Research and Development of the Energy Point System

Final Report

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Contents

Executive Summary

This report outlines the concept and development methodology of the Energy Point System (EPS) intended for consideration as an alternative path of compliance with the Energy Conservation Construction Code of New York State (ECCC NYS) for retrofit projects. The EPS allows performance trade-offs between systems included in the scope of the retrofit while avoiding the expense of energy modeling, which is often not justified for smaller retrofit projects.

EPS assigns a pair of energy points to each component included in the scope of the retrofit. The first value, EP_{PROP} (proposed retrofit Energy Points), is calculated based on the actual properties of the specified component such as efficiency of the new heating or cooling system, U-value of retrofitted roof, etc. The second value, EP_{CODE} (code Energy Points), is calculated based on the component's minimum efficiency requirements in ECCC NYS – 2010, such as minimum heating efficiency or roof thermal properties, based on the applicable mandatory and prescriptive requirements of the code. EPS compliance is achieved when the sum of EP_{PROP} for all retrofitted components included in the building permit is no less than the sum of EP_{CODE} for the same components. EPS may also be used to evaluate the performance of existing buildings on a 0-100 scale, by calculating the ratio of the total proposed energy points to the total code energy points for all systems in the building.

Building components included in this version of EPS are as follows: roof and above grade wall insulation, fenestration, air leakage, lighting, and efficiencies of certain heating, cooling, and service water heating (SWH) systems.

The DOE benchmark models for midsize office and midrise multifamily buildings in climate zones 4a, 5a and 6a were used as the basis for EPS development, for a total of 6 permutations. For each permutation, parametric models were created by modifying the properties of each of the eight components included in the EPS scope by set increments. The results of the parametric simulations were used to develop regression equations estimating the energy impact of each parameter on the total modeled energy cost, which determined its Energy Points.

The modeling in support of EPS development was done using Energy Plus V7.1. For each of the eight components included in the EPS scope and in each model permutation, five parametric models were created, to study the sensitivity of energy cost to the efficiency parameter of interest, for a total of 246 simulation runs including the original unmodified model. Such a massive modeling effort would have been impossible without automation, which was essential for both productivity and avoiding data entry mistakes. Energy Plus input files were generated using parametric features of Energy Plus. Additionally, a VBA script was developed to automatically pull electricity and gas consumption in kBtu and cost from Energy Plus comma-separated output files into an Excel spreadsheet with pre-defined savings calculations. The full deck of models was executed and analyzed multiple times during the EPS development, due to changes in parameter ranges and baseline model configurations.

This report includes the proposed new section of the ECCC NYS that incorporates the Energy Points System, as well as recommendations for future EPS enhancements and testing.

Introduction

The EPS is a quantitative tool based on data generated from energy modeling. Similar to ECCC NYS-2010 Section 506, Total Building Performance, and ASHRAE 90.1 Section 11, Energy Cost Budget Method, the EPS will allow performance trade-offs between systems included in the scope of a retrofit, while avoiding the expense of energy modeling which is often not justified for smaller retrofit projects. It is also similar in concept to Chapter 13, Performance Compliance Methods, of the 2010 Existing Building Code of New York State. The EPS may be used for the following:

- To establish a quantified measure (e.g. on 1-100 scale) of an existing building's energy performance using the ECCCNYS-2010 as the benchmark of 100% compliance;
- Provide a methodology to quantify the value added by distinct energy conservation measures;
- Provide a simple quantifiable trade-off approach for energy conservation measures included in the ECCC NYS plus other agreed-upon criteria such as construction quality.

A long term goal of the EPS is its introduction into the ECCC NYS as an alternative code path for retrofit projects. An additional short term benefit is the tool's quantifiable means of assessing unimproved, existing buildings' performance to assist with ongoing statewide compliance assessment work. Existing small and mid-size commercial buildings in New York are anticipated to benefit most from this approach.

Overview of the Relevant Prior Efforts

Department of Energy - Building Energy Codes Program Protocol

Department of Energy's (DOE's) Building Energy Codes Program (BECP) developed a protocol for rating building's energy code compliance to help states measure compliance with building energy codes [1], [2], [3]. The protocol may be applied to both new construction and renovation projects. Renovation projects are defined as any work on or in existing buildings where all or part of the work being performed has to meet code, and for which a permit was issued, including additions, alterations, and repairs. The BECP protocol assigns a compliance rating of 0–100% to a building based on the proportion of code requirements that it meets. The maximum score that a building can receive is capped at 100%, so that buildings that exceed code cannot compensate for buildings not meeting code in the overall state compliance evaluation. To capture the relative importance of different code requirements, the protocol clustered them into tiers based on their perceived impact on energy consumption. Tier 1 requirements received the maximum of 3 points, Tier 2 items received 2 points, and Tier 3 items received 1 point. There is an additional grading scale for Tier 1 requirements that are subjective in nature, such as Section 303.2 which requires that roof insulation is installed per manufacturer's instructions. The protocol allows marking such requirements as compliant, but then further qualifying installation quality as Good, Fair, or Poor. Good rating receives all 3 points, Fair rating receives 2 out of the 3 points, and a Poor rating receives 1 point. The building's compliance percentage is determined by summing the points received, and dividing by the possible points if all applicable requirements were met.

The New York Energy Code Compliance Study completed in January 2012 [4] applied the BECP protocol to 26 new commercial buildings in the state. The study's authors felt that the BEPS protocol, which combines compliance with both energy performance and administrative code requirements in a single score, allowed buildings to score relatively high if the documentation requirements were met, even if many components performed below code. This led the authors to conclude that the BECP protocol put insufficient emphasis on areas with a high impact on energy performance. Only 36% of buildings in the evaluated sample were found to pass COMcheck, compared to 85% overall compliance based on the BEPC protocol. It was also observed that non-compliant items with a relatively small effect on the overall building performance often resulted in buildings failing COMcheck, and had an exaggerated negative impact on the BECP score. For example, one building in the sample failed COMcheck because the smallest air handlers, which accounted for 1% of the project's cooling load, had efficiency ratings 12% below code. On the same project the largest air handlers, which accounted for 43% of the cooling load, were 47% more efficient than code required.

ASHRAE 90.1 Appendix G

Perhaps the most widely used method for rating performance of the design relative to code is described in ANSI/ASHRAE/IESNA Standard 90.1 (Standard 90.1) Appendix G. Introduced in the 2004 version of the Standard, the protocol involves modeling the building as designed, and comparing the energy cost projected by this model to the energy cost of the model configured as described in Appendix G, and with all systems and components minimally meeting applicable mandatory and prescriptive code requirements. The protocol is a modification of the Energy Cost Budget (ECB) Method in Section 11, and is intended for quantifying performance of designs that substantially exceed the requirements of Standard 90.1. It may be useful for evaluating the performance of all proposed designs, including alterations and additions to existing buildings, except designs with no mechanical systems.

Advanced Buildings Core Performance Guide

Advanced Buildings Core Performance Guide [6], developed by the New Buildings Institute (NBI), used a different methodology for evaluating building efficiency. The guide prescribes a set of discrete design strategies and building features which, when applied as a package, result in energy savings of at least 16% to 26% (depending on the climate) beyond the performance of a building that meets the prescriptive requirements of Standard 90.1 2007. The prescriptive requirements of the guide are based on the results of an extensive energy modeling protocol that was used to identify strategies that consistently lead to energy savings across different climates and building types. The protocol analyzed three major building prototypes, four HVAC system permutations for each prototype, in 16 US cities. A baseline building meeting the applicable requirements of the code was defined for each permutation of the above criteria, including building type, system type, and climate. The batch protocol in eQUEST was used to evaluate 14-16 design alternatives for each permutation, and to develop an ordered ranking of the energy efficiency measures modeled for each prototype. The results of this analysis were then compared across prototypes, systems and climates to determine which measures were the most consistently significant across these variations. The prescriptive requirements and analysis supporting the program was based on commercial projects ranging from 10,000 to 70,000 square feet. The NBI's

Guide suggests that in larger buildings HVAC system complexity may offer additional energy savings opportunities, but that even much larger projects with simple mechanical systems can benefit from the Core Performance Guide's savings strategies. For example, the building envelope and lighting system energy savings strategies in the Core Performance Guide are scalable to projects of any size.

NREL Benchmark Models

NBI’s analysis utilized benchmark models created by the National Renewable Energy Laboratory (NREL) in an effort funded by U.S. Department of Energy to develop Commercial Reference Building Models of the National Building Stock [5]. The benchmark models represent realistic building characteristics and construction practices for fifteen commercial building types and one multifamily building. Parameters of the models were determined by consensus between DOE, NREL, PNNL, and LBNL, and represent approximately two-thirds of the commercial building stock. Throughout the development of the reference buildings, the DOE Building Energy Codes Program, the ASHRAE simulation working group, and Standard 90.1 subcommittees provided in-depth review of the underlying assumptions. Three versions of the reference building models for each building type were developed: new construction, post-1980 construction, and pre-1980 construction. All have the same building form and area and the same operation schedules. The differences are reflected in the insulation values, lighting levels, and HVAC equipment types and efficiencies. The new construction models comply with the minimum requirements of Standard 90.1-2004, the post-1980 models meet the minimum requirements of Standard 90.1-1989, and the pre-1980 models are based on requirements from previous standards and other studies of typical construction practices. The benchmark models were developed for the following building types: small, medium and large office building, primary and secondary school, stand-alone retail, strip mall, supermarket, quick and full service restaurant, small and large hotel, hospital, outpatient healthcare, warehouse, and mid-rise apartment building. In order to expand the modeling results to represent all buildings in a region or the whole country, weighting factors have to be used that characterize the number of buildings that are similar to each reference building type in each location. National data from the 2003 CBECS (EIA 2005) was used to determine the appropriate average mix of representative buildings. The report includes the weighting factors for new buildings. Weighting factors for the pre-1980 and post-1980 reference buildings were not developed, because adequate data about the existing building stock was not identified.

The benchmark models are intended to represent new and existing buildings for use in DOE commercial buildings research, and to provide a common starting point to measure the progress toward DOE energy efficiency goals for commercial buildings. DOE’s Building Energy Code Program and PNNL use these models for analytical support in the development of new versions of Standard 90.1. The benchmark models were also used by the DOE Building Energy Codes Program to compare Standard 90.1-2007 with the commercial code in each state as of June 2009 [7], to evaluate energy and cost impact of increasing stringency of the state codes as required by the American Recovery and Reinvestment Act. The analysis used benchmark models for a medium office building, a mid-rise apartment building, and a non-refrigerated warehouse representing the Standard 90.1 nonresidential, residential, and semi-heated requirements respectively. Locations for the analysis were selected based on a sample representative of each climate zone in the state where TMY2 weather files were available. In the New York State study, the New York City TMY2 file was used as a proxy for climate zone 4a, the Albany TMY2 file was used as proxy for climate zone 5a, and the Binghamton TMY2 file was used as a proxy for climate zone 6a [11].

Rationale

Prescriptive Path Shortcomings

The prescriptive path to code compliance requires all projects, including retrofits, to meet all applicable mandatory and prescriptive code requirements. It offers limited flexibility, and due to historically lax energy code enforcement, energy code requirements have often been ignored on retrofit projects. When designers are unable to meet a particular code requirement, because of the owner's requirements or cost constraints, the only allowed recourse is to perform energy modeling following the performance approach. However, energy modeling requires significant added soft costs, and for smaller retrofit projects with limited budgets, is often not feasible. Such projects would benefit from an approach which incorporated some of the flexibility of the performance based approach, while avoiding its cost. The proposed EPS fills that role.

BECP Shortcomings

The scoring methodology of the BECP protocol does not attempt to realistically capture the relative impact of different code requirements on building energy efficiency. This shortcoming not only impacts scores for individual buildings, but also skews code compliance and enforcement priorities. For example, a survey performed as part of the New York Compliance Study found that the compliance of envelope/fenestration was most often checked by code officials, followed by pipe insulation, infiltration and water heaters. HVAC load calculations were checked least often, followed by lighting power density, lighting control, and mechanical systems. However, in most commercial buildings, the performance of mechanical and lighting systems has a much higher impact on energy consumption than envelope or water heating. A well-known management principal suggests that whatever gets measured gets optimized. A scoring system that emphasizes requirements with a high impact on energy consumption will influence the behavior of both design professionals and code officials, shifting their focus to areas with high energy implications.

The BECP Protocol points to the challenges associated with creating a nationwide energy-impact weighting given the wide variation in local building practices and in the factors that have a high energy impact in different climate zones. However, weighting is an inevitable and integral part of any evaluation method that is based on a 0-100% scale. Weighting factors are already implicitly part of the BECP scoring, reflected in the structure of the BECP checklist and scoring rules, except they are currently largely based on the editorial structure of the energy code, with points awarded for compliance with individual sub-sections. This weighting can be significantly enhanced by using energy analyses similar to what was done by NBI in the development of the Core Performance Guide. DOE Commercial Reference Building Models of the National Building Stock were specifically developed to provide a common starting point to measure progress toward DOE energy efficiency goals for commercial buildings. A scoring system based on the typical energy impact of key code requirements derived from parametric models that use the benchmark models as the basis will represent a significant improvement over the current BECP code compliance evaluation approach.

Full Performance Based Approach Shortcomings

Compliance with the energy code can be demonstrated by following either the prescriptive or performance path. The prescriptive path requires that all mandatory and prescriptive requirements applicable to the project are met without exception. The performance path requires that all the mandatory provisions are met, and allows trade-offs between prescriptive requirements. For example, if the lighting in a project exceeds the prescriptive lighting power allowance, the project may still show compliance with the code by making up for the penalty associated with the inefficient lighting by specifying mechanical systems with efficiencies that exceeds the minimum required by code. The relative value of the traded features is established based on energy modeling following 90.1 Section 11 or IECC Section 506.

Simulating building energy consumption following protocols such as described in Standard 90.1 Appendix G is admittedly the most accurate way to rate building performance relative to code. However, energy modeling requires significant effort, with substantially higher costs per square foot of building area for smaller projects. According to the 2004 FEMP Guide for Federal Project Managers on Procurement of Architectural and Engineering Services for Sustainable Buildings, energy modeling fees vary from $0.05/SF - $0.25/SF for large, simple buildings, to $0.25/SF – 0.45 $/SF for small, complicated buildings. Energy modeling is a recognized design optimization tool. However, smaller projects typically offer fewer opportunities for energy savings, and the magnitude of any achievable savings is limited by project size. Performance-based incentive programs in New York have observed that energy modeling is typically not cost-effective for smaller projects.

There are also special challenges in applying modeling-based protocols to renovation projects. In order to meaningfully evaluate the trade-off value of systems included in a given retrofit, the model must reflect existing conditions that remain un-altered. For example, a project undergoing a lighting and roof insulation may have to use energy modeling to document code compliance if the specified lighting exceeds the prescriptive lighting allowance. However, the existing HVAC system and controls must be simulated in order to properly capture the interaction between different end uses involved, and to evaluate the true cost effectiveness of the alternatives. However, performance data for the existing components is typically not collected. In this setting, the default trade-off factors developed based on DOE benchmark models in the controlled framework of a research project may produce comparable or even better results on the relative impact of retrofit options, while reducing documentation efforts and simplifying compliance verification.

Existing Code Framework

To preserve internal consistency, it is important that new code requirements fit within the existing code framework. The proposed EPS is directly related to Section 4.2.1.3 of Standard 90.1. According to Exception (b) to the section, "…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*" (underlined added). The proposed EPS is just such a calculation method.

Using default trade-off factors, such as those in the EPS, in lieu of detailed calculations is a simplification that inevitably leads to a loss of accuracy. However, such simplifications are already part of code. For example, Standard 90.1 allows projects to calculate the total lighting power allowance as a sum of allowances for different types of spaces found in the building (space-by-space method in Table 9.6.1), or as an overall building-level allowance based on the building type (building area method in Table 9.5.1). This implicitly allows direct trade-offs between lighting in different types of spaces based on an assumed fraction of building area associated with each space type, and with no regard to differences in lighting runtime across space types which greatly affect the energy consumption of the lighting system. For example, with the building area method, reduced installed lighting wattage in conference/meeting rooms, where lighting runtime is likely relatively short due to mandatory occupancy sensors required by code, may make up for increased lighting power density in corridors, where lighting is often on 24/7. The energy Conservation Construction Code of New York State - 2010 does not include space-by-space method, underlining that simpler rules are given preference over accuracy of energy impact (particularly for retrofit projects, where only one or several space types may be part of a project).

Rationale for an Energy Points System

The proposed EPS aims at allowing some of the flexibility of performance based compliance while avoiding the cost of energy modeling for projects where it's not an effort-effective design tool. EPS preserves the benefits of the scaled approach chosen by BECP for compliance evaluation, enhancing the implicit weighting factors of the BECP protocol to emphasize compliance and enforcement priorities. The EPS allows flexibility for retrofit projects to achieve compliance with code in a cost effective manner, and is consistent with the existing compliance mechanism allowed by Standard 90.1 Section 4.2.1.3.

EPS Scope

NBI's Core Performance Guide states that a simplified approach is not effective or adequate for projects involving large, complex HVAC systems, but that even projects larger than 70,000 square feet, but with simple mechanical systems, may benefit from it. The Guide further states that building envelope and lighting system energy savings strategies are scalable to projects of any size. Since the EPS is intended for retrofit projects, its applicability was established not based on total building size, but rather on the scope of the retrofit included in the building permit. The following criteria were used to identify systems and parameters to be included in the scope of the EPS:

a. The energy impact of the system or parameter can be quantified by energy modeling or field studies
b. The systems and parameters are frequently included in retrofits

c. The systems and parameters are frequently above or below minimum code requirements, making the trade-off approach useful for documenting overall compliance of the retrofit.

The New York Code Evaluation Study observed significant variations in the efficiencies of mechanical equipment, with some systems far exceeding the minimum efficiency requirements of the code, while others falling below these requirements in spite of their mandatory nature. It also noted that control strategies such as DHW recirculation control, demand control ventilation, or energy recovery were not typically implemented in accordance with code. Mechanical systems, including distribution fans serving commercial buildings, often appeared to be oversized. Load calculations, though required by code, were not typically submitted. Small buildings had the lowest compliance with building envelope requirements, failing to install slab on grade insulation, and not meeting exterior wall and roof insulation requirements. Window and door ratings were underspecified (i.e. not included in the project documents) and difficult to verify in the field due to a lack of ratings on installed components. Envelopes were not generally air sealed sufficiently, as indicated by the lack of continuous insulation and observed limited use of foam for air sealing. Lighting power density in medium buildings ranged from about 130% less efficient than code to 60% better than code. Except for the non-compliant buildings, LPDs were generally found to be significantly better than code. In projects that required automatic lighting control, these were not typically implemented in accordance with code.

Based on the above considerations, the inistial scope of the EPS was set to include the following:

- Changes to roof and exterior wall insulation
- Fenestration retrofit
- Envelope air-leakage
- Lighting retrofit
- Installation of unitary packaged or split-system air-cooled air conditioners, fuel-fired furnaces, and space heating boilers
- Service water heating

Retrofit projects that include systems that are not covered by the EPS in addition to systems included in the EPS scope may use EPS to document compliance of the covered components; components outside of the EPS scope must independently meet applicable requirements of the energy code, and thus do not participate in EPS trade-offs.

For example, consider a project that includes the replacement of lighting fixtures, roof insulation, and a new cooling tower on the chilled water system. Cooling towers are not included in the scope of the EPS outlined above, and thus must meet all applicable mandatory and prescriptive requirements of ECCC NYS Chapter 5. Compliance of lighting and roof retrofits, however, may be documented using the EPS to allow trade-offs between these systems. For example, the lighting design may exceed the prescriptive allowance from Table 505.5.2, as long as the associated penalty is negated by insulating the roof beyond the minimum required in Table 505.2.

General Concept

The EPS assigns a pair of energy points to each component included in the scope of a retrofit on a single building permit. The first value, EP_{PROP} (proposed retrofit Energy Points) is calculated based on the actual properties of the specified component such as efficiency of the new heating or cooling system, total U-value of roof after insulation is added as part of the retrofit, etc. The second value, EP_{CODE} (code Energy Points), is calculated based on the component's minimum efficiency requirements in the reference standard, such as minimum heating efficiency or roof insulation required by the applicable mandatory and prescriptive requirements of the reference standard. For the purpose of this study, ECCC NYS -2010 was used as the reference standard.

EP_{PROP} represents energy cost savings from upgrading the component from the existing condition to the post-retrofit conditions. EP_{CODE} represents energy cost savings from upgrading the component from the existing condition to the conditions prescribed by the reference standard. *Energy cost* was selected as the unit of comparison for consistency with Standard 90.1 Section 11, Appendix G, and ECCC NYS Section 506.

Since the existing conditions prior to retrofit are often not known or documented for projects applying for permit, the parameters of the DOE post-1980 benchmark models were used as an approximation. These models are based on the minimum requirements of Standard 90.1-1989, and were assumed to be representative of typical current construction of existing buildings. Pre-1980 models were not used because many of the original components in older buildings have likely been retrofitted since they were constructed, and are thus not representative of current conditions.

EP_{PROP} and EP_{CODE} of each system are proportional to the scale of the system retrofit. The nature of the selected scale variable differs depending on the type of retrofitted system. For example, Energy Points for a heating system retrofit are proportional to the system's heating capacity; Energy Points for roof retrofits are proportional to the area of the insulated roof.

EPS compliance is achieved if the sum of EP_{PROP} for all retrofitted components included in the building permit is no less than the sum of EP_{CODE} for these same components. The project's compliance may also be calculated on a 0-100 scale as the ratio of the total proposed Energy Points to the total code Energy Points.

Even though energy points are a proxy for cost savings, they are not predictive of the actual savings that may be realized due to retrofit. The reasons for this include, but are not limited to, using default existing condition (which are typically different from the actual pre-retrofit conditions), default building configuration and operating schedule, and default location within each climate zone.

Methodology

A modified version of the DOE benchmark model for medium office buildings and midrise multifamily buildings in climate zone 4a were used as the basis for EPS development. Climate specific weather data for the three different climate zones in New York (4a, 5a, and 6a) were used, for a total of 6 permutations including two building types in three climate zones. The key parameters of the benchmark models used in the study are included in Appendix A of this report. 3D views of the multifamily and office prototypes are shown in Figures 1 & 2.

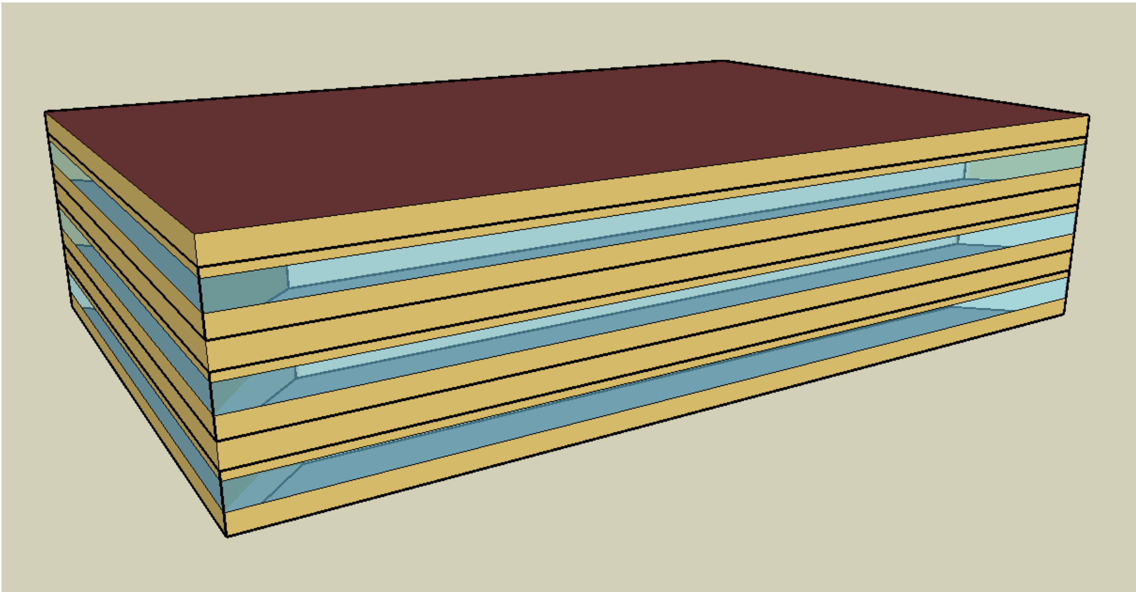

Figure 1: DOE Commercial Building Benchmark - Midrise Office Building

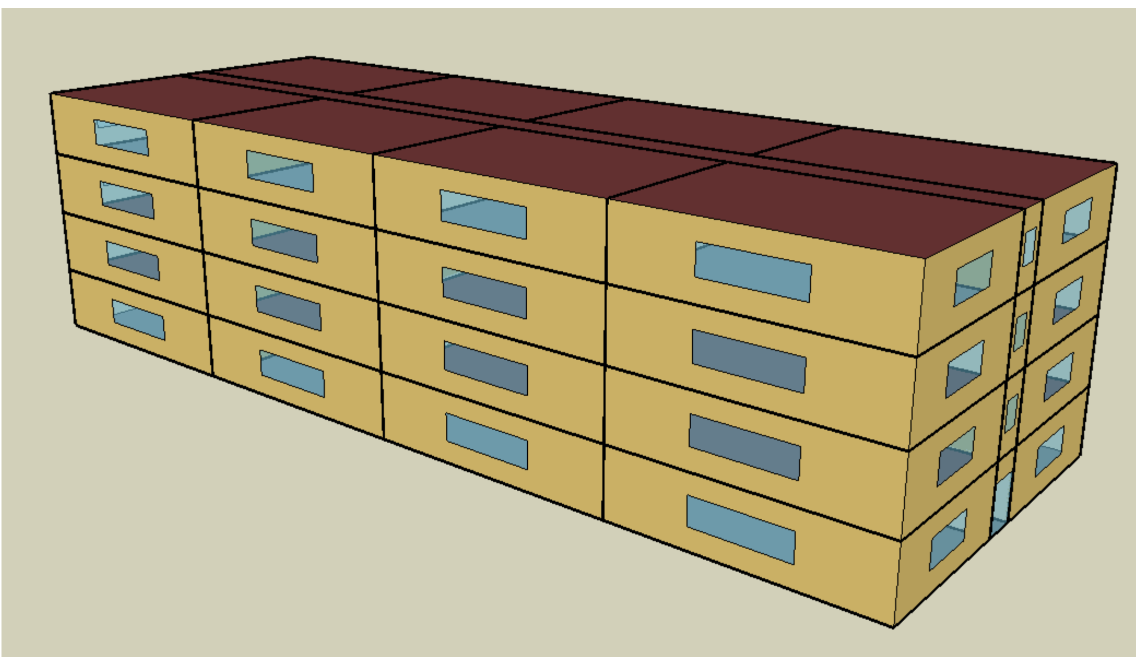

Figure 2: DOE Commercial Building Benchmark – Midrise Apartment

For each permutation, parametric models were created modifying each parameter included in the EPS scope by set increments. The results of these parametric simulations were used to develop regression equations estimating the impact of each parameter on the project's total energy cost, determining its Energy Points (representing the component's trade-off value).

As described above, the building components identified for initial inclusion into the EPS are roof and above grade wall insulation, fenestration, air leakage, lighting, and heating, cooling, and service water heating (SWH) efficiency. For each component, the key efficiency parameter was identified. Overall U-value was used as the efficiency parameter for roof, above grade wall, and fenestration; lighting power density was used for lighting systems; efficiency was used for heating, cooling and SWH systems; and leakage at 75Pa was used for infiltration. The impact of the efficiency parameters on the project's total energy cost was investigated by running parametric simulations in which each efficiency parameter was assumed to change within a certain range. This range was set between the parameter value in the post-1980 benchmark model (using a weighted average of zones 4a, 5a, and 6a by population, shown in the Benchmark Model Input column in Tables 1 and 2) and the value recommended by the NBI's Cores Performance Guide (Best Property column in Tables 1 and 2). Four additional points were defined within this range for each efficiency parameter, including the requirement of ECCC NYS 2010 (Code Requirement column in Tables 1 and 2).

Table 1: Traded Parameters and Property Ranges, Mid-rise Office Building

Parameter Name	Parameter Subtype	Benchmark Model Value, Climate Zone 4A/5A/6A/Weighted Average	Code Requirement, Climate Zone 4A/5A/6A	Best Property, Climate Zone 4A/5A/6A
Roof Insulation	Insulated entirely above deck	R-17.2 (U-0.058)/R-19.2(U-0.052/R-22.7(U-0.044)/R-18.3(U-0.055)	R-20ci (U-0.048)	R-30ci (U-0.033)
	Attic and other	NA	R-38	R-38/R-38/R-49
Above Grade Wall	Mass	NA	R-9.5ci /R-11.4ci/ R-13.3ci	R-11.4ci /R-13.3ci/ R-15.2ci
	Metal framed	R-11.24 (U-0.089)/R-12.2 (U-0.0.082)/R-15.4 (U-0.065)/R-11.9 (U-0.084)	R- 13+R 7.5ci (U-0.064)	R- 13+R 7.5ci (U-0.064)
Fenestration	Non-metal framing	U-0.58/U-0.59/U-0.52/U-0.58; SHGC 0.35/0.385/0.385/0.36	U-0.4/U-0.35/U-0.35;SHGC 0.4	U-0.35/U-0.32/U-0.32;SHGC 0.4/0.74/0.4
	Metal framing: curtain wall/store front	NA	U-0.5/U-0.45/U-0.45;SHGC 0.4	U-0.42/U-0.45/U-0.42;SHGC 0.4/0.74/0.4
	Metal framing: all other	NA	U-0.55; SHGC 0.4	NA
Lighting	Lighting Power Density	1.57 W/ ft^2	1.0 W/ ft^2	0.81 W/ ft^2
Heating Efficiency	Warm air furnace	80% Et	80% Et	90% Et
	Boiler	NA	75% Et	97% Et
Cooling Efficiency	Packaged system	8 EER	10 EER	11 EER
Infiltration	Infiltration @ 75Pa	2 CFM/ft^2	0.4 CFM/ft^2	0.28 CFM/ft^2
DWH Efficiency	DWH	78% Et	80% Et	94% Et

Table 2: Traded Parameters and Property Ranges, Multifamily Apartment Building

Parameter Name	Parameter Subtype	Benchmark Model Input, Climate Zone 4A/5A/6A/Weighted Average	Code Requirement, Climate Zone 4A/5A/6A	Best Property, Climate Zone 4A/5A/6A
Roof Insulation	Insulated entirely above deck	R-17.2 (U-0.058)/R-19.2(U-0.052/R-22.7(U-0.044)/R-18.3(U-0.055)	R-20ci (U-0.048)	R-30ci (U-0.033)
	Attic and other	NA	R-38	R-38/R-38/R-49
Above Grade Wall Insulation	Mass	NA	R-11.4ci /R-13.3 ci/ R-15.2 ci	R-11.4ci /R-13.3ci/ R-15.2ci
	Metal framed	R-11.24 (U-0.089)/R-12.2 (U-0.0.082)/R-15.4 (U-0.065)/R-11.9 (U-0.084)	R- 13+R 7.5ci (U-0.064)	R- 13+R 7.5ci (U-0.064)
Fenestration	Non-metal framing	U-0.58/U-0.59/U-0.52/U-0.58; SHGC 0.35/0.385/0.385/0.36	U-0.4/U-0.35/U-0.35;SHGC 0.4	U-0.35/U-0.32/U-0.32;SHGC 0.4/0.74/0.4
	Metal framing: curtain wall/store front	NA	U-0.5/U-0.45/U-0.45;SHGC 0.4	U-0.42/U-0.45/U-0.42;SHGC 0.4/0.74/0.4
	Metal framing: all other	NA	U-0.55; SHGC 0.4	NA
Lighting	Lighting Power Density	Corridors: 0.9 W/ft²	Corridors: 0.7 W/ft²	Corridors: 0.6 W/ft²
Heating Efficiency	Warm air furnace	80% Et	80% Et	90% Et
	Boiler	NA	75% Et	97% Et
Cooling Efficiency	Packaged system	9 EER	10 EER	11 EER
Infiltration	Infiltration @ 75Pa	2 CFM/ft²	0.4 CFM/ft²	0.28 CFM/sf²
SWH Efficiency	NA	78% Et	80% Et	94% Et

Electricity and gas costs used in the analysis were calculated based on the monthly averages for New York State in the past 10 years, from January 2002 to December 2011, as published by the Energy Information Administration. These costs were 1.024 $/Therm and 0.1445 $/kWh.

All modeling was performed using Energy Plus V7.1 software. For each of the eight components selected for inclusion in the EPS scope (shown as separate rows in Tables 1 and 2) and in each model permutation, five parametric models were created, one for each point within the established range of change of the efficiency parameter described above, for a total of 246 runs. Such a extensive modeling effort would have been impossible without automation, which was essential for both productivity and to avoid data entry mistakes. The input file for the original prototype model with all parametric components was generated and pre-processed in Energy Plus parametric pre-processor, which automatically creates Energy Plus input files for each individual parameter being modeled. Batch Energy Plus simulations were then performed for all input files combined with the appropriate weather data.

A VBA script was developed to automatically pull electricity and gas consumption (kBtu) and facility utility cost ($) from Energy Plus comma-separated output files into Excel spreadsheets with pre-defined saving calculations. The full deck of models was executed and analyzed multiple times during EPS development, due to changes in parameter ranges and the baseline model configuration. To speed up the analysis, the EPS calculations were incorporated into an EPS Calculator spreadsheet, which allowed side-by-side comparison of Energy Points achieved by components in different building types (residential versus non-residential), climate zones, and retrofit combinations.

In early versions of the tool, climate specific benchmark models were used, with different efficiency parameters in addition to the different weather files. However, the early Calculators showed some unexpected trends. For example, fenestration retrofits with the same post-retrofit U-value received lower Energy Points in the colder climate zones 5a and 6a than in the warmer climate zone 4a. Upon closer inspection, it was found that this result was due to a significant difference in the fenestration U-values in the benchmark models for different climates, which were used as a proxy for actual existing conditions. As seen from Tables 1 and 2, the prototypes in climate zone 4a have U - 1.0 fenestration, compared to U-0.6 fenestration in climate zones 5a and 6a. To ensure more uniform results across the state, a non-climate specific baseline model was used as an alternative to the DOE benchmark models. The benchmark models for office and multifamily buildings in climate zone 4a were used as the basis for the non-residential and residential baseline models respectively. The existing conditions for all efficiency parameters (Benchmark Model Input in Tables 1 and 2) were calculated as the weighted average of the existing conditions in each climate zone. Weighting factors were established based on the most recent census data on total population in counties within the state that belong to each of the three climate zones [12]. According to the source, 62% of the population lives in climate zone 4a, 28% lives in climate zone 5a, and 10% lives in climate zone 6a.

The following sections describe the methodology and assumptions used in parametric models for each of the studied components.

<u>Roof Insulation</u>

1. ECCC NYS prescribes different thermal properties for roofs insulated entirely above deck, attic roofs, and roofs of metal buildings. Since the benchmark models for post-1980 mid-rise office and apartment buildings used in the study include roofs insulated entirely above deck, the

impact of roof insulation on the overall energy cost was not explicitly studied for attic roofs and roofs of metal buildings. Instead, it was assumed that proposed Energy Points are proportional to the absolute thermal properties of the roof after the retrofit and that code Energy Points are proportional to the absolute thermal properties required by code for the given roof construction, and the same EP calculations may be used for any roof type.

2. Roof retrofit typically includes adding insulation to the existing roof structure, while code requirements are given as the total R-value of continuous and cavity insulation, or as the overall U-value of the roof assembly. The overall U-value method is more universal as it can be applied to a roof with any combination of cavity and continuous insulation, including new materials and materials left in place. Overall U-value was used as roof efficiency parameter in the EPS. However, additional guidance would be useful for users on how this overall value should be determined, including taking into account resistance of air in the attic and the condition of existing insulation.
3. Area of retrofitted roof in thousands of square feet was used as the scale parameter.
4. Figure 3 shows sample calculations used to determine roof insulation Energy Points

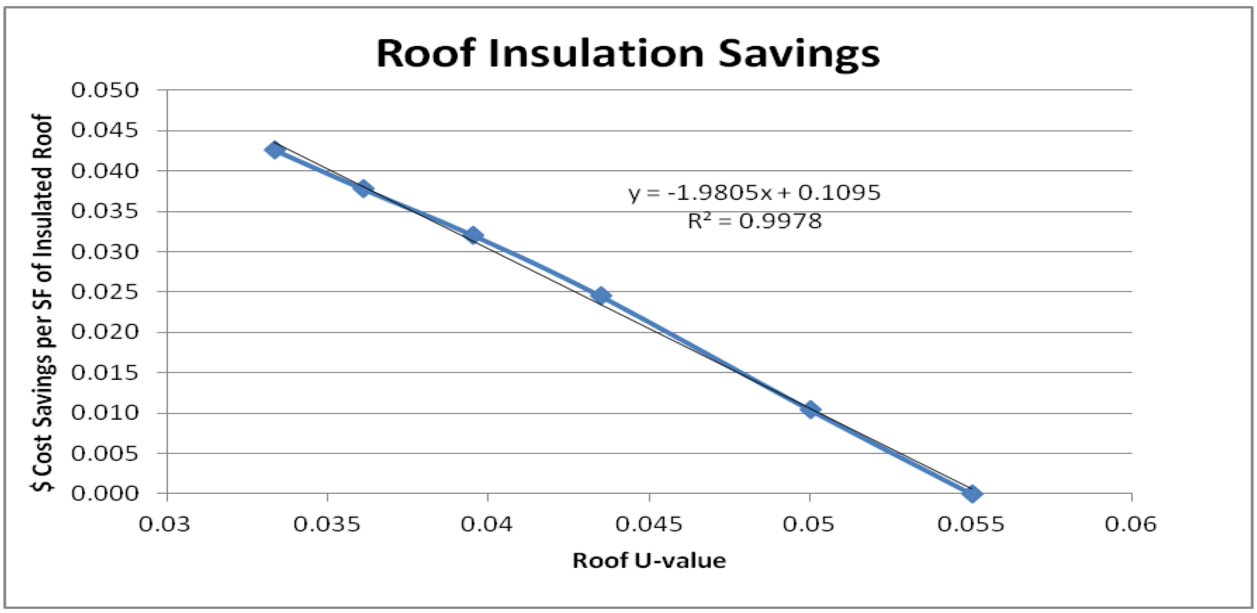

Figure 3: Savings from Roof Insulation in Commercial Prototype, Climate Zone 4a

Above Grade Wall Insulation

1. ECCC NYS prescribes different insulation levels for mass walls, walls of metal buildings, metal framed and wood framed walls. The benchmark models for post-1980 mid-rise office and apartment buildings have metal-frame walls. Thus the difference in the impact of wall insulation on overall energy cost was not studied for different wall constructions. Instead, it was assumed that proposed Energy Points are proportional to the absolute thermal properties of the wall after the retrofit and code Energy Points are proportional to the absolute thermal properties

required by code for the given wall construction. A similar approach was taken as described above for roof insulation.

2. Wall retrofit typically includes adding insulation to the existing structure, while code requirements are given as the total R-value of continuous and cavity insulation, or as the overall U-value of the assembly. Similar to the roof, the overall U-value method was used as the efficiency parameter in the EPS. Experience shows that it is commonly misunderstood how thermal bridging in steel-framed walls can be taken into account in the overall U-value calculations. Thus, additional guidance would be useful for users on determining overall U-values.
3. Area of retrofitted wall in thousands of square feet was used as the scale parameter.
4. Figure 4 shows sample data used to develop exterior wall insulation EP for the commercial prototype in climate zone 4a.

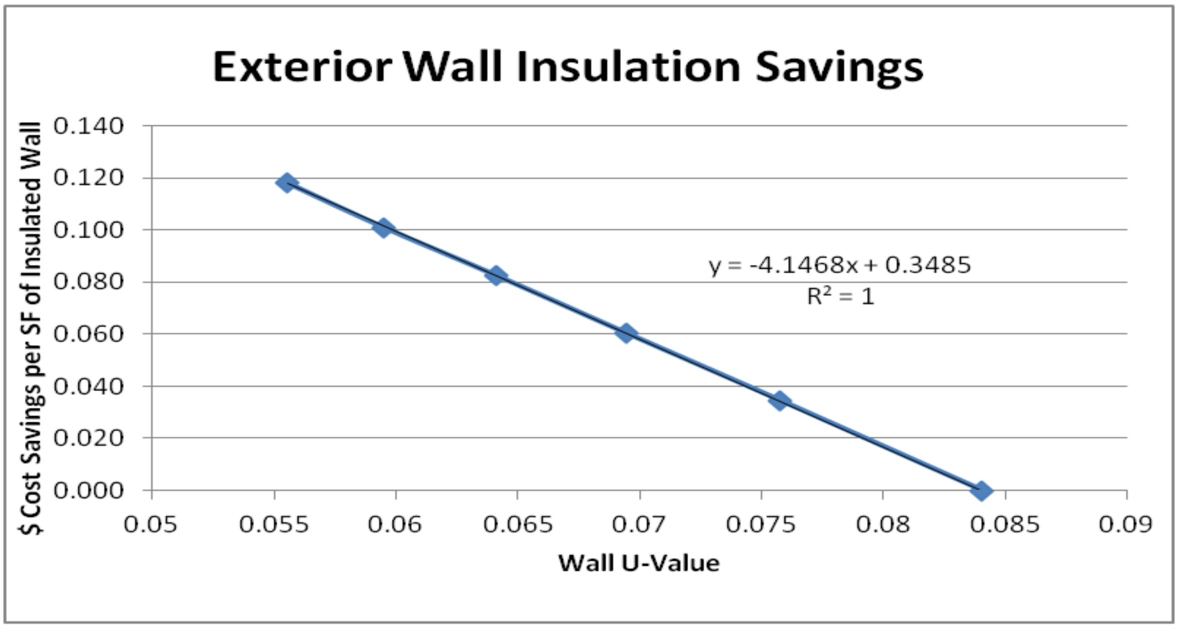

Figure 4: Savings from Exterior Wall Insulation in Commercial Prototype, Climate Zone 4a

<u>Fenestration</u>

1. ECCC NYS prescribes maximum fenestration U-value and SHGC. However, as seen in Tables 1 and 2, SHGC changes insignificantly between the benchmark post-1980 models, NBI's recommendations, and the code requirements for most climate zones. Thus, SHGC was not used as an EP efficiency parameter for fenestration.
2. The maximum fenestration U-value prescribed by ECCC NYS depends on fenestration type and is different for products with non-metal framing, and curtain wall/storefront, entrance doors, or any other fenestration with metal framing. The benchmark models for post-1980 mid-rise office and apartment buildings have fenestration with non-metal framing. Similar to roof and wall insulation, the difference in the impact of fenestration U-value on the overall energy cost was not studied for different types of fenestration. Instead, it was assumed that Energy Points are

proportional to the overall thermal properties of the assembly, and may be calculated using the same coefficient independent of the type of fenestration.

3. Area of retrofitted fenestration in square feet was used as the scale parameter.
4. Figure 5 shows sample data used to develop exterior wall insulation EP for the commercial prototype in climate zone 4a.

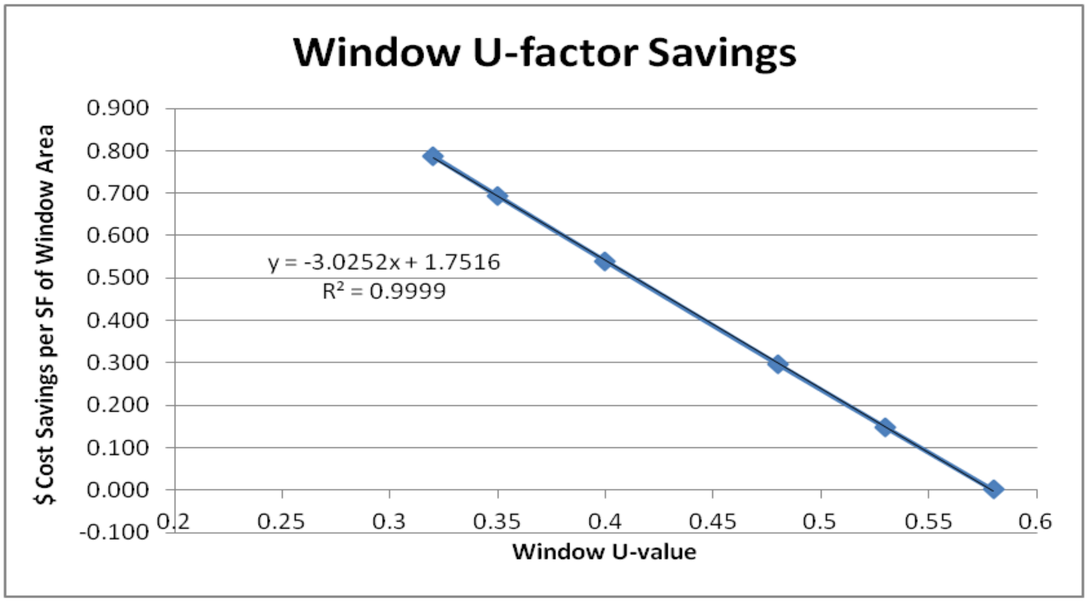

Figure 5: Savings from Fenestration U-value Reduction in Commercial Prototype, Climate Zone 4a

Lighting

1. Lighting Power Density (LPD) was used as the lighting efficiency parameter in the parametric models. In the mid-rise office benchmark model, a uniform LPD was assigned to all areas in the building. In the apartment building benchmark model, different LPDs were assigned to common spaces and apartment units. LPD in multifamily common spaces was used as the efficiency parameter in the analysis of residential buildings. Proposed Energy Points are proportional to LPD for the proposed retrofit, and code Energy points are proportional to the code requirement for given building type.
2. The area of spaces where lighting was retrofitted was used as the scale parameter. It is important to note that ECCC NYS does not have space-by-space lighting power allowances similar to those found in Standard 90.1 Table 9.6.1. Only the building-wide allowances are provided in Table 505.5.2. The building area allowances are not well suited for retrofit projects where lighting is only upgraded in certain spaces. For example, 1.0 W/ft² LPD included in ECCC NYS Table 505.5.2 for office buildings is not a suitable target for a lighting retrofit that is limited to corridor lighting. For reference, Standard 90.1 Table 9.6.1 (space-by-space method) prescribes a maximum LPD 0.5 W/ft² corridor LPD.
3. Figure 6 shows sample data used to develop lighting EP for the commercial prototype in climate zone 4a.

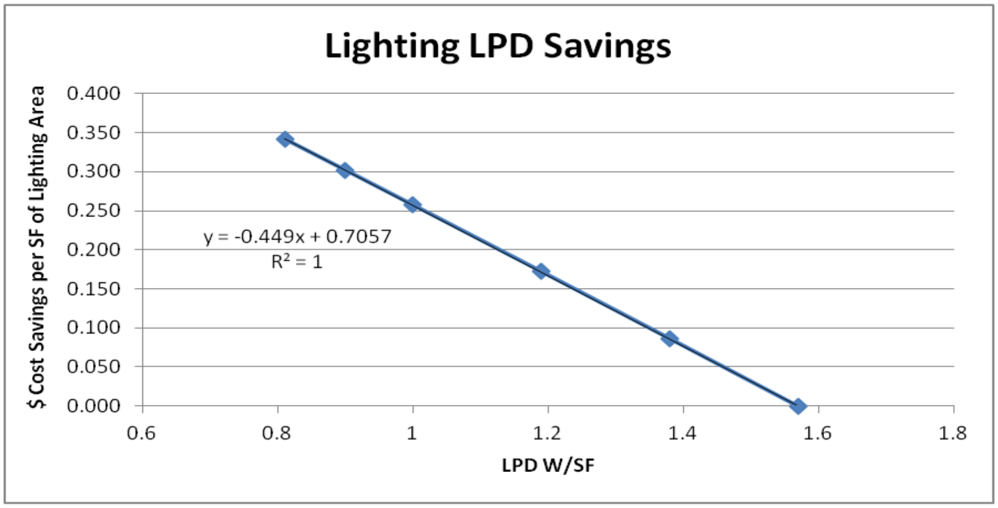

Figure 6: Savings from LPD Reduction in Commercial Prototype, Climate Zone 4a

<u>Heating Efficiency</u>

1. The benchmark models for office and apartment buildings have heating provided by warm air furnaces. Thus, the parametric analysis was done based on this system type. However, it was considered acceptable to use the resulting equations to calculate energy points for other types of heating systems in the scope of EPS, including space heating boilers. The proposed Energy Points are proportional to the efficiency of the system installed as part of the retrofit, and code Energy Points are proportional to the efficiency required by code for the given system type. Both efficiencies must be expressed in the same units for the code and proposed components. For example, both may be in expressed as AFUE, or both may be expressed as thermal efficiency Et.
2. The heating capacity of the retrofitted system is used as the scale variable.
3. Figure 7 shows sample data used to develop heating EP for the commercial prototype in climate zone 4a.

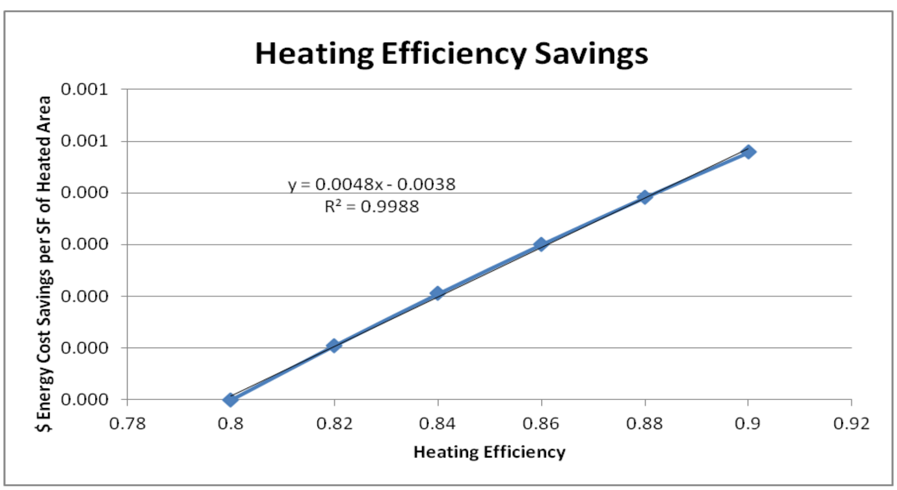

Figure 7: Savings from Heating Efficiency Improvement in Commercial Prototype, Climate Zone 4a

Cooling Efficiency

1. The benchmark models for office and apartment buildings have packaged DX cooling systems. Proposed Energy Points are proportional to the efficiency of the system installed as part of the retrofit and code Energy Points are proportional to the efficiency required by code for the given system type. Both the code and proposed efficiency must be expressed in the same units. For example, both can be expressed in EER or both can be expressed in SEER.
2. The cooling capacity of the retrofitted system is used as the scale variable.
3. Figure 8 shows sample data used to develop cooling EP for the commercial prototype in climate zone 4a.

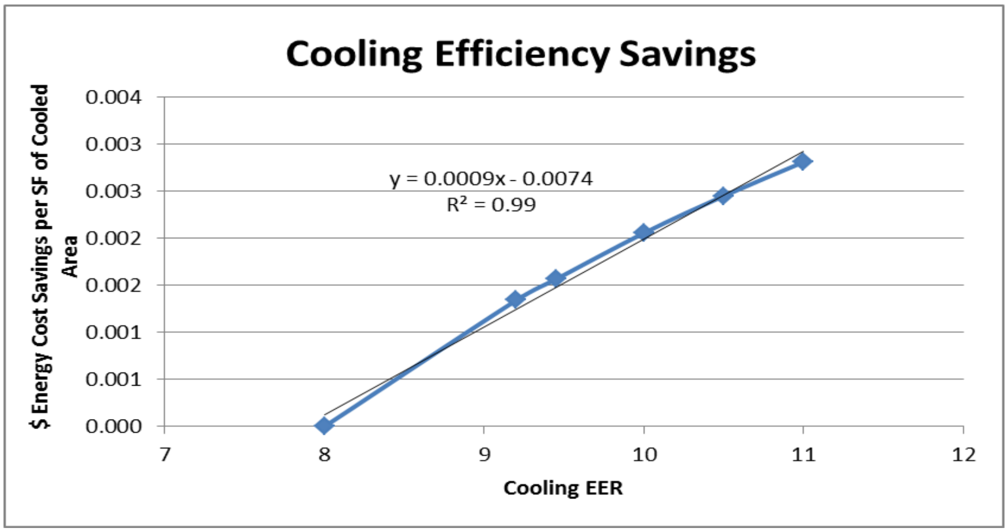

Figure 8: Savings from Cooling Efficiency Improvement in Commercial Prototype, Climate Zone 4a

Infiltration

1. Air-leakage is regulated in ECCC NYS by mandatory Section 502.4. The section offers several options for documenting compliance, including testing to demonstrate that the envelope air leakage rate does not exceed 2.0 L/s•m^2 under a pressure differential of 75Pa (0.4 CFM/ft^2 at a pressure differential of 0.3 in. water [1.57 psf]) in accordance with ASTM E 779 or an equivalent approved method.
2. Leakage at 75PA was converted to leakage at the normal operating conditions for input into the models [13].
3. Since target air leakage was not included in the NBI guide, 0.28 CFM/SF @ 75 Pa was used as the Best Property in establishing the range.
4. Different air leakage was used in the original benchmark models for perimeter and core spaces. In the analysis, air leakage in conditioned perimeter spaces was adjusted by set increments, while the leakage in core spaces was left unchanged.
5. The total area of conditioned spaces in square feet where air leakage was modified (i.e. conditioned perimeter spaces) was used as the scale variable.

6. Unlike with other components, EP_{CODE} for infiltration is calculated based on the existing air leakage, not the leakage required by Section 502.4. This approach was selected because air sealing is not customarily part of a retrofit project, so any air tightening of an existing building would exceed minimum code requirements.
7. Figure 9 shows sample data used to develop air leakage EP for the commercial prototype in climate zone 4a.

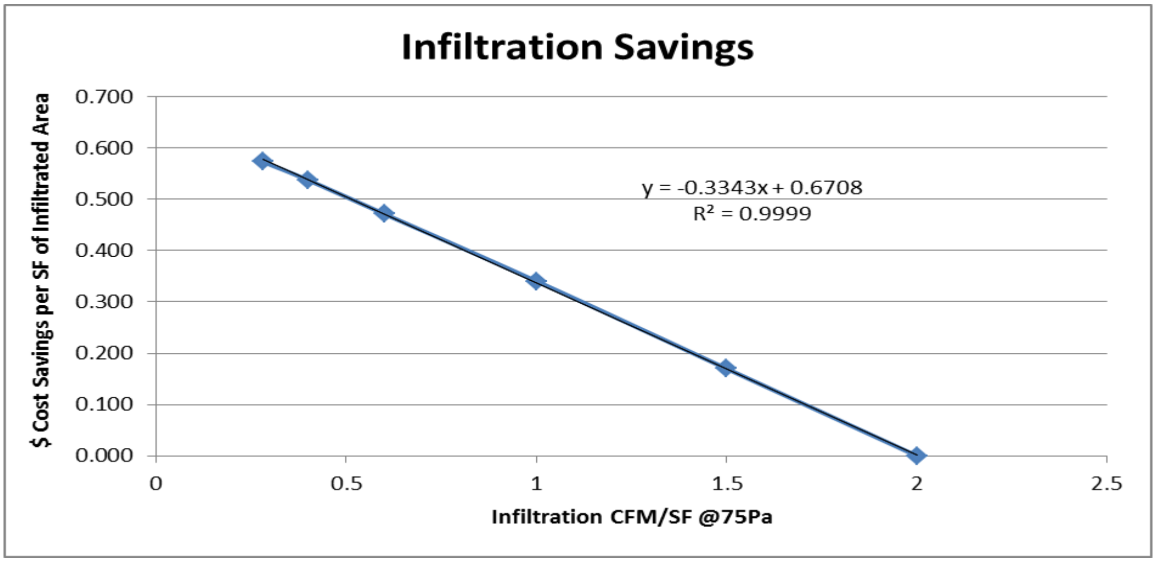

Figure 9: Savings from Infiltration Reduction in Commercial Prototype, Climate Zone 4a

<u>SWH Efficiency</u>

1. Gas water heaters were included in the benchmark models. However, it was assumed that the impact of SWH efficiency on total building energy cost is similar for other types of systems.
2. The capacity of the retrofitted system is used as the scale variable.
3. SWH capacity for the benchmark buildings was determined based on AO Smith Pro-Size calculator found at http://www.hotwatersizing.com, assuming a natural gas water heater, 40F cold water temperature, and 140F stored water temperature. In addition, the following prototype-specific parameters were used:

   Office Benchmark: No external storage, one hour peak demand period, 268 occupants, 5 private lavatories, 20 public lavatories, 3 kitchen sinks, 3 pantry sinks, 20% oversizing factor. The calculator estimated the peak demand to be 129 GPH. Suggested heaters ranged from 100,000 Btu/hr to 150,000 Btu/hr. A capacity of 120,000 Btu/hr was used to develop EPS equations.

   Multifamily Benchmark: External storage at 25% capacity, medium peak demand load profile, 32 apartments with 1 bath, 2 people per apartment, no clothes washers, 20% oversizing factor. The calculator estimated the peak demand to be 334 GPH. Suggested heater sizes ranged from 300,000 Btu/hr to 499,000 Btu/hr. A capacity of 400,000 Btu/hr was used to develop EPS equations.

4. Figure 10 shows sample data used to develop SWH EP for the commercial prototype in climate zone 4a.

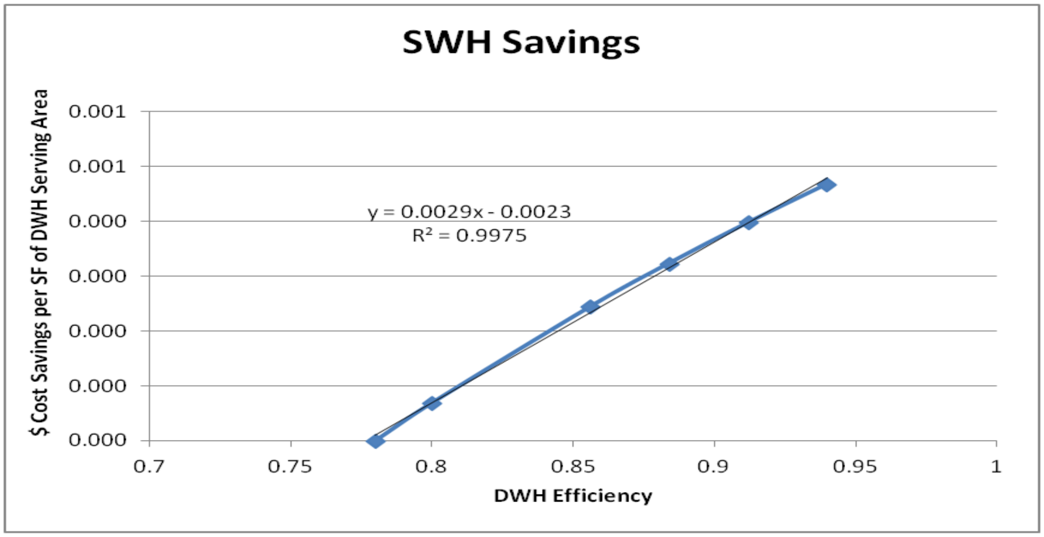

Figure 10: Savings from SWH Efficiency Improvement in Commercial Prototype, Climate Zone 4a

Proposed Changes to ECCC NYS to Incorporate EPS Compliance Path for Retrofit Projects

Proposed changes to ECCC NYS are shown below. New text is underlined.

501.2 Application. The commercial building project shall comply with the requirements in Section 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.

Exceptions:

1. Buildings conforming to Section 506, provided Sections 502.4, 502.5, 503.2, 504, 505.2, 505.3, 505.4, 505.6 and 505.7 are satisfied.
2. Where one or more components of an *existing building* or portions thereof are being replaced, the compliance of the comprehensive design may be established as described in Section 507.

507.1 Scope. This section establishes criteria for compliance using Energy Point System (EPS), and may be used to document compliance of comprehensive retrofit projects that include two or more of the following measures:

1. Changes to exterior wall or roof insulation
2. Fenestration retrofit
3. Air-sealing
4. Retrofit or replacement of building mechanical systems listed in Tables 503.2.3(1) and 503.2.3(3) through 503.2.3(5)
5. Retrofit of service water heaters or service water heating boilers
6. Lighting retrofits

Work to be performed under the current permit application that includes building systems not addressed in Section 507.1 shall meet the applicable requirements of Sections 502 through 505.

507.2 Mandatory requirements. Compliance with this section requires that the criteria outlined below are met by the retrofitted components included in the building permit.

507.2.1 Envelope retrofit involving opaque surfaces and fenestration must comply with sections 502.2.2, 502.2.4, 502.2.5, 502.2.6, 502.2.7, 502.2.8, and 502.5.

507.2.2 Retrofits involving air sealing measure must comply with sections 502.4.1, 502.4.2, 502.4.4, 502.4.5, 502.4.6, and 502.4.7.

507.2.3 Mechanical System retrofits must comply with Sections 503.2.1, 503.2.2, 503.2.3, 503.2.4.4, and 503.2.5.

507.2.4 Service Water Heating system retrofits must comply with Section 504.

507.2.5 Lighting system retrofits must comply with Sections 505.2 – 505.4 and 505.6.

507.3 Energy Point System Compliance. Energy Point System compliance is achieved if the Total Proposed Energy Points (TPEP) of the comprehensive retrofit is greater than or equal to the Total Code Energy Points (TCEP) of the reference retrofit where each component in the scope minimally complies with the applicable Code requirements.

507.4 Documentation. The compliance documentation shall include completed Tables 507.5.2 and 507.5.3. The code enforcement official shall be permitted to require a certification signed by the builder providing characteristics of the components included in the comprehensive scope of the retrofit evaluated using the Energy Point System. Compliance is achieved if the Total Proposed Energy Points are greater than or equal to the Total Code Energy Points.

507.5 Calculation procedure. The calculation procedure specified herein shall be followed for all components of the comprehensive retrofit evaluated using the Energy Point System. For each retrofit component, Proposed Energy Points and Code Energy Points shall be calculated as described in Table 507.5.1.

TABLE 507.5.1
RETROFIT ENERGY POINT CALCULATION

CLIMATE ZONE		4		5		6	
		ALL OTHER	**GROUP R**	**ALL OTHER**	**GROUP R**	**ALL OTHER**	**GROUP R**
Roof	A	$U_{ROOF,PROP}$= Overall U-factor of the retrofitted roof, including new and existing insulation					
	B	$U_{ROOF,CODE}$ = Overall roof U-factor based on Section 101.4.3 Exceptions 3 and 5 and Table 502.1.2 for the same roof type as retrofit					
	C	A_{ROOF}= gross area of the retrofitted roof , square feet x1000					
	$EP_{ROOF,PROP}$	(-1980.5× A+109.5) × C	(-4738.5× A+260.1) × C	(-2648×A+146.3) × C	(-3234.3 × A+178) × C	(-2778.3× A+156.4) × C	(-3080.8 × A+169.3) × C
	$EP_{ROOF,CODE}$	(-1980.5× B+109.5) × C	(-4738.5× B+260.1) × C	(-2648×B+146.3) × C	(-3234.3 × B+178) × C	(-2778.3×B+156.4) × C	(-3080.8 × B+169.3) × C
Walls, Above Grade	A	$U_{WALL,PROP}$= Overall U-factor of the retrofitted wall, including new and existing insulation					
	B	$U_{WALL,CODE}$= Overall wall U-factor based on Section 101.4.3 exceptions 3and 4 and Table 502.1.2 for the same wall type as retrofit					
	C	A_{WALL}= gross area of the retrofitted wall, square feet x1,000					
	$EP_{WALL,PROP}$	(-4146.8 × A+348.5) × C	(-3324.4 × A+278.7) × C	(-5557.6 × A+466.9) × C	(-2278.2 × A+191.2) × C	(-5626.3 × A+471.5) × C	(-2209.4 × A+185.4) × C
	$EP_{WALL,CODE}$	(-4146.8 × B+348.5) × C	(-3324.4 × B+278.7) × C	(-5557.6 × B+466.9) × C	(-2278.2 × B+191.2) × C	(-5626.3 × B+471.5) × C	(-2209.4 × B+185.4) × C
Fenestration	A	$U_{FEN,PROP}$= U-factor of the retrofitted fenestration, including frame and glazing					
	B	$U_{FEN,CODE}$= U-factor from Section 101.4.3 Exceptions 1 and 2 and Table 502.3 for the same fenestration type as retrofit					
	C	A_{FEN}= gross area of the retrofitted fenestration, square feet					
	$EP_{FEN,PROP}$	(-3025.2 × A+1751.6) × C	(-2543.2 × A+1468.7) × C	(-4323 × A+2500.3) × C	(-1672.4 × A+965.6) × C	(-4285.7 × A+2477.1) × C	(-1723.5 × A+994.9) × C
	$EP_{FEN,CODE}$	(-3025.2 × B+1751.6) × C	(-2543.2 × B+1468.7) × C	(-4323 × B+2500.3) × C	(-1672.4 × B+965.6) × C	(-4285.7 × B+2477.1) × C	(-1723.5 × B+994.9) × C
Air Sealing	A	CFM/ft^2@75P $_{PROP}$ = air leakage 75 Pa after retrofit, based on testing in accordance with ASTM E 779 or an equivalent approved method					
	B	CFM/ft^2@75Pa $_{CODE}$ = air leakage at 75 Pa prior to retrofit, based on testing in accordance with ASTM E 779 or approved equivalent					
	C	A_{SPC}=Total conditioned floor of spaces where air leakage was tested, square feet					
	$EP_{INF,PROP}$	(-0.3343 × A+0.6708) × C	(-0.3614 × A+0.7294) × C	(-0.5235 × A+1.0465) × C	(-0.2509 × A+0.5049) × C	(-0.5091 × A+1.0223) × C	(-0.2454 × A+0.4946) × C
	$EP_{INF,CODE}$	(-0.3343 × B+0.6708) × C	(-0.3614 × B+0.7294) × C	(-0.5235 × B+1.0465) × C	(-0.2509 × B+0.5049) × C	(-0.5091 × B+1.0223) × C	(-0.2454 × B+0.4946) × C
Unitary Air Conditioners and Condensing Units, Packaged Terminal Air Conditioners	A	EER_{PROP}= Cooling efficiency of the specified equipment					
	B	EER_{CODE} = Minimum cooling efficiency requirements from Table 503.2.3(1)-(3),(6)					
	C	CAP_{COOL} = Cooling capacity of the retrofitted system, Btu/hr					
	$EP_{COOL,PROP}$	(0.0009 × A-0.0074) × C	(0.0009 × A-0.0083) × C	(0.0009 × A-0.0067) × C	(0.0003 × A-0.0026) × C	(0.0007 × A-0.0056) × C	(0.0002 × A-0.0015) × C
	$EP_{COOL,CODE}$	(0.0009 × B-0.0074) × C	(0.0009 × B-0.0083) × C	(0.0009 × B-0.0067) × C	(0.0003 × B-0.0026) × C	(0.0007 × B-0.0056) × C	(0.0002 × B-0.0015) × C
Warm Air Furnaces	A	EFF_{PROP} = $AFUE_{PROP}$, Et_{PROP} or Ec_{PROP}					
	B	EFF_{CODE} = $AFUE_{CODE}$, Et_{CODE} or Ec_{CODE} minimum efficiency from Table 503.2.3(4)-(5)					
	C	CAP_{HEAT} = Heating capacity of the retrofitted system, Btu/hr					
	$EP_{HEAT,PROP}$	(0.0048 × A-0.0038) × C	(0.0324 × A-0.0259) × C	(0.0072 × A-0.0057) × C	(0.0181 × A-0.0144) × C	(0.0078 × A-0.0062) × C	(0.0192 × A-0.0153) × C
	$EP_{HEAT,CODE}$	(0.0048 × B-0.0038) × C	(0.0324 × B-0.0259) × C	(0.0072 × B-0.0057) × C	(0.0181 × B-0.0144) × C	(0.0078 × B-0.0062) × C	(0.0192 × B-0.0153) × C
Gas Service Water Heaters	A	$EFF_{SWH,PROP}$= rated efficiency of retrofitted water heating equipment, Et or AFUE					
	B	$EFF_{SWH,CODE}$ = efficiency of water heating equipment from Table 504.2, Et or AFUE					
	C	CAP_{SWH} = Heating capacity of the retrofitted System, Btu/hr					
	$EP_{SWH,PROP}$	(0.0029 × A-0.0023) × C	(0.0148 × A-0.0115) × C	(0.0032 × A-0.0025) × C	(0.0082 × A-0.0064) × C	(0.0033 × A-0.0026) × C	(0.0085 × A-0.0066) × C
	$EP_{SWH,CODE}$	(0.0029 × B-0.0023) × C	(0.0148 × B-0.0115) × C	(0.0032 × B-0.0025) × C	(0.0082 × B-0.0064) × C	(0.0033 × B-0.0026) × C	(0.0085 × B-0.0066) × C
Interior Lighting System	A	LPD_{PROP}= total installed lighting wattage in spaces where at least 50% of luminaries were retrofitted divided by the total area of these spaces, watt/square foot					
	B	LPD_{CODE}= interior lighting power allowance from Table 505.5.2, watt/square foot					
	C	A_{LIGHT}= area of the spaces with at least 50% of luminaries being replaced , square feet					
	$EP_{LIGHT,PROP}$	(-0.449 × A+0.7057) × C	(-2.245 × A+2.0421) × C	(-0.4113 × A+0.6473) × C	(-1.5682 × A+1.4269) × C	(-0.4032 × A+0.6341) × C	(-1.5219 × A+1.3847) × C
	$EP_{LIGHT,CODE}$	(-0.449 × B+0.7057) × C	(-2.245 × B+2.0421) × C	(-0.4113 × B+0.6473) × C	(-1.5682 × B+1.4269) × C	(-0.4032 × B+0.6341) × C	(-1.5219 × B+1.3847) × C

TABLE 507.5.2
RETROFIT ENERGY POINT DOCUMENTATION

Roof						
	Roof Area 1	Roof Area 2	Roof Area 3	Roof Area 4	Roof Area 5	Total
$U_{ROOF,PROP}$						
$U_{ROOF,CODE}$						
A_{ROOF} x1,000 SqFt						
$EP_{ROOF,PROP}$						
$EP_{ROOF,CODE}$						
Wall, Above Grade						
	Wall Area 1	Wall Area 2	Wall Area 3	Wall Area 4	Wall Area 5	Total
$U_{WALL,PROP}$	.					
$U_{WALL,CODE}$						
A_{WALL} x1,000 Square Feet						
$EP_{WALL,PROP}$						
$EP_{WALL,CODE}$						
Fenestration						
	Fenestration 1	Fenestration 2	Fenestration 3	Fenestration 4	Fenestration 5	Total
$U_{FEN,PROP}$						
$U_{FEN,CODE}$						
A_{FEN}						
$EP_{FEN,PROP}$						
$EP_{FEN,CODE}$						
Air Sealing						
	Area 1	Area 2	Area 3	Area 4	Area 5	Total
$ACH75_{PROP}$	.					
$ACH75_{CODE}$						
$A_{SPC,}$ Square Feet						
$EP_{WALL,PROP}$						
$EP_{WALL,CODE}$						
Unitary Air Conditioners and Condensing Units, Packaged Terminal Air Conditioners						
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Total
EER_{PROP}	.					
EER_{CODE}						
CAP_{COOL} (Btu/h)						
$EP_{COOL,PROP}$						
$EP_{COOL,CODE}$						
Warm Air Furnaces						
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Total
EFF_{PROP}	.					
EFF_{CODE}						
CAP_{HEAT} Btu/hr						
$EP_{HEAT,PROP}$						
$EP_{HEAT,CODE}$						
Service Water Heaters						
	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Total
$EFF_{SWH,PROP}$	.					
$EFF_{SWH,CODE}$						
CAP_{SWH} (Btu/hr)						
$EP_{SWH,PROP}$						
$EP_{SWH,CODE}$						
Interior Lighting						
	Area 1	Area 2	Area 3	Area 4	Area 5	Total
LPD_{PROP}	.					
LPD_{CODE}						
A_{LIGHT}						
$EP_{LIGHT,PROP}$						
$EP_{LIGHT,CODE}$						

TABLE 507.5.3
RETROFIT ENERGY POINT SUMMARY

	$EP_{PROP,TOT}$	$EP_{CODE,TOT}$	Points Earned ($EP_{PROP,TOT}$ - $EP_{CODE,TOT}$)
Roof			
Wall, Above Grade			
Fenestration			
Air Sealing			
Unitary Air Conditioners and Condensing Units, Packaged Terminal Air Conditioners			
Warm Air Furnaces			
Service Water Heaters			
Interior Lighting			
Total			

Recommendations for Future Work

1) Enhance modeling and result analysis
   a. Use typical weather conditions in TMY3 files instead of TMY2 files in the modeling. TMY3 files are more representative of the recent weather trends.
   b. The current multifamily prototype uses gas heating, which means that envelope heating loads can be satisfied relatively inexpensively. Commercial prototype uses gas heating in the air handling unit with electric zonal reheat. Energy Points associated with envelope retrofits including surface insulation, fenestration, and air leakage, would be significantly higher for electrically heated buildings. Consider making heating fuel an explicit input into EPS forms, resulting in different EPS coefficients when calculating envelope-related points for electrically heated versus non-electrically heated buildings.
   c. Perform an analysis to optimize significant figures. This will increase the accuracy of the Energy Point system in some areas, and simplify the calculations in other areas where additional significant digits do not contribute to accuracy in a meaningful way.

2) Refine EPS scope and code language
   a. Consider incorporating Section 303.1.1 into EPS calculations. For example, EP_{PROP} may be reduced by 10% if performance of the component is not documented based on the required rating procedure (e.g. fenestration NFRC rating is unknown, custom HVAC unit does not have ARI efficiency rating, etc.)
   b. Include selected lighting and HVAC controls into EPS. For example, savings from lighting occupancy sensors may be established using Standard 90.1 Appendix G, which allows up to 15% lighting power density reduction for lighting systems controlled by occupancy sensors where such automatic controls are not required by code.
   c. Allow EPS credit for acceptance testing and retro-commissioning. Studies have shown that 8%-32% savings may be achieved [10].

d. Evaluate mandatory requirements in Section 507.2 to see if some of them can be relaxed for retrofit projects.
e. Evaluate other opportunities for expanding the scope of EPS to include additional retrofit options.
f. Simplify EPS calculation tables proposed for inclusion into code by restructuring them to combine code and proposed equations into one row. This can be done without changing the calculations themselves.

3) Peer review and rollout
    a. Perform additional testing to verify EPS coefficients. A comprehensive approach should be taken, with thorough documentation and numerous case studies.
    b. Incorporate EPS into a software tool to streamline calculations.
    c. Create an advisory panel to peer-review the EPS
    d. Present EPS in a peer-reviewed professional publication(s) and/or conference(s).

Appendix A: Description of Prototype Buildings

Tables A-1 and A-2 show summarized description of the prototype models (DOE Benchmark Models,[14],[15]) used as the basis of the EPS development.

A-1 Medium Office Building Prototype

GENERAL	
Building Type	Medium Office
Gross Floor Area	53,600 ft²
Building Shape	Rectangle
Aspect Ratio	1.5 (164 ft x 109 ft)
Number of Floors	3
Window to Wall Ratio	33% (modeled as strip windows 5 ft. in height)
Floor Height	13 ft
Floor-to-Ceiling Height	9 ft
Exterior Wall	Steel-framed wall
Roof	Built-up flat roof, insulation entirely above deck
Floor	Mass Floor (4 in slab w/carpet)
INTERNAL LOADS	
Number of People	5 persons / 1000 SF
Lighting Power Density	1.57 W/SF
Average Plug Load Density	1.0 W/SF
HVAC	
Heating Type	Gas furnace And Electric Reheat
Cooling Type	Packaged Air-Conditioning Unit
Fan Control	Variable Volume
Distribution/Terminal Units	Multi Zone/Variable Air Volume
Cooling T-stat	75°F (80°F setback)
Heating T-stat	70°F (60°F setback)
SERVICE WATER HEATER	
Water Heater Type	Gas Water Heater
Thermal Efficiency (%)	78
Supply Temperature, °F	140

Table A-2: Multifamily Building Prototype

GENERAL	
Building Type	Midrise Apartment
Gross Floor Area	33,700 SF
Building Shape	Rectangle
Aspect Ratio	2.7 (152 ft x 56 ft))
Number of Floors	4
Activity Area	8 apartments with central corridor on each floor, office on first floor, 2x multiplier on middle floor
Window to Wall Ratio	15% (modeled as strip windows of 5 ft. high)
Floor Height	10 ft
Floor-to-Ceiling Height	10 ft
Exterior Wall	Steel-framed wall
Roof	Built-up flat roof, insulation entirely above deck
Floor	Mass Floor (4 in slab w/carpet)
INTERNAL LOADS	
Number of People	80 persons total (average 2.5 persons per apartment unit)
Average Lighting Power Density	• Apartment units: 0.4 W/SF • Corridors: 0.9 W/SF • Office area: 2.0 W/SF
Average Plug Load Density	0.5 W/SF
HVAC	
Heating Type	Gas furnace
Cooling Type	Split system DX (one per apartment)
Fan Control	Constant Air Volume
Distribution/Terminal Units	Single zone/Direct air
Cooling T-stat	75°F (no setback assumed)
Heating T-stat	70°F (no setback assumed)
SERVICE WATER HEATER	
Water Heater Type	Gas Water Heater
Thermal Efficiency (%)	78
Supply Temperature, °F	140

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