooled system (cooling only).
Renovated Equipment	1 Split system (DX cooling) - 13.64 EER
Cooling System	Split DX
Heating System	None
Air Distribution System	Ducted - constant volume
Major Modeling Assumptions	All walls, floor, and roof were modeled as adiabatic surfaces since the impacted space is a core zone located on the 13th floor of a 15 story office tower. Cooling capacity is auto-sized in the model. The space has been modeled to operate 24X7. The miscellaneous equipment density has been assumed to be 10W/SF to represent average server technology loads. Fans are constant volume. No heating system/source has been modeled to represent the conditions as verified. Economizer shut-off limit is set at 45F to represent economizer is not installed.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	22,730	-	77,557,942	77,557,942
As Verified	21,130	-	72,098,518	72,098,518
Savings	1,600	-	5,459,424	5,459,424

Building ID	B-40
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Mechanical – 1.00
Building Type	Office MidRise
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	135,000
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1910
Project Description	The Project is an office building with 9 stories above ground and 1 below ground. The building is conditioned by a series of split DX systems and heating is provided through steam loop baseboards. The split units are water-cooled by a cooling tower. The cooling tower was replaced.
Renovated Equipment	240 tons - 2 cell cooling tower with VFD fans.
Cooling System	Split DX with Water Cooled Condenser
Heating System	Natural Draft Gas Steam Boiler - baseboard heating
Air Distribution System	Standard VAV with Steam baseboard
Major Modeling Assumptions	Modeled each floor with 15 ft deep perimeter zones and 1 core zone. Assigned one system per zone and assigned condenser as water-cooled condenser. Auto-sized the capacities for all equipment. Assigned baseline efficiencies for all equipment due to lack of data. The baseline cooling tower and the as verified case is modeled to be axial type and have variable speed fans.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	1,201,100	56,500	9,748,321,354	4,098,321,354
As Verified	1,197,400	56,500	9,735,696,436	4,085,696,436
Savings	3,700	-	12,624,918	12,624,918

Building ID	B-41
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Mechanical – 0.99
Building Type	Office
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	23,025
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1940
Project Description	Building is primarily office, 9 stories total but only stories 4-9 were part of alteration. Main AHU serving offices and a spa on floors 4-9 was replaced.
Renovated Equipment	Packaged AC Unit (1 qty) - 10.3 EER, 10.9 IEER
Cooling System	DX Cooling
Heating System	Electric resistance preheat coil, with zonal heating provided by baseboard hot water radiators.
Air Distribution System	VAV
Major Modeling Assumptions	Envelope properties were derived from the prototypical model. Because the renovated area only includes floors 4-9, the bottom floor of the model was defined as an adiabatic surface. The AHU was modeled with an economizer, as verified in the field, with an assumed high limit shutoff as prescribed by ASHRAE 90.1. Fan power was calculated according to ASHRAE 90.1. The heating hot water boiler system was modeled per ASHRAE 90.1.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	248,580	20,903	2,938,489,761	848,189,761
As Verified	246,420	20,903	2,931,119,539	840,819,539
Savings	2,160	-	7,370,222	-

Building ID	B-42
Overall Energy Compliance Index	0.97
Measure Energy Compliance Index	Mechanical 0.97
Building Type	Office High-rise
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	15,104 ft^2 (server room on the 21st floor)
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1964
Project Description	Project is a 45 story office tower that replaced 3 supplemental Packaged DX cooling systems that serve the 21st floor. Systems operate to provide cooling during after hours when the central plant cooling is unavailable. Units are water-cooled.
Renovated Equipment	3 Packaged DX system (water cooled)
Cooling System	Packaged DX cooling
Heating System	Hydronic - baseboard
Air Distribution System	Ducted - variable volume
Major Modeling Assumptions	The floor and roof were modeled as adiabatic surfaces since the impacted space is a core zone located on the 21st floor of a 45 story office tower. Cooling capacity is autosized in the model. The replaced systems operate during after ours so all schedules have been modified to reflect only after hour operations. The central plant chiller is the main source of cooling during the day but since it is never coincident with the 3 DX cooling systems, it hasn't been modeled. Fans are variable volume. No heating system/source has been modeled to represent the conditions as verified, except for baseboard hydronic loop. Economizer shut-off limit is set at 65F to represent dry-bulb OA economizer.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	375,190	10,926	2,372,800,807	1,280,200,807
As Verified	364,720	10,926	2,337,075,701	1,244,475,701
Savings	10,470	-	35,725,106	35,725,106

Building ID	B-46
Overall Energy Compliance Index	1.01
Measure Energy Compliance Index	Lighting – 1.01
Building Type	Office
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Alteration Type 2
Alteration Type	Lighting
Impacted Area (ft^2)	4,827
Location	New York County (Manhattan)- Climate Zone 4A
Project Description	Project installed new lighting fixtures in a small office building. Space types include enclosed offices, corridors, conference rooms, lobby and active storage areas...
Renovated Equipment	Lighting
Cooling System	Did not Verify
Heating System	Did not Verify
Air Distribution System	Did not Verify
Major Modeling Assumptions	Baseline and installed lighting power densities were calculated from inspection findings. These lighting power densities were incorporated into eQUEST using proto-typical building models to estimate compliance index including interactive effects.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	63,740	3,771	594,619,804	594,619,804
As Verified	66,620	3,729	600,216,767	600,216,767
Savings	(2,880)	42	(5,596,963)	(5,596,963)

Building ID	B-47
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Mechanical - 0.97
Building Type	Synagogues and School
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	100,140
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1920s
Project Description	Project is a five stories above-grade, one story below-grade synagogue and school building. Replaced heat pumps, FCU and AC units. Replaced boiler.
Renovated Equipment	Steam Boiler (1 qty) - 80.9% thermal efficiency (Assumed min. code). AHU (2 qty). FCU (4 qty). Split Units (14 qty)- 15 SEER.
Cooling System	Packaged rooftop AHU, FCU, and split units.
Heating System	Steam Boiler
Air Distribution System	VAV
Major Modeling Assumptions	The chapel is served by a combination of AHUs and spit systems. One FCU serves each floor, with supplemental conditioning from split systems. Since PNNL does not have a prototype for religious facilities or public assembly buildings, the school prototype was referred.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	900,280	41,410	7,212,881,399	7,212,881,399
As Verified	897,210	40,489	7,110,306,129	7,110,306,129
Savings	3,070	921	102,575,270	102,575,270

Building ID	B-51
Overall Energy Compliance Index	1.01
Measure Energy Compliance Index	Lighting – 1.03; Mechanical 0.97
Building Type	Office
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	1,410
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1935
Project Description	One-story garage building used to store police vehicles. Two new rooftop AC units serve office space and a break room. A lighting alteration also took place.
Renovated Equipment	Packaged AC Units: AC-1 SEER 13.5, AC-2 SEER 13, Interior Lighting
Cooling System	DX Cooling during winter season, chilled water during summer season
Heating System	Hot water baseboard radiators
Air Distribution System	VAV
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. Only the zones served by the renovated AC units were modeled. Because the new units only utilize DX cooling during the winter heating season, during the summer season the DX cooling was disabled so no cooling has been modeled during the summer months. The winter heating season was assumed to include the months of October through April. Baseline fans are constant volume, and installed systems are VAV as verified in field. Fan powers were calculated per section G3.1.2.9 of ASHRAE 90.1 2007. Economizer shut-off limit is set at 45F to represent that an economizer is not installed. Lighting in Baseline and As-verified cases modeled according to lighting calculations for the mezzanine/locker room space type. Verified LPD was found to exceed allowance.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	7,750	254	51,843,109	51,843,109
As Verified	7,948	254	52,497,006	52,497,006
Savings	(198)	0	(473,897)	(473,897)

Building ID	B-52
Overall Energy Compliance Index	0.93
Measure Energy Compliance Index	Mechanical – 0.93
Building Type	Mid-Rise Multifamily
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	226,560
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1984
Project Description	Project proposed to replace 12 self-contained DX air conditioning units. During the time of the inspection, 15 self-contained units were renovated, therefore modeled 15 units. An existing cooling tower equipped with VFDs was installed as part of the project. The cooling tower provides condenser water to all 48 Floors of the building.
Renovated Equipment	15 Self Contained DX Units on 15 Floors with EER - 14.9, tied to existing cooling tower.
Cooling System	Packaged DX with Water Cooled Condenser
Heating System	Natural Draft Gas Steam Boiler - baseboard heating
Air Distribution System	Standard VAV with HW Reheat
Major Modeling Assumptions	15 self-contained DX units were modeled per audit information. Only 15 floors (48 story building) were modeled to isolate for areas impacted by the alteration only. Mechanical equipment was auto-sized in the simulation model. Mechanical alteration only. Applied DOE Assumptions for roof, wall, window construction and specifications based on vintage and building type. Mechanical system modeled as observed.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	2,150,500	105,800	17,917,807,070	7,337,807,070
As Verified	1,998,100	105,800	17,397,796,934	6,817,796,934
Savings	152,400	-	520,010,136	520,010,136

Building ID	B-53
Overall Energy Compliance Index	0.98
Measure Code Compliance Index	Mechanical – 0.98
Building Type	Hospital
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	3,375,000
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1923
Project Description	Central Plant serves a 12 building hospital campus totaling 3.4 million square feet. Alteration was refurbishment of 2 boilers (Boilers 3 & 4). Plant also includes four boilers, but only two are required to meet the load. Boilers 1 & 2 were replaced in 2006.
Renovated Equipment	(2) Boilers - added economizers, new forced draft fans with VFDs and steam drives
Cooling System	Water-cooled centrifugal chillers
Heating System	Steam Boilers
Air Distribution System	VAV w/reheat
Major Modeling Assumptions	All envelope properties are modeled per NREL document guidance for Pre-1980 constructed buildings. Modeled as a single building shell of 3,375,000 square feet. Total modeled building area was approximated based on a multiplier of the PNNL prototype model floor area resulting in a total as close as possible to reported total building area of 3.4 million sf. No permit documentation was available, therefore compliance code was assumed to be ASHRAE 90.1-2007. Notes state that boilers primarily run on natural gas, so they were modeled as gas-fired. Analysis/Study report by AKF Engineers provided an efficiency rating based on tested conditions post-implementation of the boiler alterations. This efficiency value was used in the As Verified model to account for all aspects of the boiler refurbishment measure as a whole.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	65,825,105	2,327,100	457,314,473,923	457,314,473,923
As Verified	65,551,319	2,256,700	449,340,276,279	449,340,276,279
Savings	273,786	70,400	7,974,197,643	7,974,197,643

Building ID	B-59
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Mechanical – 1.00
Building Type	Hospital
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	3,224,695
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1938
Project Description	Central Plant serves a 13 building hospital campus totaling 3.2 million square feet. Alteration was replacement of 7 cooling towers, with variable speed fans. Thirteen additional single-speed towers are pre-existing.
Renovated Equipment	Cooling Towers (7)
Cooling System	Water-cooled centrifugal chillers
Heating System	Gas boilers
Air Distribution System	VAV w/reheat
Major Modeling Assumptions	All envelope properties are modeled per NREL document guidance for Pre-1980 constructed buildings. Modeled as a single building shell of 3,224,695 square feet. Total modeled building area was approximated based on a multiplier of the PNNL prototype model floor area resulting in a total as close as possible to reported total building area of 3.2 million sf. No permit documentation was available, therefore compliance code was assumed to be ASHRAE 90.1-2007.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	62,050,000	2,314	443,073,287,000	211,723,287,000
As Verified	61,900,000	2,314	442,561,466,000	211,211,466,000
Savings	150,000	-	511,821,000	511,821,000

Building ID	B-60
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Mechanical – 1.00
Building Type	Office- High Rise
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	556,688 ft^2 (entire building)
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1971
Project Description	The project is a high rise office building that has 40 stories above ground and 2 stories below ground. The building is served by a central plant that provides chilled water and steam for cooling and heating spaces. Air is distributed through VAVs. Perimeter zones have Reheat.
Alteration Details	Project replaced the chiller, installed VFDs on existing chillers and CW. CHW pumps
Cooling System	Hydronic- CHW loop
Heating System	Steam Loop
Air Distribution System	Std VAV with perimeter reheat
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. The building has VAV boxes with perimeter reheat. Fans are variable speed. Fan powers were calculated per section G3.1.2.9 of ASHRAE 90.1 2007. Chillers, have a lock-out temp of 50.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	5,419,200	252,700	43,761,069,088	18,491,069,088
As Verified	5,419,200	252,700	43,761,069,088	18,491,069,088
Savings	-	-	-	-

Building ID	B-64
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Lighting – 0.99
Building Type	Office
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Alteration Type 2
Alteration Type	Lighting
Impacted Area (ft^2)	13,525
Location	New York County (Manhattan)- Climate Zone 4A
Project Description	Project installed new lighting fixtures in a small office building. Space types include open office areas.
Renovated Equipment	Lighting
Cooling System	Did not Verify
Heating System	Did not Verify
Air Distribution System	Did not Verify
Major Modeling Assumptions	Baseline and installed lighting power densities were calculated from inspection findings. These lighting power densities were incorporated into eQUEST using proto-typical building models to estimate compliance index including interactive effects.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	142,310	8,639	1,349,431,643	1,349,431,643
As Verified	134,310	8,750	1,333,304,523	1,333,304,523
Savings	8,000	(112)	16,127,120	16,127,120

Building ID	B-65
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Mechanical – 0.99
Building Type	Multifamily High-rise
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	262,953 ft^2 (entire building)
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1963
Project Description	Project replaced the chiller, cooling tower, CHW pump, CW pump and associated controls.
Cooling System	Hydronic- CHW loop
Heating System	HW Loop
Air Distribution System	Ducted - constant volume fan coils
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. The building has 2 pipe fan coils units that either provide cooling or heating at any given point. Fans are constant volume. Fan powers were calculated per section G3.1.2.9 of ASHRAE 90.1 2007. A chiller and boiler system with individual loops is modeled to represent the heat exchanger, such that the boiler has a lock-out temp of 52. This prevents the boiler from running simultaneously with the chiller during the cooling season. Economizer shut-off limit is set at 45F to represent economizer is not installed.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	1,881,300	146,400	21,059,258,982	6,419,258,982
As Verified	1,864,400	146,400	21,001,593,816	6,361,593,816
Savings	16,900	-	57,665,166	57,665,166

Building ID	B-66
Overall Energy Compliance Index	0.98
Measure Energy Compliance Index	Lighting – 0.98
Building Type	Office
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Alteration Type 2
Alteration Type	Lighting
Impacted Area (ft^2)	35,384
Location	Queens - Climate Zone 4A
Project Description	Project installed new lighting fixtures in a small office building. Space types include corridors and atriums
Renovated Equipment	Lighting
Cooling System	Did not Verify
Heating System	Did not Verify
Air Distribution System	Did not Verify
Major Modeling Assumptions	Baseline and installed lighting power densities were calculated from inspection findings. These lighting power densities were incorporated into eQUEST using proto-typical building models to estimate compliance index including interactive effects.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	261,300	20,289	2,920,492,182	2,920,492,182
As Verified	231,990	20,765	2,868,082,359	2,868,082,359
Savings	29,310	(476)	52,409,823	52,409,823

Building ID	B-68
Overall Energy Compliance Index	0.96
Measure Energy Compliance Index	Mechanical – 0.96
Building Type	School
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	12,200
Location	Queens - Climate Zone 4A
Year Constructed	1930
Project Description	Three-story building that operates as a school for the disabled. Mainly composed of admin offices, classrooms, and gym/auditorium
Renovated Equipment	Boiler replacement
Cooling System	Packaged DX
Heating System	Gas-fired steam boiler, radiant heating manifolds
Air Distribution System	Constant volume
Major Modeling Assumptions	The building area was obtained via an internet search of property records, as it was not confirmed by the field auditor. All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. Boiler lockout is 60F, as verified in field. Cooling system was assumed to be packaged DX based on presence of RTUs in Google Maps image.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	160,480	6,386	1,186,150,227	638,570,000
As Verified	160,480	6,112	1,158,750,227	611,170,000
Savings	-	274	27,400,000	27,400,000

Building ID	B-69
Overall Energy Compliance Index	0.94
Measure Energy Compliance Index	Mechanical – 0.95; DHW – 0.99
Building Type	High-rise Multifamily
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical and DHW
Impacted Area (ft^2)	56,342
Location	Queens - Climate Zone 4A
Year Constructed	Post-1980
Project Description	Multifamily residential building containing 80 apartment units. Eight stories above grade plus basement.
Renovated Equipment	Gas-fired Hot Water Boiler (provides heating and DHW)
Cooling System	Two split DX units serve basement and first floor only - no cooling for floors 2-8
Heating System	Boiler, Baseboard Radiators
Air Distribution System	Constant volume
Major Modeling Assumptions	All envelope properties are modeled per NREL document guidance for post-1980 constructed buildings. Boiler modeled with a hot water reset based on OAT, as verified in field. The Indirect DHW heater was modeled as a separate gas water heater with the corresponding boiler efficiency applied in both the Baseline and As Verified cases.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	251,340	38,661,000	3,866,957,607,268	3,866,100,000,000
As Verified	251,340	36,372,000	3,638,057,607,268	3,637,200,000,000
Savings	-	2,289,000	228,900,000,000	228,900,000,000

Building ID	B-70
Overall Energy Compliance Index	1.34
Measure Energy Compliance Index	Lighting 1.34
Building Type	Retail
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Lighting
Impacted Area (ft^2)	0
Location	Queens - Climate Zone 4A
Year Constructed	Pre-1980's
Project Description	Single story library building.
Renovated Equipment	Two story retail facility installed fluorescent fixtures for exterior lighting applications.
Cooling System	Water Cooled DX
Heating System	Boiler
Air Distribution System	VAV
Major Modeling Assumptions	Baseline and installed lighting power densities were calculated from inspection findings. Annual operating hours was estimated at 4,380 hours/year (12 hrs/day)

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	2,700	0	9,212,778	9,212,778
As Verified	3,700	0	12,62,4918	12,624,918
Savings	(1,000)	-	(3,412,140)	(3,412,140)

Building ID	B-71
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Mechanical – 0.99
Building Type	Library
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	7,845
Location	Queens - Climate Zone 4A
Year Constructed	Pre-1980's
Project Description	Single story library building.
Renovated Equipment	Replaced old condenser for the built-up rooftop AC system that serves the entire building (same capacity as previous system and uses same AHU and ductwork). Also added a new packaged AC unit to serve the computer lab.
Cooling System	DX Cooling
Heating System	Steam boiler
Air Distribution System	Dual-fan, dual-duct, CV mixing boxes
Major Modeling Assumptions	The modeling starting point was the PNNL school prototype, changed to year-round occupancy. All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings (based on date in Work Application). The AHUs were modeled with economizers, as verified in the field. Fan power was calculated according to ASHRAE 90.1. The steam boiler system was modeled as a gas-fired boiler.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	150,150	3,142	826,552,821	826,552,821
As Verified	147,980	3,142	819,148,477	819,148,477
Savings	2,170	-	7,404,344	7,404,344

Building ID	B-72
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Mechanical – 1.00
Building Type	Warehouse/Manufacturing
Code Compliance	ASHRAE 90.1-2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	21,750
Location	Queens - Climate Zone 4A
Year Constructed	1940
Project Description	Warehouse/manufacturing building used for packaging and distribution of medication. Mix of space types including a large shipping/receiving area, workshop, office. The RTUs provide both heating and cooling to the entire building, including the warehouse space - the facility ships pharmaceuticals that need to be kept at a constant temperature.
Renovated Equipment	Packaged Gas/Electric Rooftop Units (3)
Cooling System	DX Cooling
Heating System	Natural Gas Furnace
Air Distribution System	VAV
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. Code used for compliance was assumed to be ASHRAE 90.1 2007. Units have integrated dry bulb economizers, as verified in field, and therefore were included in the model.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	157,260	10,443	1,580,893,136	1,580,893,136
As Verified	155,850	10,443	1,576,082,019	1,576,082,019
Savings	1,410	-	4,811,117	4,811,117

Building ID	B-73
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Mechanical – 0.99
Building Type	Warehouse/Manufacturing
Code Compliance	ASHRAE 90.1-2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	43,852
Location	Queens - Climate Zone 4A
Year Constructed	1968
Project Description	Warehouse/manufacturing building used for packaging and distribution of medication. Mix of space types including a large shipping/receiving area, workshop, office. The RTUs provide both heating and cooling to the entire building, including the warehouse space - the facility ships pharmaceuticals that need to be kept at a constant temperature.
Renovated Equipment	Packaged Gas/Electric Rooftop Units (5)
Cooling System	DX Cooling
Heating System	Natural Gas Furnace
Air Distribution System	VAV
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for Pre-1980 constructed buildings. Code used for compliance was assumed to be ASHRAE 90.1 2007. Units have integrated dry bulb economizers, as verified in field, and therefore were included in the model. It was assumed that the small RTU serves the office space.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	306,700	18,172	2,863,703,338	2,863,703,338
As Verified	301,980	18,172	2,847,598,037	2,847,598,037
Savings	4,720	-	16,105,301	16,105,301

Building ID	B-75
Overall Energy Compliance Index	0.97
Measure Energy Compliance Index	Lighting – 0.97; Mechanical – 1.00
Building Type	Retail
Code Compliance	ECCCNYS-2010
Alteration	Alteration Type 2
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	2,600
Location	Staten Island - Climate Zone 4A
Year Constructed	1960
Project Description	Single story pharmacy. Space is served by an existing gas-fired RTU with cooling and supplemental heating provided by a new ductless mini-split. The sales floor was also retrofitted with new efficient fixtures.
Renovated Equipment	Four new RTUs serving the sales floor. Lighting alteration
Cooling System	Air-cooled DX
Heating System	Natural Gas furnaces
Air Distribution System	Constant volume, single-zone RTUs
Major Modeling Assumptions	The shipping/receiving area was not modeled as part of the renovated area. The building vintage could not be confirmed, and therefore was assumed to be post-1980. All envelope properties were modeled per NREL document guidance for post-1980 constructed buildings. The tenant demising wall was modeled as an adiabatic surface. The auditor was not able to access the rooftop units, therefore all HVAC equipment properties have been modeled according to the model numbers in the mechanical schedule. Baseline and As Verified lighting power densities were modeled according to the lighting calculations. Weather file location used was Buffalo, NY.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	204,110	11,598	1,856,251,895	1,856,251,895
As Verified	176,660	11,989	1,801,688,652	1,801,688,652
Savings	27,450	(391)	54,563,243	54,563,243

Building ID	B-77
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Lighting – 0.99
Building Type	Office
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Alteration Type 2
Alteration Type	Lighting
Impacted Area (ft^2)	7,941
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1971
Project Description	Project installed new lighting fixtures in a small office building. Space types include corridors and atriums
Renovated Equipment	Lighting
Cooling System	Water Cooled Chiller
Heating System	Steam Boiler
Air Distribution System	VAV, perimeter reheat
Major Modeling Assumptions	Baseline and installed lighting power densities were calculated from inspection findings. These lighting power densities were incorporated into eQUEST using proto-typical building models to estimate compliance index including interactive effects.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	91,860	5,461	859,499,180	859,499,180
As Verified	86,590	5,539	849,307,203	849,307,203
Savings	5,270	(78)	10,191,978	10,191,978

Building ID	B-78
Overall Energy Compliance Index	0.98
Measure Energy Compliance Index	Mechanical – 0.98
Building Type	Mid-rise Multifamily/ Retail on first floor
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	197,119
Location	Bronx County - Climate Zone 4A
Year Constructed	1926
Project Description	Project is a 10 story mid-rise apartment/mixed use building. Retail space is served by a different system. Building underwent 5 boiler, replacement that serve the hot water supply for baseboards in the apartments.
Renovated Equipment	HW Gas Boiler (5 qty) - 85.1% combustion efficiency
Cooling System	PSZ - units for retail spaces. No cooling for apartments. Hot water baseboard heating only for apartments.
Heating System	Natural Draft Gas HW Boilers
Air Distribution System	Baseboard heat only for residences and PSZ for retail spaces
Major Modeling Assumptions	Modeled Unit heater with no fan power to represent no active conditioning for residences. Baseboard heating is through hot water loop connected to the new gas HW boilers. PSZ and DHW systems have been modeled with baseline efficiencies. Combustion efficiency of installed boilers is 85.1% therefore assumed thermal efficiency to be 83% to account for standby losses.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	1,206,100	35,923	7,707,682,054	3,592,300,000
As Verified	1,206,100	35,257	7,641,082,054	3,525,700,000
Savings	-	666	66,600,000	66,600,000

Building ID	B-79
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Mechanical – 0.99; DHW – 1.00
Building Type	High-rise Multifamily
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical and DHW
Impacted Area (ft^2)	171,496
Location	Kings County (Brooklyn) - Climate Zone 4A
Year Constructed	1979
Project Description	Multifamily residential building containing 132 apartments. 25 floors above grade, 1 floor below grade. Campus of three buildings, all tie to a central heating and DHW plant. Boilers provide space heating, as well as domestic hot water heating via steam to DHW heat exchangers.
Renovated Equipment	HHW + DHW Boiler (quantity of 3)
Cooling System	DX - Window AC units
Heating System	Steam Boiler, gas-fired - Baseboard Radiators
Air Distribution System	PTACs
Major Modeling Assumptions	All envelope properties are modeled per NREL document guidance for Pre-1980 constructed buildings. Basement level assumed to be unconditioned. DHW system was modeled as a separate hot water loop and gas heater with the installed boiler efficiency applied to both the Baseline and As Verified DHW heater.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	771,930	114,000	14,033,933,230	11,400,000,000
As Verified	771,930	112,900	13,923,933,230	11,290,000,000
Savings	-	1,100	110,000,000	110,000,000

Building ID	B-80
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Mechanical – 0.99
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	60,840
Location	Kings County (Brooklyn) - Climate Zone 4A
Year Constructed	1979
Project Description	Multifamily residential building containing 36 apartments. 7 floors above grade, 1 floor below grade. Campus of three buildings, all tie to a central heating.
Renovated Equipment	Steam Boilers
Cooling System	DX - Window AC units
Heating System	Steam Boiler, gas-fired - Baseboard Radiators
Air Distribution System	PTACs
Major Modeling Assumptions	All envelope properties are modeled per NREL document guidance for Pre-1980 constructed buildings. Basement level assumed to be unconditioned.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	271,500	39,525	4,878,896,010	3,952,500,000
As Verified	271,500	39,210	4,847,396,010	3,921,000,000
Savings	-	315	31,500,000	31,500,000

Building ID	B-81
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Mechanical – 0.99
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	60,840
Location	Kings County (Brooklyn) - Climate Zone 4A
Year Constructed	1979
Project Description	Multifamily residential building containing 36 apartments. 7 floors above grade, 1 floor below grade. Campus of three buildings, all tie to a central heating and DHW plant. Boilers provide space heating, as well as domestic hot water heating via steam to DHW heat exchangers.
Renovated Equipment	HHW (quantity of 3)
Cooling System	DX - Window AC units
Heating System	Steam Boiler, gas-fired - Baseboard Radiators
Air Distribution System	PTACs
Major Modeling Assumptions	All envelope properties are modeled per NREL document guidance for Pre-1980 constructed buildings. Basement level assumed to be unconditioned.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	271,500	39,609	4,887,296,010	3,960,900,000
As Verified	271,500	39,210	4,847,396,010	3,921,000,000
Savings	-	399	39,900,000	39,900,000

Building ID	B-82
Overall Energy Compliance Index	0.98
Measure Energy Compliance Index	Mechanical – 0.98
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	7,000
Location	Kings County (Brooklyn) - Climate Zone 4A
Year Constructed	1930
Project Description	Apartment building with 7 apartments, four stories (one apartment on first floor, 2 apartments per floor all others). Retail on first floor (~1000 sf) is not fed by boiler.
Renovated Equipment	Boiler
Cooling System	DX
Heating System	HW Boiler, gas-fired - Baseboard Radiators
Air Distribution System	PTACs
Major Modeling Assumptions	The building area was obtained by a Google search of property records, as it could not be confirmed by the auditor. All envelope properties are modeled per NREL document guidance for Pre-1980 constructed buildings. The south wall directly adjoins the neighboring building, as has been modeled as an adiabatic surface. The first floor retail space is outside of the HVAC alteration scope, and therefore has not been included in the model. Cooling was assumed to be PTACs.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	28,240	5,914	687,748,834	591,390,000
As Verified	28,240	5,799	676,208,834	579,850,000
Savings	-	115	11,540,000	11,540,000

Building ID	B-83
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Mechanical – 1.00
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1-2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	14,400
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1920
Project Description	Project is a 5 story mid-rise apartment building and a basement floor with apartments on each floor including the basement and common area on first floor. Building underwent replacement of HW gas boiler.
Renovated Equipment	HW Gas Boiler (1 qty) - 80% thermal efficiency
Cooling System	No cooling or air-distribution system except exhaust fans
Heating System	Gas HW Boiler
Air Distribution System	None. Baseboard heat only
Major Modeling Assumptions	Modeled Unit heater with no fan power to represent no active conditioning. Baseboard heating is provided through steam loop connected to the new gas HW boiler. One gas domestic hot water heater with an EF of 0.57 has been assumed to supply DHW for all the apartments. Domestic hot water heater is modeled identically in both cases.
Compliance Notes	HW design supply temperature shall be modeled as 180 deg F and a design return temperature of 130 deg F.
	HWST shall be reset based on OSAT. Exception A. Applies.
	19W/GPM
	HW Boiler efficiency and DHW heater efficiency should be at least 75% and EF - 0.57, respectively.
	Area < 120,000 ft^2, pump curve.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	44,660	8,788	1,031,176,172	878,790,000
As Verified	44,660	8,788	1,031,176,172	878,790,000
Savings	-	-	-	-

Building ID	B-85
Overall Energy Compliance Index	0.98
Measure Energy Compliance Index	Mechanical - 0.98
Building Type	Office MidRise
Code Compliance	ASHRAE 90.1-2007
Alteration	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	13,497
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1910
Project Description	The Project is an office building with 9 stories above ground and 1 below ground. The building is conditioned by a series of split DX systems and heating is provided through steam loop baseboards. The split units are water-cooled by a cooling tower. The cooling tower was replaced. Improvement measure only pertains to replacement of two self-contained cooling units for one floor. The units are connected to cooling tower condenser loop.
Renovated Equipment	2 - 10 ton DX cooling only units (EER 12.5)
Cooling System	Split DX with Water Cooled Condenser
Heating System	Natural Draft Gas Steam Boiler - baseboard heating
Air Distribution System	Standard VAV with Steam baseboard
Major Modeling Assumptions	Modeled each floor with 15 ft deep perimeter zones and 1 core zone. Assigned two systems for two halves of the floor and assigned condenser as water-cooled condenser. The baseline cooling tower and the as verified case is modeled to be axial type and have Variable speed fans.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	131,580	7,311	1,180,039,381	448,969,381
As Verified	129,590	7,311	1,173,249,223	442,179,223
Savings	1,990	-	6,790,159	6,790,159

Building ID	B-88
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Envelope – 1.00
Building Type	Office High-Rise
Code Compliance	ECCCNYS-2010
Alteration	Alteration Type 2
Alteration Type	Envelope
Impacted Area (ft^2)	11,250
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1980
Project Description	The Project is a 28-story office building. Alteration was roof replacement over the top two floors. Floors 27 and 28 are 5,625 sf each. COMCheck documentation states roof has continuous R-20 insulation above deck and an assembly U-value of 0.048
Renovated Equipment	Building Envelope - Roof
Cooling System	Water cooled Chiller
Heating System	Natural Draft Gas Steam Boiler - baseboard heating
Air Distribution System	Standard VAV with Steam baseboard
Major Modeling Assumptions	Modeled top two floors of building only, with the bottom floor as an adiabatic surface. Envelope properties other than roof modeled per NREL document guidance for post-1980 constructed buildings. Code used for compliance was ECCCNYS 2010 based on COMCheck documentation.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	131,830	6,197	1,069,542,416	1,069,542,416
As Verified	131,830	6,197	1,069,542,416	1,069,542,416
Savings	-	-	-	-

Building ID	B-89
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Envelope – 1.00
Building Type	Office Low-Rise
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Alteration Type 2
Alteration Type	Envelope
Impacted Area (ft^2)	6,000
Location	New York County (Manhattan)- Climate Zone 4A
Year Constructed	1980
Project Description	The Project is an office building with a storage area and an office area. The project underwent roof replacement in the 6000 SF.
Renovated Equipment	Tapered Insulation on 6” concrete deck. Based on the roofing contractor the average insulation board thickness is 3". The insulation is a Siplast Paratherm sheets with 1/2" Dens Deck board.
Cooling System	Water cooled Chiller
Heating System	Natural Draft Gas Steam Boiler - baseboard heating
Air Distribution System	Standard VAV with Steam baseboard for office/ Unit Heater for Storage
Major Modeling Assumptions	Modeled two zones: office and storage. Assigned one system per zone and assigned condenser as water-cooled condenser to the cooling system. Auto-sized the capacities for all equipment. Assigned baseline efficiencies for all equipment. The baseline roof insulation is based on ASHRAE 90.1-2007 while the as-installed roof is based on field verified data and discussion with the roofing contractor.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	53,160	2,584	439,789,362	439,789,362
As Verified	53,160	2,584	439,789,362	439,789,362
Savings	-	-	-	-

Building ID	B-93
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Mechanical – 1.00
Building Type	Prison (Multifamily High-rise)
Code Compliance	ASHRAE 90.1 - 2007
Alteration Type	Alteration Type 2
Alteration Type	Mechanical
Impacted Area (ft^2)	211,200
Location	Queens - Climate Zone 4A
Year Constructed	1993
Project Description	The project is one of several residential facilities for detainees of the NYC Department of Corrections on Rikers Island. It provides bed space for 500 prisoners in two separate structures; one is 6 stories and the other is 4 stories. Aside from the height the two buildings are identical, and served by the same central plant.
Renovated Equipment	Chiller Replacement (1 qty)
Cooling System	Hydronic- CHW loop
Heating System	HW Loop
Air Distribution System	Ducted - constant volume fan coils
Major Modeling Assumptions	All envelope properties are modeled per NREL document guidance for post-1980 constructed buildings. Because this is a closely guarded facility, the heating and air distribution systems were not able to be observed during the field visit. It is assumed that the spaces are served by hydronic fan coil units. Fans are constant volume. Fan powers were calculated per section G3.1.2.9 of ASHRAE 90.1 2007.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	1,633,700	134,400	19,014,413,118	5,574,413,118
As Verified	1,633,700	134,400	19,014,413,118	5,574,413,118
Savings	-	-	-	-

Building ID	B-94
Overall Energy Compliance Index	0.97
Measure Energy Compliance Index	Lighting – 0.97; Mechanical – 1.00
Building Type	Retail
Code Compliance	ASHRAE 90.1 - 2007
Alteration	Alteration Type 2
Alteration Type	Lighting and Mechanical
Impacted Area (ft^2)	1,647
Location	Queens - Climate Zone 4A
Year Constructed	1940
Project Description	Hair salon on the first floor of a multistory building. Alteration scope is heating system (one new unit heater serves entire space) as well as lighting retrofit.
Renovated Equipment	Gas-fired Unit Heater
Cooling System	N/A
Heating System	Unit Heater
Air Distribution System	N/A
Major Modeling Assumptions	All envelope properties were modeled per NREL document guidance for pre-1980 constructed buildings. The two tenant demising walls on the south and east sides as well as the roof were modeled as adiabatic surfaces. Modeled Baseline and As Verified/Permitted lighting power densities according to lighting calculations.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	15,440	845	137,203,442	137,203,442
As Verified	10,762	963	133,061,451	133,061,451
Savings	4,678	(118)	4,141,991	4,141,991

Building ID	B-95
Overall Energy Compliance Index	0.95
Measure Energy Compliance Index	Lighting – 1.00; Mechanical – 0.96; DHW – 0.98
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Alteration Type 2
Alteration Type	Lighting, Mechanical and DHW
Impacted Area (ft^2)	66,260
Location	Bronx County - Climate Zone 4A
Year Constructed	1928
Project Description	Multifamily residential building containing 60 apartments. Six floors above grade, one floor below grade. Boilers provide both DHW and space heating, and therefore operate year round.
Renovated Equipment	HHW + DHW Boiler (quantity of 2). Lighting replaced in common areas.
Cooling System	DX - Window AC units
Heating System	HW Boiler, gas-fired - Baseboard Radiators
Air Distribution System	PTACs
Major Modeling Assumptions	Building area and year of construction were obtained by a Google search of property records, as neither could be confirmed by the auditor. All envelope properties are modeled per NREL document guidance for pre-1980 constructed buildings. DHW system was modeled as a separate hot water loop and gas heater with the identical corresponding boiler efficiency applied in each case. Corridor and lobby LPDs in the Baseline and As Verified models were based on lighting savings calculations.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	375,990	35,432	4,826,130,519	4,826,130,519
As Verified	374,540	33,300	4,607,982,916	4,607,982,916
Savings	1,450	2,132	218,147,603	218,147,603

Building ID	B-96
Overall Energy Compliance Index	0.97
Measure Energy Compliance Index	Lighting – 1.01; HVAC – 0.97; DHW – 0.99
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1-2007
Alteration Type	Alteration Type 2
Alteration Type	Lighting, Mechanical and DHW
Impacted Area (ft^2)	47,797
Location	Bronx County - Climate Zone 4A
Year Constructed	1925
Project Description	Multifamily residential building containing 49 apartments. Six floors above grade, one floor below grade. Boilers provide both DHW and space heating, and therefore operate year round.
Renovated Equipment	HHW + DHW Boiler (quantity of 3). Lighting in common areas was also replaced.
Cooling System	DX - Window AC units
Heating System	HW Boiler, gas-fired - Baseboard Radiators
Air Distribution System	PTACs
Major Modeling Assumptions	Building area and year of construction were obtained by a Google search of property records, as neither could be confirmed by the auditor. All envelope properties are modeled per NREL document guidance for pre-1980 constructed buildings. DHW system was modeled as a separate hot water loop and gas heater with the identical corresponding boiler efficiency applied in each case. Common Area lighting in Baseline and As Verified cases modeled based on LPD calculations. Installed LPD was found to exceed allowance.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	290,310	26,528	3,643,378,363	3,643,378,363
As Verified	298,250	25,218	3,539,470,755	3,539,470,755
Savings	(7,940)	1,310	103,907,608	103,907,608

Building ID	B_97
Overall Energy Compliance Index	0.83
Measure Energy Compliance Index	Mechanical – 0.88; DHW – 0.95
Building Type	Mid-rise Multifamily
Code Compliance	ASHRAE 90.1- 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical and DHW
Impacted Area (ft^2)	42,740 sq. ft.
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1940
Project Description	Project is four, five-story mid-rise apartment building with retail on first floor and apartments on each floor above. Building underwent replacement of (2) steam gas boilers for space heating and (3) DHW tanks.
Renovated Equipment	Steam Gas Boiler (1 qty) - 92% thermal efficiency, Steam Gas Boiler (1 qty) - 95% thermal efficiency, DHW heater (3 qty)- 119 gallon, 98% efficiency
Cooling System	No cooling
Heating System	Gas Steam Boiler
Air Distribution System	Baseboard heat only
Major Modeling Assumptions	Project underwent replacement of two Steam Boilers for heating and three hot water heaters for DHW. Baseboard heating is provided through steam loop connected to the new gas steam boiler. Three gas domestic hot water heaters supply DHW for all the apartments. All envelope properties have been modeled per NREL document guidance per the building's vintage.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	130,790	22,131	2,659,373,791	2,213,100,000
As Verified	130,790	18,406	2,286,873,791	1,840,600,000
Savings	-	3,725	372,500,000	372,500,000

Building ID	B-98
Overall Energy Compliance Index	0.94
Measure Energy Compliance Index	Mechanical – 0.98; DHW – 0.96
Building Type	Mid-rise Multifamily/ Retail on first floor
Code Compliance	ASHRAE 90.1- 2007
Alteration	Alteration Type 2
Alteration Type	Mechanical and DHW
Impacted Area (ft^2)	19,500
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1930
Project Description	Project is a four (above grade) story mid-rise apartment/mixed use building. Retail on first floor. Building underwent HW boiler and DHW heater replacement.
Renovated Equipment	Gas Boiler (2 qty) - 83.5% thermal efficiency. DHW Heater (1qty)- 91.6% thermal efficiency.
Cooling System	Packaged rooftop AC units for retail spaces. No cooling for apartments.
Heating System	Natural Draft Gas HW Boiler
Air Distribution System	Baseboard heat for all and packaged AC for retail spaces
Major Modeling Assumptions	Modeled Unit heater with no fan power to represent no active conditioning for residences. Baseboard heating is through hot water loop connected to the new two gas HW boiler. A new domestic hot water heater has been installed that supplies all DHW for the apartments and retail spaces.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	96,270	12,241	1,552,586,718	1,224,100,000
As Verified	96,270	11,463	1,474,786,718	1,146,300,000
Savings	-	778	77,800,000	77,800,000

Building ID	B-99
Overall Energy Compliance Index	0.91
Measure Energy Compliance Index	DHW – 0.91
Building Type	Mid-Rise Multifamily Campus
Code Compliance	ASHRAE 90.1- 2007
Alteration	Alteration Type 2
Alteration Type	DHW
Impacted Area (ft^2)	792,650
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1980
Project Description	Project is a multifamily campus with two 13 story mid-rise apartment buildings and one three-story apartment building. All three buildings share two new natural gas domestic hot water heaters. Includes four storage tanks.
Renovated Equipment	238 gallon DHW Heaters (2 qty) - 87% thermal efficiency
Cooling System	No cooling
Heating System	Electric Baseboard heating
Air Distribution System	Baseboard heat only - no fan
Major Modeling Assumptions	Modeled Unit heater with no fan power to represent no active conditioning. Two gas domestic hot water heater has been modeled that supplies DHW for all the apartments. All envelope properties have been modeled per NREL document guidance per the building's vintage.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	5,570,000	37,292	22,734,819,800	3,729,200,000
As Verified	5,570,000	34,010	22,406,619,800	3,401,000,000
Savings	-	3,282	328,200,000	328,200,000

Building ID	B-100
Overall Energy Compliance Index	0.91
Measure Energy Compliance Index	DHW – 0.91
Building Type	Mid-Rise Multifamily Campus
Code Compliance	ASHRAE 90.1- 2007
Alteration	Alteration Type 2
Alteration Type	DHW
Impacted Area (ft^2)	792,650
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1980
Project Description	Project is a multifamily campus with two 13 story mid-rise apartment buildings and one three-story apartment building. All three buildings share one new natural gas domestic hot water heaters.
Renovated Equipment	238 gallon DHW Heaters (1 qty) - 87% thermal efficiency
Cooling System	No cooling
Heating System	Electric Baseboard heating
Air Distribution System	Baseboard heat only - no fan
Major Modeling Assumptions	Modeled Unit heater with no fan power to represent no active conditioning. One gas domestic hot water heater has been modeled that supplies DHW for all the apartments. All envelope properties have been modeled per NREL document guidance per the building's vintage.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	5,570,000	36,950	22,700,619,800	3,695,000,000
As Verified	5,570,000	33,698	22,375,419,800	3,369,800,000
Savings	-	3,252	325,200,000	325,200,000

Building ID	B-101
Overall Energy Compliance Index	1.00
Measure Energy Compliance Index	Lighting – 1.00
Building Type	Office
Code Compliance	ASHRAE 90.1- 2007
Alteration	Alteration Type 2
Alteration Type	Lighting
Impacted Area (ft^2)	5,731
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1971
Project Description	Project installed new lighting fixtures in a small office building. Space types include open office, conference rooms, private offices and corridors.
Renovated Equipment	Lighting
Cooling System	Water Cooled Chiller
Heating System	Steam Boiler
Air Distribution System	VAV, perimeter reheat
Major Modeling Assumptions	Baseline and installed lighting power densities were calculated from inspection findings. These lighting power densities were incorporated into eQUEST using proto-typical building models to estimate compliance index including interactive effects.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	71,510	4,237	667,712,131	667,712,131
As Verified	71,510	4,237	667,712,131	667,712,131
Savings	-	-	-	-

Building ID	B-102
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Lighting – 0.99
Building Type	Office
Code Compliance	ASHRAE 90.1- 2007
Alteration	Alteration Type 2
Alteration Type	Lighting
Impacted Area (ft^2)	9,443
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1971
Project Description	Project installed new lighting fixtures in a small office building. Space types include open office space.
Renovated Equipment	Lighting
Cooling System	Water Cooled Chiller
Heating System	Steam Boiler
Air Distribution System	VAV, perimeter reheat
Major Modeling Assumptions	Baseline and installed lighting power densities were calculated from inspection findings. These lighting power densities were incorporated into eQUEST using proto-typical building models to estimate compliance index including interactive effects.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	105,860	6,346	995,759,140	995,759,140
As Verified	102,850	6,390	989,948,599	989,948,599
Savings	3,010	(45)	5,810,541	5,810,541

Building ID	B-103
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Lighting – 0.99
Building Type	Office
Code Compliance	ASHRAE 90.1- 2007
Alteration	Alteration Type 2
Alteration Type	Lighting
Impacted Area (ft^2)	7,981
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1971
Project Description	Project installed new lighting fixtures in a small office building.
Renovated Equipment	Lighting
Cooling System	Water Cooled Chiller
Heating System	Steam Boiler
Air Distribution System	VAV, perimeter reheat
Major Modeling Assumptions	Baseline and installed lighting power densities were calculated from inspection findings. These lighting power densities were incorporated into eQUEST using proto-typical building models to estimate compliance index including interactive effects.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	84,570	5,035	792,094,680	792,094,680
As Verified	80,200	5,101	783,773,628	783,773,628
Savings	4,370	(66)	8,321,052	8,321,052

Building ID	B-104
Overall Energy Compliance Index	0.99
Measure Energy Compliance Index	Lighting – 0.99
Building Type	Office
Code Compliance	ASHRAE 90.1- 2007
Alteration	Alteration Type 2
Alteration Type	Lighting
Impacted Area (ft^2)	3,353
Location	New York County (Manhattan) - Climate Zone 4A
Year Constructed	1971
Project Description	Project installed new lighting fixtures in a small office building.
Renovated Equipment	Lighting
Cooling System	Water Cooled Chiller
Heating System	Steam Boiler
Air Distribution System	VAV, perimeter reheat
Major Modeling Assumptions	Baseline and installed lighting power densities were calculated from inspection findings. These lighting power densities were incorporated into eQUEST using proto-typical building models to estimate compliance index including interactive effects.

Analysis Results Summary	**Electric (kWh/yr)**	**Gas (therms/yr)**	**Total Energy (Btu/yr)**	**Total Energy for Impacts (Btu/yr)**
Code Baseline	56,650	3,391	532,427,731	532,427,731
As Verified	54,490	3,420	527,937,509	527,937,509
Savings	2,160	(29)	4,490,222	4,490,222

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CODE-COM-15nyeccs-r-1-v1 5/15