MEMORANDUM

To: Massachusetts Program Administrators and EEAC Consultants

From: Yogesh Patil, Tim Steis (NMR), and Nathan Caron (DNV)

Cc: Monica Nevius, Zack Tyler (NMR), and David Barclay (DNV)

Date: May 5, 2021

Re: Non-Residential New Construction EUI Baseline Enhancement Study (MA20X02-B-EUIBASE) Final Memo

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Introduction

This memorandum serves as the final report for the Non-Residential New Construction EUI Baseline Enhancement Study (MA20X02-B-EUIBASE). It presents the NMR team's recommended energy use intensity (EUI) baselines for select building types and describes the overall methodology in determining the EUI baseline values.

The NMR team conducted the study for the Massachusetts energy-efficiency Program Administrators (Berkshire Gas, Cape Light Compact, Eversource, Liberty Utilities, National Grid, and Unitil). The 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 Program Administrators (PAs) have been waiting on EUI-related policy decisions before determining the focus of the simulations in Phase 2. These policy decisions are taking longer than expected. Due to the uncertainty in the timing of the policy decisions, the PAs and study team have mutually agreed to close out the study without completing the Phase 2 building simulations. Hence, this report only includes Phase 1 results.

Background

Under the New Buildings and Major Renovations initiative, the PAs have historically offered an enhanced and optimized integrated design path in two standard packages for new construction projects in the earliest development phases: "Small Buildings Whole Building Solution" for new construction projects between 20,000 and 100,000 sq. ft. and "Large Buildings Whole Building Solution" for larger new construction projects. The packages have offered a scaled incentive structure tied to savings above the applicable energy code. Smaller buildings, renovations, and

buildings already under construction can access prescriptive and system-specific custom incentives.

Due to increasingly stringent energy codes, municipal mandates, and industry standard practices (ISPs) that often exceed code, the PAs' non-residential new construction (NRNC) program faces diminishing opportunities for energy savings as it is currently structured.[1] An evaluation[2] of 2014 custom comprehensive design assistance (CDA) projects within the new construction program found relatively low realization rates for electric and demand savings, primarily due to adjustments for lighting ISP. It also found that the EUIs of participating projects in the study sample were higher than those of the existing building stock and other new construction buildings. The 2019-2021 three-year plan describes how the PAs will explore more extensive design innovations that include (1) engaging with design teams to set EUI targets that can lead to more Zero-Net-Energy-ready projects and (2) offering incentives based on project performance rather than modeled savings.

To help with redesigned NRNC program, the PAs contracted with NMR through the Commercial and Industrial (C&I) process evaluation contract to facilitate a series of charrettes to inform a new program structure that is focused on four pathways: two new pathways and two[3] that are consistent with the current 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.

The savings for the new pathways will likely be calculated using sector-based EUI baseline values that can be compared to participating projects.- Because of this, the PAs recently investigated EUI baselines for these new pathways through the Massachusetts Non-residential New Construction EUI Baseline Study[4] (referred to here as the NRNC EUI Baseline Study). This study was conducted by DNV GL (now DNV) and was delivered to the PAs in January 2020. It used the PAs' billing and tracking data, Massachusetts Level 3 (L3) tax data, and Boston tax data housed in the Massachusetts Data Warehouse to estimate the EUIs for buildings identified as non-residential true new construction. The study recommended that the PAs consider developing baselines informed by the results of the analysis for certain building use and size categories with less variable EUIs. The study also noted that the data sources included a small number of the types of buildings most likely to participate in the PAs' new building construction initiative (e.g., colleges, hospitals). The study also used data from the Commercial Buildings Energy Consumption Survey (CBECS) to provide context for the calculated EUIs.

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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] *Massachusetts Commercial and Industrial Impact Evaluation of 2014 Custom CDA Installations*. DNV GL, DMI, SBW Consulting, and ERS. April 25, 2018.

[3] One of them is an improvement upon the existing structure.

[4] Massachusetts Non-Residential New Construction EUI Baseline Study – Revised Results Memo. DNV GL. January 24, 2020.

GOALS

The goal of this study is to develop EUI baseline recommendations for newly constructed buildings.

Note that this memo only summarizes findings from Phase 1. The key research questions for Phase 1 were as follows:

- What are the additional data sources that can be used to inform the EUI baselines?
- Are there specific building types or sub-types that should be targeted first, and what are the recommended baselines?
- Can we use the data from the NRNC EUI Baseline Study, along with the additional data sources, to determine more robust EUI baselines?
- What additional primary sources of data can be used to address the outliers in the NRNC EUI Baseline Study data and possibly reduce the variability of the EUI values?

SUMMARY OF EVALUATION ACTIVITIES

Phase 1 included the following key research activities:

1. Identifying and reviewing secondary data sources that could be used to inform EUI baselines
2. Working with the subject matter expert committee to identify whether to use site or source EUI values and a method to calculate source EUI values
3. Augmenting the NRNC EUI Baseline Study dataset with appropriate additional data and calculating revised EUI baseline values for different building types
4. Recommending specific EUI baselines that the program should use for a subset of building types
5. Discussing EUI baseline recommendations with the consensus group
6. Reporting interim results in this memo

RECOMMENDED SITE EUI BASELINE VALUES

Table 1 presents the site EUI values the NMR team is recommending for each building type of interest. The NMR team developed the recommended values based on the participant and non-participant EUI breakdown, comparison with secondary sources, CV values, population distribution by size, distribution in the box plots, and inputs from the consensus group.

Additional details for each building type is presented in Section 2.

Table 1: Recommended Site EUI Baseline Values

Building Type	Recommended Site EUI Baseline (kBtu/ft^2)
Multifamily	45
Offices	70
Medical Office	80
Hotel	75
Supermarket/Grocery Store	200
Library	80
Fire/Police Stations	90
K-12	65

1 Methodology and Approach

This section presents the NMR team's approach to calculating the baseline EUI values.

1.1 Data Sources

1.1.1 Primary Data Sources

Similar to the Massachusetts NRNC EUI Baseline Study, to determine the EUI baselines by building type, this study used the PAs' billing and tracking data, MA L3 tax data, and Boston tax data housed in the MA Data Warehouse. The data (henceforth referred to as "MA Data") were for buildings constructed from 2010 through 2018. Overall, the NMR team assessed EUIs for 1,233 buildings over 36 building types.

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. The city of Boston is an exception since it does not participate in the L3 project. However, Boston makes similar information available for public use; the NMR team accessed this separately.

The L3 tax data provides building square footage values and classifies parcels by land-use code. There are ten one-digit (high-level) land use classifications: multiple-use, residential, open space, commercial, industrial, personal property, forest property, agricultural/horticultural, recreational property, and exempt property. Under these high-level classifications, there are 40 two-digit and 262 three-digit classification codes, each providing an increased level of detail.[5,6]

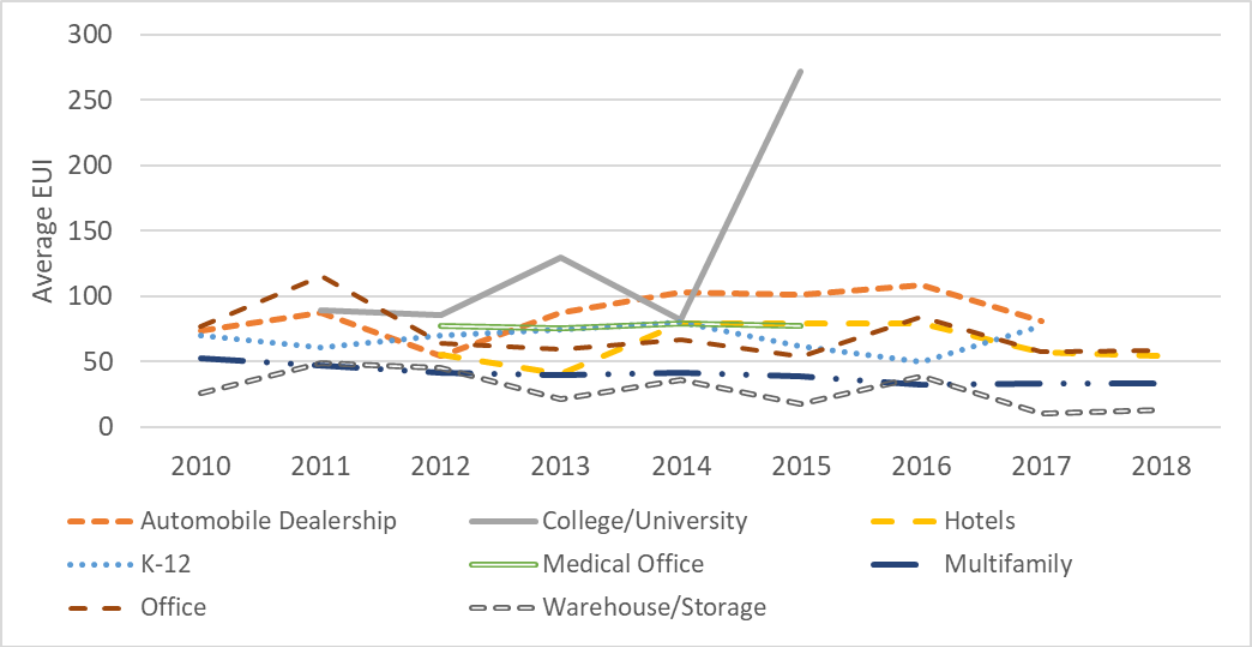
The NMR team downloaded the tax data from MassGIS and the City of Boston in April 2020. Of the 351 municipalities in MA, 338 (96%) had tax data that had been updated between 2018 and 2020, while 13 (4%) had tax data that had not been recently updated as of April 2020.

[5] https://www.mass.gov/doc/property-type-classification-codes-non-arms-length-codes-and-sales-report-spreadsheet/download

[6] NMR verified the building types assigned in the tax data through web searches and made appropriate corrections where necessary.

The Massachusetts NRNC EUI Baseline Study investigated trends at the building-use level, calculating EUIs using data from 2010 to 2018.[7] The NRNC EUI Baseline Study 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 allowed the NMR team to use longer periods of data from 2010 onwards, comprising a larger, more robust data set. Figure 1 shows the EUI trends for a sample of building types with area greater than 20,000 ft^2 from 2010 through 2018.

Figure 1: Average EUIs by Building Type Over the Years (Area > 20,000 ft^2)



To facilitate comparison across datasets, the NMR team reviewed the land use codes and compared them with the building types used by CBECS and ENERGY STAR® Portfolio Manager. Based on the review, the NMR team updated the land use codes to match the building types described in ENERGY STAR Portfolio Manager DataTrends (DataTrends). DataTrends building types were more detailed and allowed the NMR team to limit the number of building categories for EUI analysis. For select building types, such as offices, the NMR team conducted research to provide a more granular breakdown within that category.

Table 2 presents the overall building type mapping used in the EUI analysis and for secondary data comparison.

[7] MA-NRNC-EUI-Final-Memo-MA19C12-B-NCEUIBSLN-1-24-2020-.pdf (ma-eeac.org)

Table 2: Building Type Mapping

Category	Subcategory
Education	Adult Education
	College/University
	K-12
	Pre-School/Daycare
	Vocational School/Other
Food Sales/Grocery	Supermarket/Grocery Store
	Wholesale Club/Supercenter
	Convenience Store
	Other Food Sales
Food Service	Bar/Nightclub
	Fast Food Restaurant
	Restaurant
	Other Food Services
Health Care	Ambulatory Surgical Center
	Hospital (General Medical & Surgery)
	Other/Specialty Hospital
	Medical Office
	Outpatient Rehabilitation/Physical Therapy
	Residential Care Facility
	Senior Care Community
	Urgent Care/Clinic/Other Outpatient
Lodging	Barracks
	Hotels
	Prison/Incarceration
	Residential Care Facility
	Senior Care Community
	Other - Lodging/Residential
	Residence Hall/Dormitory
Mercantile	Automobile Dealership
	Convenience Store
	Enclosed Mall
	Lifestyle Center, Strip Mall
	Other - Mall
	Retail Store
	Supermarket/Grocery Store
	Wholesale Club/Supercenter
Mixed Use	Mixed Use
Multifamily	Multifamily
Office	Medical Office
	Office

Category	Subcategory
	Veterinary Clinic
Other	Other
Public Assembly	Convention Center
	Movie Theater, Museum, Performing Arts
	Recreation: Bowling alley, Gym, Ice Rink, Roller Rink, Swimming Pool, Other Recreation
	Social/Meeting Hall
	Stadium, Aquarium, Casino, Zoo, Other Entertainment
	Bar/Nightclub
Public Order and Safety	Courthouse
	Fire Station
	Library
	Mailing Center/Post Office
	Police Station
	Social/Meeting Hall
	Transportation Terminal/Station
	Other - Public Services
Religious	Religious
Service	Service
Unknown	
Warehouse/Storage	Self-Storage Facility
	Distribution Center, Non-Refrigerated Warehouse
	Refrigerated Warehouse
Nursing Home	
Banking	Bank Branch
	Financial Office
Technology/Science	Data Center
	Laboratory
	Other - Technology/Science
Utility	Utility

1.1.2 Secondary Data Sources

The NMR team researched the following secondary data sources for established EUI value by building types:

- 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. 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]

- ENERGY STAR Portfolio Manager DataTrends: This is an ongoing series of original research and analysis from ENERGY STAR Portfolio Manager. Initially, the NMR team 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). We used the 2012 data since the 2018 data is not yet available. The complete 2018 data is expected to be made available in Summer of 2022.

1.2 Data Analysis and EUI Baseline Recommendations

The NMR team used the primary data to develop site EUI values for the revised building types. EUI values are calculated as the ratio of annual energy consumption to the overall floor area of the building.

The NMR team used an approach similar to that used in the prior study to determine and account for outliers. To reduce the outliers, the NMR team dropped the buildings with very low annual consumption (<2,000 kWh or < 70 therms) and capped the outliers using the interquartile (IQR) range rule.

$$if\ EUI > Q3 + 1.5\ x\ IQR\ then\ EUI = Q3 + 1.5\ x\ IQR$$

$$if\ EUI < Q1 - 1.5\ x\ IQR\ then\ EUI = Q1 - 1.5\ x\ IQR$$

The NMR team 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 billing data includes a flag for sites that are net-metered, which allowed the NMR team to remove them from the dataset. The NMR team also checked for sites that had negative annual consumption as a possible flag for on-site generation and removed them from the dataset. In addition, the NMR team explored using the solar renewable energy certificate (SREC)/solar Massachusetts renewable target (SMART) programs website to identify a list of sites with solar/on-site generation installations. However, that data source was inadequate for this purpose since the only identifiers in the data were the town and applicant name (which is not always the

[8] *Is the BPD Nationally Representative?* Lawrence Berkeley National Laboratory. March 2019.

same as the site owners). This made it impossible for the NMR team to identify specific sites/accounts in the primary data used in this study.

The secondary research involved taking a look at data from the sources listed in Section 1.1.2. Since DataTrends provides both site and source EUIs and includes more detailed types of buildings, the NMR team decided to do a direct comparison with DataTrends EUIs.[9] The DataTrends uses CBECS as the primary source of data while supplementing from other sources for a number of building types. The NMR team also looked at the regional CBECS data for a better understanding of expected regional EUI values for building types that could be directly compared.[10] Since the DataTrends did not provide a detailed breakdown of the data by region for the EUIs, the NMR team did not normalize the data.

1.2.1 Source-site Ratios

To calculate the source EUIs, the NMR team developed electric and gas source-site ratios specific to Massachusetts. The NMR team used the percentage of generation by fuel mix for Massachusetts from the Massachusetts MMBtu Study to calculate the overall generation.[11] The MMBtu study also provided the overall heat generation by plant type. Based on the research on ISO-NE's website, the NMR team assumed an average of 8% transmission and distribution (T&D) losses.[12] The NMR team then used the overall generation by plant type, heat generated, and the calculated generation losses to calculate the electric source-site ratio (heat generated / [generation - losses]). Table 3 presents the details for electric source-site ratio.

Table 3: Massachusetts Electric Source-Site Ratios by Fuel Mix[13]

Energy Source	Generation by Plant Type (MWh)	T&D Losses (8%) (MWh)	Heat Output by Plant Type (MMBtu)	Heat Output by Plant Type (MWh)	Heat Rate (MMBtu / MWh)	Source-site Ratio (MWh / MWh)
Coal - Steam Turbine	1,635,549	130,844	16,857,389	4,944,225	10.31	3.29
Natural Gas - Combined Cycle	57,771,462	4,621,717	430,684,387	126,318,534	7.45	2.38
Natural Gas - Combustion Turbine	945,622	75,650	9,386,933	2,753,161	9.93	3.16
Natural Gas - Steam Turbine	27,895	2,232	354,739	104,044	12.72	4.05

[9] 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).
[10] The NMR team considered EUI values for CBECS data for buildings constructed from 1990-2012 in the comparison.
[11] Navigant conducted the "Study to Propose a More Refined Method to Account for the Conversion of Electric Savings to MMBtu Savings" for the Electric and Gas Program Administrators of Massachusetts.
[12] https://www.iso-ne.com/
[13] The NMR team used the 2020 values from the "Total Heat Output" and "Total Generation" tabs of the "MMBtu Study_Task3 MMBtu and Emissions Factor.XLS" spreadsheet provided by the PAs. The spreadsheet tabs contain

Energy Source	Generation by Plant Type (MWh)	T&D Losses (8%) (MWh)	Heat Output by Plant Type (MMBtu)	Heat Output by Plant Type (MWh)	Heat Rate (MMBtu / MWh)	Source-site Ratio (MWh / MWh)
Nuclear	25,178,684	2,014,295	253,828,127	74,447,084	10.08	3.21
Hydro	22,977,898	1,838,232	78,354,632	22,981,196	3.41	1.09
Wind	4,668,993	373,519	15,921,268	4,669,664	3.41	1.09
Solar	3,530,341	282,427	12,038,464	3,530,848	3.41	1.09
Other Renewable	8,355,863	668,469	94,623,950	27,752,942	11.32	3.61
Other	5,487	439	77,859	22,836	14.19	4.52
Total	**125,097,794**	**10,007,824**	**912,127,748**	**267,524,534**	**N/A**	**N/A**
Overall Heat Rate & Ratio					**7.29**	**2.32**

The NMR team used the technical reference on source energy by ENERGY STAR Portfolio Manager as a guideline in calculating the source-site ratio.[14] 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.[15] 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.

1.2.2 EUI Analysis

The NMR team developed the following information for the various building types using the primary data:

- Overall site EUIs (median, quartile 1, and quartile 3 values)
- Gas and electric site EUIs
- Participant and non-participant site EUIs
- Overall source EUIs
- Gas and electric source EUIs
- Participant and non-participant source EUIs
- Coefficient of variation (CV) for site and source EUIs
- PA error for site EUIs
- Box plots for site EUIs

The NMR team worked with the PAs to form a subject-matter experts committee to assist with the initial discussion of the applicability of the site versus source EUIs. This committee consisted of PA implementation staff members and an EEAC consultant. During the subject-matter experts

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the forecast of heat output and generation by fuel type on an annual basis and for four costing periods (summer and winter on-/off-peak) for the period 2020-2050. Data for 2020-2040 are forecasted using a combination of Guidehouse's proprietary Portfolio Optimization Model (POM) and PROMOD, and 2041-2050 is extrapolated. This study used 2020 data to develop the source-site ratios.

[14] https://portfoliomanager.energystar.gov/pdf/reference/Source%20Energy.pdf

[15] The PAs currently use a source-site ratio of 2.15. This is based on the 2019 data, according to the information in the screening tools. The NMR team believes the difference in this source-site ratio for this study and the PAs is due to accounting for the T&D losses. With the T&D losses, the source-site ratio would have been 2.14.

committee call, all-electric EUI baselines and defining outlier building characteristics were identified as key issues requiring further internal discussion by the PAs. At the time of writing this report, the PAs were working internally to make the necessary policy decisions related to these issues.

The NMR team also formed a consensus group to discuss the recommended EUI baseline values and potentially agree on the values for use by the programs. The consensus group consisted of key stakeholders, such as PA implementation and evaluation staff, EEAC, and the evaluation team members. The NMR team held a total of two consensus calls.

2 Recommendations & Considerations

This section presents the recommended EUI baseline values and related considerations.

During the consensus calls, the stakeholders identified eight building types for which the NMR team provided EUI baseline recommendations for Massachusetts. For the majority of the building types, the NMR team chose to use 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 NMR team also determined the average percent fuel breakdown for five building types that the PAs were interested in. The PAs are planning to use this breakdown to claim savings from mixed fuel baselines. Table 4 summarizes the % fuel breakdowns.

Table 4: Average Site Fuel Breakdown

Building Type	% Electric	% Gas
Hotels	51%	49%
K-12	42%	58%
Library	60%	40%
Office	58%	42%
Fire/Police Station	48%	52%

The following sub-sections present the recommended EUI values for each building type of interest. The NMR team determined the EUI baseline values recommended here based on the participant and non-participant EUI breakdown, comparison with secondary sources, CV values, population distribution by size, distribution in the box plots, and inputs from the consensus group.

2.1 Recommended EUI Baseline Values

2.1.1 Multifamily

The recommended EUI value for the multifamily sector is **45** kBtu/ft^2.

Table 5 shows the MA Data for Site EUI values compared to available secondary data. The MA Data median is 30% lower than the national ENERGY STAR Portfolio Manager median.

Table 5: Multifamily Site EUI (kBTU) Comparison with Secondary Sources

MA Data Median – Capped Outliers	MA Data Mean – Capped Outliers	ENERGY STAR Portfolio Manager – Median	NBI – Climate Zone 5 - Mean		MA Data vs ENERGY STAR % Difference - Median
42	43	60	Low-rise MF	24	-30%
			Mid-rise MF	26	
			High-rise MF	33	

The NMR team looked further at three different multifamily building size categories (<10,000 ft^2, 10,000-50,000 ft^2, and >50,000 ft^2). The overall CV with capped outliers is 34%. At 24%, the CV is significantly smaller for larger building sizes (>50,000 ft^2) than for smaller building sizes (<10,000 ft^2), at 39%.

Table 6: Multifamily Site EUI (kBTU) - MA Data

Building Size	Median – Capped Outliers	Mean – Capped Outliers	N		CV – Capped Outliers	CV – All Records
			All Records	Outliers		
<10,000 ft^2	46	44	99	18	39%	265%
10,000-50,000 ft^2	44	44	86	5	33%	81%
>50,000 ft^2	37	38	75	14	24%	60%
All MF Buildings	**42**	**43**	**260**	**37**	**34%**	**325%**

2.1.2 Office

The recommended EUI value for the office sector is **70** kBtu/ft^2. This recommendation is applicable only to buildings above 10,000 ft^2.[16]

Table 7 compares the PA data site EUI median and mean values for office buildings to secondary sources. The PA median site EUI value of 66 for office buildings falls between the ENERGY STAR Portfolio Manager and DOE EUI values. The PA median is 25% larger than the ENERGY STAR Portfolio manager median EUI value and 14% smaller than DOE 2010-2019 median values.

[16] Buildings under 10,000 ft2 are not eligible under Paths 1 and 2 of the redesigned NRNC program.

Table 7: Office Site EUI (kBTU) Comparison with Secondary Sources

MA Data Median – Capped Outliers	MA Data Mean – Capped Outliers	ENERGY STAR Portfolio Manager – Median	CBECS Northeast – Mean	DOE 2010-2019 (MA, CT, NY) – Median	NBI – Climate Zone 5A – Mean	MA Data vs ENERGY STAR % Difference – Median
66	64	53	100	77	24	25%

Table 8 shows the PA data EUI medians and means for three different building size categories. Over half (53%) of the PA data office buildings are less than 10,000 square feet. The median EUI value is smaller for <10,000 ft^2 office buildings compared to the other size categories, while the CV remains constant for the three building size categories. The CV for all office buildings is 43%.

Table 8: Offices Site EUI (kBTU) - MA Data

Building Size	Median – Capped Outliers	Mean – Capped Outliers	N		CV – Capped Outliers	CV – All Records
			All Records	Outliers		
<10,000 ft^2	63	60	75	11	42%	495%
10,000-50,000 ft^2	72	70	44	8	44%	129%
>50,000 ft^2	73	66	23	4	43%	87%
All Office Buildings	**66**	**64**	**142**	**23**	**43%**	530%

2.1.3 Medical Office

The recommended EUI value for the medical office sector is **80** kBtu/ft^2. This recommendation is applicable only to buildings above 10,000 ft^2.

Table 9 compares the PA data site EUI estimates to the only available secondary source – the ENERGY STAR Portfolio Manager. The PA data EUI median is 35% greater than the ENERGY STAR Portfolio Manager median.

Table 9: Medical Office Site EUI (kBTU) Comparison with Secondary Sources

MA Data Median – Capped Outliers	MA Data Mean – Capped Outliers	ENERGY STAR Portfolio Manager – Median	MA Data vs ENERGY STAR % Difference – Median
69	71	51	35%

Table 10 breaks down the PA data site EUI estimates by three size categories. About half (48%) of the medical office buildings are <10,000 ft^2. The CV value for medical offices >50,000 ft^2 is significantly smaller at 28% compared to medical offices <10,000 ft^2 at 46%.

Table 10: Medical Office Site EUI (kBTU) - MA Data

Building Size	Median – Capped Outliers	Mean – Capped Outliers	N		CV – Capped Outliers	CV – All Records
			All Records	Outliers		
<10,000 ft^2	49	49	16	2	46%	193%

10,000-50,000 ft^2	78	86	13	1	42%	73%
>50,000 ft^2	98	106	4	0	28%	28%
All Medical Office Buildings	**69**	**71**	**33**	**3**	**51%**	**137%**

2.1.4 Hotel

The recommended EUI value for the hotel sector is **75** kBtu/ft^2.

Table 11 shows the PA data site EUI mean and median estimates side by side with EUI estimates from secondary sources. Compared to ENERGY STAR Portfolio Manager, the PA data EUI median estimate is 17% larger, but is 30% smaller than the DOE median estimate for MA, CT, and NY.

Table 11: Hotel Site EUI (kBTU) Comparison with Secondary Sources

MA Data Median – Capped Outliers	MA Data Mean – Capped Outliers	ENERGY STAR Portfolio Manager – Median	CBECS Northeast – Mean	DOE 2010-2019 (MA, CT, NY) – Median	NBI – Climate Zone 5A – Mean	MA Data vs ENERGY STAR % Difference – Median
74	73	63	98	105	38	17%

Table 12 breaks down the hotels by size categories. Most of the hotels (92%) are >50,000 ft^2, while none of the hotels are less than 10,000 ft^2. The CV for all hotels is 23%.

Table 12: Hotel Site EUI (kBTU) – MA Data

Building Size	Median – Capped Outliers	Mean – Capped Outliers	N		CV – Capped Outliers	CV – All Records
			All Records	Outliers		
10,000-50,000 ft^2	61	61	2	0	48%	48%
>50,000 ft^2	73	74	23	4	22%	56%
All Hotels	**74**	**73**	**25**	**4**	**23%**	**88%**

The NMR team also looked into other characteristics, such as hotels with swimming pools or proximity to a highway,[17] and how these affected the EUI values. Table 13 provides a breakdown by these various site characteristics.

Table 13: Hotel Site EUI (kBTU) – Other Site Characteristics

Hotel with Indoor Swimming Pool EUI (kBtu/ft^2)			Hotel with No Swimming Pool EUI (kBtu/ft^2)		
N	Median	Average	N	Median	Average
15	**74**	76	6	**65**	66

Not Close to Highway EUI (kBtu/ft^2)	Close to Highway EUI (kBtu/ft^2)

[17] The NMR team considered hotels within 1 mile of interstate as “close to highway.”

N	Median	Average	N	Median	Average
10	**73**	69	11	**73**	77

2.1.5 Supermarket/Grocery Store

The recommended EUI value for the supermarket/grocery store sector is **200** kBtu/ft^2.

Table 14 compares PA data median and mean site EUI values with other secondary sources. The PA data median EUI value is only 3% higher than the ENERGY STAR Portfolio Manager median EUI estimate.

Table 14: Supermarket/Grocery Site EUI (kBTU) Comparison with Secondary Sources

MA Data Median – Capped Outliers	MA Data Mean – Capped Outliers	ENERGY STAR Portfolio Manager – Median	CBECS Northeast – Mean	DOE 2000-2009 (MA, CT, NY) – Median	MA Data vs ENERGY STAR % Difference – Median
201	207	196	228	308	3%

Table 15 breaks down the supermarket/grocery buildings into building size categories. None of the buildings were <10,000 ft^2. Eighty-two percent of the supermarket/grocery buildings fell into the >50,000 ft^2 category. The CV value for all PA data supermarket/grocery store buildings is 41%.

Table 15: Supermarket/Grocery Store Site EUI (kBTU) - MA Data

Building Size	Median – Capped Outliers	Mean – Capped Outliers	N		CV – Capped Outliers	CV – All Records
			All Records	Outliers		
10,000-50,000 ft^2	116	174	3	1	93%	93%
>50,000 ft^2	201	216	14	3	28%	40%
All Supermarket/Grocery Buildings	**201**	**207**	**17**	**4**	**41%**	**45%**

2.1.6 Library

The recommended EUI value for libraries is **80** kBtu/ft^2.[18]

Table 16 shows the comparison of PA data median and mean site EUIs with the ENERGY STAR Portfolio Manager. The PA data median EUI is only 3% greater than the ENERGY STAR Portfolio Manager estimate.

[18] The EUI baseline value was set at 80 during a consensus group call, as this value was deemed to be closer to the PA data than either the ENERGY STAR EUI value or the Massachusetts non-participant EUI value.

Table 16: Library Site EUI (kBTU) Comparison with Secondary Sources

MA Data Median – Capped Outliers	MA Data Mean – Capped Outliers	ENERGY STAR Portfolio Manager – Median	MA Data vs ENERGY STAR % Difference – Median
74	66	72	3%

All the libraries in the MA Data are between 10,000 and 50,000 ft^2. The CV for libraries is 31%.

Table 17: Library Site EUI (kBTU) - MA Data

Building Size	Median – Capped Outliers	Mean – Capped Outliers	N		CV – Capped Outliers	CV – Capped Outliers
			All Records	Outliers		
10,000-50,000 ft^2	74	66	7	1	31%	32%
All Libraries	**74**	**66**	**7**	**1**	**31%**	**32%**

2.1.7 Fire/Police Stations

The recommended EUI value for fire/police stations is **90** kBtu/ft^2. This recommendation is applicable only to buildings above 10,000 ft^2.

Table 18 compares MA Data median and mean site EUI values with other secondary sources. The MA Data median EUI value is 19% lower than the ENERGY STAR Portfolio Manager median EUI estimate.

Table 18: Fire/Police Station Site EUI (kBTU) Comparison with Secondary Sources

MA Data Median – Capped Outliers	MA Data Mean – Capped Outliers	ENERGY STAR Portfolio Manager - Median	CBECS Northeast - Mean	DOE 2000-2009 (MA, CT, NY) - Median	NBI – Climate Zone 5A – Mean	MA Data vs ENERGY STAR % Difference - Median
101	116	125	108	107	33	-19%

Table 19 breaks down the fire station buildings into building size categories. About 50% of the buildings were <10,000 ft^2 and the remaining were <50,000 ft^2. The CV value for all MA Data fire station buildings is 25%.

Table 19: Fire/Police Station Site EUI (kBTU) - MA Data

Building Size	Median – Capped Outliers	Mean – Capped Outliers	N		CV – Capped Outliers	CV – All Records
			All Records	Outliers		
<10,000 ft^2	146	153	5	1	8%	22%
10,000-50,000 ft^2	89	98	11	3	7%	20%
All Fire Station Buildings	**98**	**116**	**16**	**4**	**25%**	**28%**

2.1.8 K-12

The recommended EUI value for K-12 buildings is **65** kBtu/ft^2.

Table 20 compares MA Data median and mean site EUI values with other secondary sources. The MA Data median EUI value is 34% higher than the ENERGY STAR Portfolio Manager median EUI estimate.

Table 20: K-12 Site EUI (kBTU) Comparison with Secondary Sources

MA Data Median – Capped Outliers	MA Data Mean – Capped Outliers	ENERGY STAR Portfolio Manager - Median	DOE 2010-2019 (MA, CT, NY) - Median	NBI – Climate Zone 5A – Mean	MA Data vs ENERGY STAR % Difference - Median
65	69	48.5	86	26.5	34%

Table 21 breaks down the K-12 buildings into building size categories. About 81% of the buildings were >50,000 ft^2 with a CV of 30%. The CV value for all MA Data K-12 buildings is 40%.

Table 21: K-12 Site EUI (kBTU) – MA Data

Building Size	Median – Capped Outliers	Mean – Capped Outliers	N		CV – Capped Outliers	CV – All Records
			All Records	Outliers		
<10,000 ft^2	56	48	4	1	31%	49%
10,000-50,000 ft^2	111	110	4	0	44%	44%
>50,000 ft^2	65	66	34	4	30%	112%
All K-12 Buildings	**65**	**69**	**42**	**5**	**40%**	**104%**

2.1.9 Conduct EUI Baseline Study

The NMR team recommends conducting a similar EUI baseline study in three years. CBECS is expected to update its building characteristics data in the summer of 2021 and its energy consumption data in the summer of 2022. The new CBECS data will include building stock constructed between 2010 and 2018. The future baseline study should use the revised CBECS data.

The baseline study should coordinate with the relevant market effect studies, with an emphasis on providing insights for better alignment between the updated baselines and the net-to-gross approach.

2.2 CONSIDERATIONS

2.2.1 EUI Baselines Update

The new program paths 1 and 2 are primarily focused on reducing the building EUIs. As more projects participate in these paths with site-specific simulation models used as the basis to determine baseline EUIs, the PAs will start building an EUI baselines repository by virtue of documenting the details in the project files. This information, specifically from projects with

building simulation models, could be useful to re-assess the baseline EUI values as part of future program evaluations (or at least once every five years). As the number of projects participating in these two paths increase, EUI baseline values could be recommended for more building types.

CBECS is expected to update its building characteristics data in the summer of 2021 and its energy consumption data in the summer of 2022. The new CBECS data will now include building stock constructed between 2010 and 2018.

The following are the key considerations for the PAs as they update the EUI baselines:

a. Capture and track the EUI values appropriately in their existing tracking system to facilitate future baseline efforts.

b. Specifically account for the influence of participant and non-participant baseline values.

2.2.2 Site-specific EUI Baselines

This study recommends EUI baselines for only eight building types. The rest of the building types either lack sufficient sample or were found to have a high CV, making it difficult to assign a specific EUI baseline value. The PAs are currently in the process of identifying building characteristics that will make the building an outlier. For buildings without recommended EUI baseline values or for those considered outliers, the PAs may opt to continue the current practice of determining site-specific EUI baseline values.[19]

[19] Any project using site-specific baseline will be subject to baseline risk, consistent with past evaluation practices.

Appendix A Box Plots