Towards More Robust EUI Baselines for Non-residential New Construction

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ABSTRACT

Increasingly stringent energy codes, municipal mandates, and industry-standard practices that often exceed code have become so common in Massachusetts with long-established energy efficiency programs that the state's program administrators have chosen to redesign their non-residential new construction program. Among the design innovations on which the new program focuses is engaging with design teams to set energy use intensity (EUI) targets that can lead to more Zero-Net-Energy (ZNE) -ready projects. The redesigned program now has four pathways: two new pathways and two that are consistent with the previous program offering. The two new pathways are focused on deep energy savings and involve expert technical assistance and tiered incentives based on achieving low EUIs. These new pathways will use EUI baselines by building use type for certain types of buildings to calculate savings associated with participant projects.

The state's program administrators conducted a study to investigate the EUI baselines by building use type for these new pathways that includes a novel yet robust approach. The study uses the administrators' billing and tracking data and the state's Level 3 tax data to estimate the EUI values for buildings identified as non-residential "true" new construction. The study assessed EUIs for a total of 1,233 buildings over 36 building use types and developed EUI baseline recommendations for a selection of eight building use types that are most likely to participate in the redesigned program: multifamily, office, medical office, hotel, supermarket/grocery store, library, fire/police station, and K-12. These eight building use types together account for 60% of the total buildings assessed. The study also relies on several secondary sources of data for comparison to determine the appropriate range for the calculated EUI values. The recommended EUI baseline values took into consideration the participant and non-participant EUI breakdowns, comparison with secondary sources, coefficient of variation values, population distribution by building size, and inputs from the consensus group. The program administrators and state representatives are currently working out a policy framework by which to use the recommended EUI baseline values in the program. The implementation policy will take into consideration several factors, such as site versus source EUI, fuel-specific EUI values, and applicability for exceptions such as all-electric buildings.

This paper will present an overview of the robust baseline-setting methods, the baseline recommendations, outliers, baseline update framework, and lessons learned from the EUI baseline research. These insights can be readily used by program administrators across the country.

Background and Introduction

The Program Administrators (PAs) in Massachusetts, through their non-residential new construction (NRNC) program, historically offered an enhanced and optimized integrated design path in two standard packages for new construction projects in the earliest development phases – one for new construction projects between 20,000 and 100,000 sq. ft. and the other for larger new construction projects. The packages have offered a scaled incentive structure tied to savings above the applicable energy code. But due to increasingly stringent energy codes, municipal mandates, and industry standard practices (ISPs) that often exceed code, the NRNC program faced diminishing opportunities for energy savings given the way the program was structured.[1] The PAs redesigned the program with a focus on offering incentives based on actual building performance rather than modeled savings and engaging the design teams to set energy use intensity (EUI) targets that can lead to more ZNE-ready projects.

The redesigned program now has four pathways: two new pathways and two that are consistent with the previous PA offerings. The two new pathways, now referred to as the Deep Energy Savings path (Path 1) and the Whole Building Modeled path (Path 2), are focused on deep energy savings and involve expert technical assistance (TA) and tiered incentives based on achieving low EUIs. The Simplified Whole Building path (Path 3) will provide less intensive TA, while the Systems path (Path 4) will primarily be a prescriptive program available for smaller buildings. These new pathways will use EUI baselines by building use type for select building types to calculate savings associated with participant projects.

To investigate these building use type EUI baselines, the PAs commissioned a Massachusetts Non-residential New Construction (NRNC) EUI Baseline Study in 2019 (referred to here as the NRNC EUI Baseline Study).[2] In addition to the NRNC Baseline study, a second study (referred to here as the Enhanced EUI Baseline Study or the study) that built on the previous study was also conducted.[3] The enhanced EUI baseline study took a deeper look at a handful of the building types for which establishing EUI baselines made sense. This paper is based on the findings from the Enhanced EUI Baseline study.

The primary objective of the Enhanced EUI Baseline study was to identify specific building types for which EUI baselines could be recommended for ready use in the programs. The Enhanced EUI Baseline study was originally intended to be completed in two phases. Phase 1 involved reviewing secondary data sources, analyzing data from these sources, and developing EUI baseline recommendations. Phase 2 was to consist of building simulation modeling to inform savings and incentive ranges. However, the PAs were waiting on EUI-related policy decisions before determining the focus of the simulations in Phase 2 and given the time it was taking for policy decisions, the PAs and the study team mutually agreed to close out the study without completing the Phase 2 building simulations. At the time of writing this paper, the policy decisions were still pending.

Methodology

EUI is calculated by dividing the annual energy consumed by the building by the total gross floor area of the building. The study used primary data from several different sources to calculate the site-level EUI values for a total of 1,233 buildings constructed from 2010 through 2019. The total population included 36 different building types. The study also developed a Massachusetts specific source-site ratio to calculate the source EUI values. The calculation methodology is discussed later in this section.

The primary data used in the analysis included the following:

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[1] ISPs are applicable to the equipment being installed/replaced, and hence are relative to equipment selection and not to the whole building operations.

[2] https://ma-eeac.org/wp-content/uploads/MA-NRNC-EUI-Final-Memo-MA19C12-B-NCEUIBSLN-1-24-2020-.pdf

[3] https://ma-eeac.org/wp-content/uploads/MA20X02-B-EUIBASE_Report_2021.05.05_Final.pdf

- PA billing and tracking data – This data included billing and tracking data for buildings constructed between 2010 and 2019.
- MA L3 tax data – The Massachusetts L3 tax database comprises a standardized (Level 3) parcel mapping dataset that contains property (land lot) boundaries and parcel attributes from each community's tax assessor.
- Boston-specific tax data – The city of Boston is not included in the L3 tax database since it does not participate in the L3 project. However, Boston makes similar information available for public use.

The tax data provides building square footage values and classifies parcels by land-use code. There are ten one-digit (high-level) land use classifications. Under these high-level classifications, there are 40 two-digit and 262 three-digit classification codes, each providing an increased level of detail. These classification codes were reviewed and mapped for consistency and comparison with secondary data sources (discussed later in this section).

To reduce the outliers, the study dropped the buildings with very low annual consumption (<2,000 kWh or < 70 therms) and capped the outliers using an interquartile (IQR) range rule.[4] In addition, the study dropped sites with renewables or on-site generation, which can skew the EUIs and make it difficult to assess true building performance with the PA consumption data, from the dataset.

The prior Massachusetts NRNC EUI Baseline Study investigated trends at the building-use level and did not find a definite trend showing either increasing or decreasing EUIs over the years, suggesting that the EUIs were not impacted as the building codes became more stringent. This is demonstrated in Figure 1 below. This allowed the Enhanced EUI Baseline study to also use longer periods of data from 2010 onwards, comprising a larger, more robust data set.

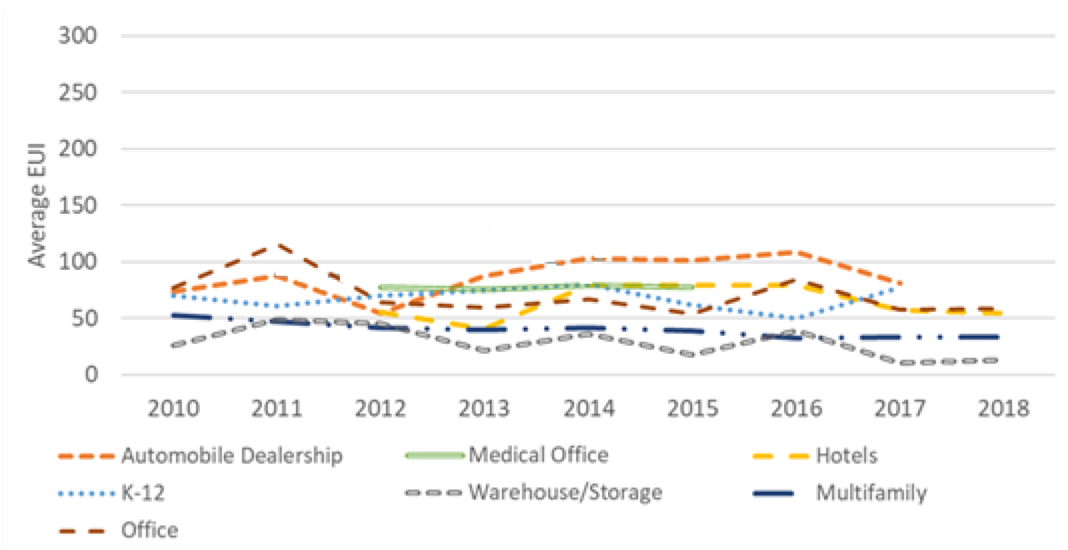

Figure 1. EUI trends for a sample of building types from 2010 through 2018 for areas greater than 20,000 ft^2.

[4] if EUI>Q3+1.5 x IQR then EUI=Q3+1.5 x IQR and if EUI<Q1-1.5 x IQR then EUI=Q1-1.5 x IQR

The study also calculated Massachusetts-specific source-site ratios that allowed for conversion of site EUI values to source EUI values.[5] Site EUIs help understand the energy use for an individual building while source EUI helps whereas source EUIs account for the losses that are incurred in the generation, transmission, and delivery of energy to buildings. To calculate these ratios, the study used the percentage of generation by fuel mix for Massachusetts from the Massachusetts MMBtu Study. The source-site ratios were calculated by using the overall generation by plant type, heat generated, and the calculated generation losses.[6] The study used the technical reference on source energy by ENERGY STAR Portfolio Manager as a guideline in calculating the source-site ratio. The NMR team calculated an electric source-site ratio for Massachusetts of 2.32, as compared to the nationwide electric source-site ratio of 2.80 used by Portfolio Manager. The NMR team assumed that the gas source-site ratio in Massachusetts would be the same as the national gas source-site ratio of 1.05. Additional information was not available to make a judgement otherwise.

Once the site and source EUI values were calculated, they were compared with EUI values obtained from several secondary data sources. The EUI values obtained from the secondary sources were used in adjusting the recommended EUI values for the selected building types.

The various secondary sources of data reviewed were:

- Department of Energy's (DOE's) Building Performance Database (BPD) – BPD is one of the largest publicly available collections of measured energy performance data for buildings in the United States.[7]
- ENERGY STAR Portfolio Manager DataTrends – DataTrends is an ongoing series of original research and analysis from ENERGY STAR Portfolio Manager. Initially, the study was only going to use this source to supplement the low population building types in the primary data. However, given the information available, the NMR team used this as the main source of comparison since it provided a more granular breakdown of the building types.
- New Buildings Institute (NBI) – NBI is a nonprofit organization pushing for better energy performance in buildings, working collaboratively with industry market players – governments, utilities, energy-efficiency advocates and building professionals – to promote advanced design practices, innovative technologies, public policies, and programs that improve energy efficiency.
- The 2012 Commercial Buildings Energy Consumption Survey (CBECS) – CBECS is a national sample survey that collects information on the stock of U.S. commercial buildings, including their energy-related building characteristics and energy usage data (consumption and expenditures).

As part of the process, the study established a subject-matter experts committee and the consensus group. The purpose of the subject-matter expert committee was to assist with the initial discussion of the applicability of the site versus source EUIs. This committee consisted of PA implementation staff members and a Massachusetts Energy Efficiency Advisory Council (EEAC) consultant.[8]

A consensus group, to discuss the recommended EUI baseline values and potentially agree on the values for use by the programs, was also formed. The consensus group consisted of key stakeholders, such

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[5] As per ENERGY STAR, primary energy is the raw fuel that is burned to create heat and electricity, such as natural gas, fuel oil, or coal and secondary energy is the energy product created from a raw fuel, such as electricity (purchased from the grid) or heat (received from a district steam system)

[6] Source-site ratio = (heat generated / [generation - losses])

[7] BPD contains data from any source that was willing to contribute data. As a result, BPD may not be representative of the national building stock. However, Lawrence Berkeley National Laboratory compared the BPD to CBECS and found that the BPD is reasonably representative in terms of site and source EUI and does not show evidence of systemic bias.

[8] Massachusetts EEAC members guide the development of state- and nation-leading energy efficiency plans by the Commonwealth's investor-owned gas and electric utilities and energy providers.

as PA implementation and evaluation staff, EEAC, and the evaluation team members. A total of two consensus calls were conducted.

Results

The stakeholders, during the consensus calls, identified eight building types for which EUI baselines were then recommended. The recommended site EUI values for the selected building types were adjusted based on the participant and non-participant EUI breakdown, comparison with secondary sources, coefficient of variation values, population distribution by size, distribution in the box plots, and inputs from the consensus group.

For majority of the building types, the study recommended median site EUI values. The median value is the middle of the population (i.e., half of buildings use more energy and half use less). The median works better than the mean (the arithmetic average) for comparing relative energy performance because it more accurately reflects the midpoint of energy use for most building types. The study also included the average fuel breakdown for five building types (five of the eight building types for which EUI values were recommended and are indicated in Table 1 below in italics) that the PAs were interested in. The fuel breakdown is the percent of total building EUI accounted for by either electric or gas consumption The PAs plan to use this breakdown to claim savings from mixed fuel baselines. The recommended EUI baselines and the average percent fuel breakdown are presented in Table 1 below.

Building Type	**Recommended Site EUI Baseline (kBtu/ft2)**	**% Electric Breakdown**	**% Gas Breakdown**
Multifamily	45	-	-
Offices	70	58%	42%
Medical Office	80	-	-
Hotel	75	51%	49%
Supermarket/Grocery Store	200	-	-
Library	80	60%	40%
Fire/Police Stations	90	48%	52%
K-12	65	42%	58%

Table 1. Recommended EUI Baselines and percent electric and percent gas breakdown. *Source:* Enhanced EUI Baseline Study

For offices, medical offices, and fire/police stations, the recommended EUI baseline values are applicable for buildings greater than 10,000 ft^2.

In addition, some of the key observations from the EUI effort in Massachusetts are listed below:

- Several building types, other than the ones for which EUI baselines were recommended, did not have large enough sample points for development of defensible EUI values.
- The EUI values were found to be highly variable within the building types.
- There was no noticeable change observed in the EUI values for the building types over the past decade.

Conclusion

Program changes to NRNC programs like those observed in Massachusetts are starting to become a norm in the Northeast. Soon after Massachusetts, Connecticut also revamped their NRNC program to include similar program paths. The programs are increasingly emphasizing the whole building approach with early intervention thereby making EUI baselines an important aspect of the process. Currently, the programs use a custom approach to determine savings for projects that undergo the whole building treatment. Baseline EUI values are evaluated on a case-by-case basis since the programs have not formally adopted building type-specific site EUI baseline values. However, at present, the PAs are internally debating a few policy questions prior to accepting the recommended EUI baselines. For example, some of the issues that need to be resolved before adopting the recommended EUI baseline values include determination of what characteristics make a building an outlier, and how an all-electric buildings should be handled when gauged against baselines mostly informed by buildings using both electricity and natural gas.

The study recommended conducting a similar EUI baseline study in three years using the 2018 CBECS data. While the study was being conducted, CBECS was updating its building characteristics data to include newer building stock constructed between 2010 and 2018. At the time of writing this paper, the 2018 CBECS building characteristics data was available. CBECS expects to update the energy consumption data in summer of 2022.

The EUI studies suggest that only a few building types show more promise than others in being able to set building-type-specific EUI baselines due to the high variability in the calculated EUI values within each building type. Unfortunately, the amount of detailed, building level information available was limited, which made it difficult to examine apparent outlier buildings by characteristics that could explain their deviation from the median (such as operating hours, functionality, etc.). With such additional information, one could possibly group those buildings into narrower categories, reducing the EUI variability and allowing a study to draw correlations between the anticipated operation of a proposed new construction building and adjustments to any building type-specific baseline that would apply to the facility, thus allowing the PAs to apply building type-specific EUI baselines to more new construction projects without having to model each specific facility. This is a significant enough barrier in conducting future EUI research; however, as more buildings go through the program paths 1 and 2, the PAs will be able to build a comprehensive repository of EUI values based on the actual building simulation models. This information will aid future baseline efforts in fine tuning the EUI baselines and help expand the baselines to more building types (outside of the currently selected eight building types).

As noted earlier, the EUI effort in Massachusetts revealed that there has not been a noticeable change in building EUIs over the past decade. This may suggest that the recent changes to the program – focusing more on reducing the building EUI – is a more prudent approach compared to the previous program designs.

Continuing to build on the EUI baseline effort in Massachusetts will greatly help the new construction programs in the region. For example, the research from this study will be leveraged in currently ongoing baseline efforts in Connecticut.[9]

References

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Caron N. and Telarico C. 2020. Massachusetts Non-Residential New Construction EUI Baseline Study. Medford, MA. DNV.

[9] Connecticut is assessing the baselines for their new construction program (Energy Conscious Blueprint Program).