

## Deep Energy Retrofits in Nova Scotia



## **Acknowledgments**

Writing this paper was a collaborative effort between EfficiencyOne and the Halifax Regional Municipality. It conducts a detailed analysis of Nova Scotian housing, commercial, and institutional building stock to assess the potential and challenges for an integrated, whole building approach to deep energy efficiency retrofits.

This endeavor would not be possible without the contributing authors from EfficiencyOne and contributing author Kevin Boutilier from the Halifax Regional Municipality.

## Executive Summary

Nova Scotia has set ambitious climate change goals, targeting a 53% reduction in greenhouse gas (GHG) levels from 2005 by 2030 and net-zero<sup>1</sup> provincial emissions by 2050. Nova Scotia has led the country in reductions – achieving a 30%<sup>2</sup> reduction of total emissions since 2005. These historical reductions have been mainly achieved by adding renewable energy to the electricity supply, reducing reliance of fossil fuel-based power generation, and through energy efficiency programs. Efficiency Nova Scotia programs have led to 22% of the total emission reductions since 2011. The challenge is that reductions from adding renewable energy to the grid will have less impact on emissions after 2035 when the grid is expected to be much less carbon intensive. Combustion engine light duty vehicles will no longer be offered for sale by this time, and we will need an increased focus on energy efficiency to achieve decarbonization targets.

The three most prominent sources of GHG emissions in Nova Scotia are power generation, transportation, and buildings. The electricity and fossil fuels used in Nova Scotia buildings currently account for 45% to 53% of total provincial emissions, with much of that energy being used to heat indoor space and domestic water. The most cost-effective pathways to meeting environmental policy goals must include deep energy efficiency retrofits to homes and buildings. Deep energy retrofits go beyond basic upgrades to achieve reductions in annual energy use by 50%, or more. Thus, homes and buildings that undergo a deep energy retrofit would only require 50% or less of their energy needs be met by renewable energy generation sources to achieve net-zero emissions.

The analysis we conducted combines the findings from two key sources – independent modeling of common Nova Scotian building archetypes to assess costs and savings for upgrade paths, and market research -- to identify non-technical barriers.

We analyzed the technical, financial, and market-related challenges of implementing deep energy retrofits for Nova Scotia's commercial and institutional (C&I) and residential buildings. Industrial buildings were not included due to their varying and unique requirements. We selected representative archetypes, created models to analyze the energy savings from upgrade packages, estimated the costs of the upgrade packages, and extrapolated these across the building population to estimate the magnitude of the challenge. We surveyed and talked to homeowners, C&I decision makers, contractors, and consultants to understand the perspectives, motivations, and barriers faced by customers and the industry.

Not only are the technologies readily available to achieve deep energy retrofits across Nova Scotia, but they are more cost-effective than generating energy from renewable or non-emitting sources. The cost of deep energy retrofits over the expected lifetime ranges from -\$277 to \$18 per tonne of CO<sub>2</sub> avoided. In contrast, renewable energy generation is estimated to cost between \$236 to \$2089 per tonne of CO<sub>2</sub> avoided over the expected lifetime. This lifetime cost of carbon avoided is applicable to renewable energy generation technologies available now in Nova Scotia including wind, solar photovoltaic, hydro, tidal, and geothermal. Deep energy retrofits have the added benefit of resulting in utility bill savings for consumers

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<sup>1</sup> Net-zero does not mean that 100% of all GHG emissions will be eliminated. To achieve net-zero, the balance between emissions and offsets must add to zero.

<sup>2</sup> GHG emissions in 2020 were abnormally low due to the pandemic and are expected to rise in 2022. For that reason, our projections are based on 2019 emissions.

post-investment, which explains the negative cost per tonne of CO<sub>2</sub> avoided for some deep energy retrofits.

Among Canadian provinces, Nova Scotia has unique challenges: it has a relatively old building stock, oil is still a prominent source of heating energy (which must also be converted to electric or a clean fuel), and an estimated 27% of households in the Halifax Regional Municipality (HRM), and an overall average of approximately 43% elsewhere in the province, experience energy poverty and are challenged financially to pay for expensive upgrades (energy poverty rates vary greatly as commodity costs have changed significantly over the past year).

A key benefit to homeowners and building owners undertaking energy-efficiency retrofits is the reduction of utility bill costs. A review of deep energy retrofit lifetime utility bill savings and the upfront retrofit costs indicates savings will outpace the initial investment. The lifetime savings exceed the retrofit cost<sup>3</sup> by 110% to 310%.

Given the high cost of deep energy retrofits and the levels of energy poverty in Nova Scotia, it is important that we overcome financial barriers by establishing and marketing programs that directly address energy poverty. Accessibility of programs and affordability must be important considerations when planning programs and developing policies for deep energy retrofits.

Home and business owners generally understand the benefits of energy efficiency retrofits. However, there is much economic uncertainty and a limited ability<sup>4</sup> to pay for large capital projects. Without considering the costs, 40% of homeowners and 30% of businesses would be willing to undertake deep energy retrofits now, with energy bill savings being the primary motivator. When considering costs, only 12.5% of homeowners and 14.3% of businesses would be willing to undertake retrofits or able to make the needed investment without innovative financing solutions, increased monetary incentives, and other forms of support.

Although innovative forms of financing such as interest buy-downs, extended loan terms, and risk-sharing mechanisms could help close the gap between deep energy retrofit costs and customers' ability to pay, financing alone will not be sufficient. Without incentives, average simple payback periods (not including the costs to address added non-technical barriers described below) are 17 years for homes and 13 years for C&I buildings, which requires loans over longer terms than many are not willing or able to accept.

A review of the investments and energy savings from a decade of energy efficiency programs shows that existing programs are not delivering energy savings that are at the levels of deep energy retrofits. Lack of programs and insufficient incentives due to program budgets or eligibility constraints are current barriers to the delivery of deep energy retrofits. Demand Side Management (DSM) programs funded by electricity ratepayers must pass a cost-effectiveness test that, in its current form, is challenging for deep energy retrofits, indicating a gap between government policy goals and the regulatory requirements for DSM programs. Furthermore, limited or absence of financial incentives makes it difficult for C&I building owners seeking to reduce their non-electrical energy use.

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<sup>3</sup> This ratio is of that of the first-year upgrade costs to the sum of nominal annual bill savings expected to occur over the lifetime of the measures.

<sup>4</sup> Narrative Research. (2022). *2022 Deep Energy Retrofit Quantitative and Qualitative Report*.

The least-expensive time to make any building energy efficient is during its design and construction, or during major renovations. Once constructed or upgraded, it could be decades before a home or building owner is willing or able to make further major investments. In the coming years, the energy efficiency requirements of building codes will need to evolve and be adopted at a pace that ensures we are not creating new buildings that need expensive upgrades later in their life to meet longer-term GHG targets.

Although the technology is available now for many homes and businesses to achieve deep emissions reductions through energy efficiency, there remain challenges in bringing these products to market at scale.

Deep energy retrofits present added barriers for customers. For example, some buildings will need electrical service upgrades or structural repairs before they can be retrofitted; others will require abatement of harmful substances such as asbestos; and owners of commercial, institutional, and multi-family buildings will incur added costs if they need to displace tenants for intrusive work such as building-envelope upgrades. While these activities do not directly produce energy savings, they are necessary for deep energy retrofits to happen, so future programs and policies must consider these as integral project costs. It is also important to recognize that homes in marginalized communities often have a disproportionate need for such upgrades, while their owners are experiencing energy poverty.

A deep energy retrofit is not merely a technical challenge. These complex projects require coordination of multiple trades and project management, which can be overwhelming for home and small business owners. This support must be provided by future funding and programs as its costs will be significant and unaffordable for many.

If programs and funding are available, more industry capacity will be needed to do the work. To meet climate goals over the next decade, upwards of 1.5 million green-building-sector professionals will be required across Canada (including more than 31,000 in Nova Scotia) – a threefold increase in the current workforce. This is a significant opportunity for long-term job creation and economic benefit.

From E1's own experience and market research some contractors responsible for installing individual energy saving measures (e.g., heat pumps) are currently unwilling to manage entire deep energy retrofit projects or they lack the needed expertise.<sup>4</sup> General contractors who have this project management experience and skill set are reluctant to take on what they perceive to be high-risk projects, especially when many cannot meet the current demand for their services. Future programs will need to mitigate this issue through training, demonstration projects, and stable, long-term program funding commitments.

With support, industry members would be willing to undertake more intensive energy efficiency projects. However, residential contractors have been limited by capacity, limiting their ability to educate and inform customers about the benefits of energy efficiency when responding to renovation requests. That support and education would need to be provided by future programs, and by institutional education and training for industry.<sup>4</sup>

Building industry capacity is an iterative cycle; policies, programs, and training must provide effective support and adequate funding to create market demand. Businesses in the sector will respond to market

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<sup>4</sup> Narrative Research. (2022). *2022 Deep Energy Retrofit Quantitative and Qualitative Report*.

demand by investing in capacity to offer new services, providing there is adequate and predictable support over their investment horizons. In addition to creating an attractive investment climate, programs for training and education should seek other innovative ways to help a business grow in this sector such as the Center for the Built Environment at Nova Scotia Community College (NSCC).

Although Nova Scotia has led the country in reducing GHG emissions, as electricity becomes less carbon intensive, increasing focus on energy efficiency will be needed to achieve net-zero targets. Completing deep energy retrofits at scale can make a substantial contribution to this effort.

In summary, deep energy retrofits of Nova Scotia's building stock are needed to meet net-zero policy goals and are technically feasible today. Implementation of these upgrades at the needed pace will require a step-change from the levels of investment and support currently offered to building owners and industry. A disruptive, large-scale, adequately funded set of initiatives that addresses the barriers and constraints identified in this paper will be needed to meet Nova Scotia's and Canada's ambitious emissions reduction goals.

We have identified 19 recommendations in five key areas that we believe can help bring deep energy retrofits to market. The five key areas the recommendations focus on include improving core economic factors for Nova Scotians, increasing industry capacity, addressing challenges around cost-effectiveness and ratepayer-funded energy efficiency programs, increasing market awareness, and engaging building owners. Recommendations can be found below and in both Section 5: Conclusions and Recommendations and Appendix D: Recommendations.

1. ***Deep energy retrofit projects are cost prohibitive to both homeowners and business owners. Multiple initiatives are required to improve the core economic factors for Nova Scotians to undertake deep energy retrofits.***

| <b>Key Challenges:</b>                                                     | <b>Recommendations:</b>                                                                                                                                                                                                                                                                |
|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| High cost of deep energy retrofit projects                                 | <b>R1.1</b> Substantially increase incentives to help alleviate the costs of deep energy retrofits for Nova Scotia building owners.                                                                                                                                                    |
| Lack of economic incentives                                                | <b>R1.2</b> Investigate tax strategies to drive the needed pace of deep energy retrofits (tax-based economic drivers could be an effective form of incentive along with program rebates).                                                                                              |
| Lack of existing economical upgrade packages for exterior facade retrofits | <b>R1.3</b> Provide support for exterior-facade retrofits (financial, marketing, education, training) and incentivize large-scale community retrofits to minimize per-project costs.                                                                                                   |
| Availability of costing information                                        | <b>R1.4</b> Conduct additional research to quantify and refine updated Energy Conservation Measure (ECM) costs by building type and other enabling project costs when deep energy retrofit programs are being developed. This information will help refine estimates for the levels of |

| <b>Key Challenges:</b>                                                                                                                                                                  | <b>Recommendations:</b>                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                         | incentives needed to increase program uptake and build a database of knowledge to be shared with contractors.                                                                                                                                                 |
| Detailed non-electrical energy consumption data for commercial, industrial, and institutional buildings in Nova Scotia would be helpful in the design of a deep energy retrofit program | <b>R1.5</b> Absent is a requirement for mandatory reporting or building performance labeling, conduct research to gather this information by archetype, for all non-electric energy consumption.                                                              |
| Lack of financing options                                                                                                                                                               | <b>R1.6</b> Government innovative financing program for deep energy retrofit costs at attractive interest rates that have repayment terms of more than 15 years. One option could be to share risk with project owners by creating a loan-loss recovery fund. |
| Limited awareness and understanding of deep energy retrofits among consumers                                                                                                            | <b>R1.7</b> Invest in education and awareness programs and services that advance consumer knowledge of the economic benefits, energy benefits, emission reductions, and non-energy benefits (NEBs) associated with deep energy retrofits.                     |
| Limited incentives for saving non-electrical energy in commercial, industrial, and institutional buildings                                                                              | <b>R1.8</b> Future programs for these sectors should provide incentives for deep energy retrofits that save non-electrical energy.                                                                                                                            |

**2. *There is a need for more industry capacity to undertake wide-scale deep energy retrofit projects.***

| <b>Key Challenges:</b>                                                       | <b>Recommendations:</b>                                                                                                                                                                                                                                                                                                                                                                                |
|------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Limited project management capacity, equipment, and trade experience         | <b>R2.1</b> Build capacity by investing in specialized project management and trades programs as well as the tools and equipment needed to complete these projects. Future programs and policies should create a stable, predictable investment climate that encourages private industry to grow capacity and increase the number of qualified professionals willing to deliver deep energy retrofits. |
| Building codes must continue to drive improvements in construction practices | <b>R2.2</b> Adoption of tiered building codes and a future retrofit code as early as possible will heighten industry focus on developing the needed skills and building designs to implement deep energy retrofits.<br><br>All municipalities in Nova Scotia should use the same codes (i.e., NBC, NECB, and any future retrofit code) to ensure continuity in the market, but the provincial          |

| <i>Key Challenges:</i>                                                                              | <i>Recommendations:</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                     | government should set an energy performance tier floor and afford municipalities the discretion to require higher tiers within those codes if desired.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Deep energy retrofits are rare, custom, one-off projects that are not appealing to many contractors | <b>R2.3</b> Reducing costs via incentives and economies of scale by incentivizing large-scale, community retrofits that would enable bulk pricing for that community and create a compelling business case for contractors.                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Technical solutions are well-known, but new delivery models are needed to succeed                   | <p><b>R2.4</b> Exterior facade retrofits are extremely costly. If the cladding on a building is being replaced, the incremental cost of adding insulation and replacing windows is the lowest it will ever be. Programs that provide incentives to encourage comprehensive exterior facade retrofits whenever cladding or window replacement projects occur will leverage this advantage and maximize savings potential of otherwise costly upgrades.</p> <p>Combining such programs with investments in scalable, repeatable solutions such as the Energiesprong-inspired ReCover initiative could simplify and make facade retrofits more economical through economies of scale.</p> |

**3. Deep energy retrofits do not pass the current cost-effectiveness test for electricity ratepayer-funded energy efficiency programs.**

| <i>Key Challenges:</i>                                                                          | <i>Recommendations:</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|-------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Limited scope of cost-effectiveness testing for electricity ratepayer-funded programs           | <b>R3.1</b> Expand the scope of the current cost-effectiveness test used for DSM programs. Focus should be placed on added non-energy benefits, such as improved health and safety, reduced operating and maintenance costs, auxiliary costs, increased comfort, and reduced carrying costs to the utility system. Without considering these benefits, it may limit the ability to design and deliver innovative pilot programs that could reduce the barriers to deep energy retrofits. |
| Deep energy retrofit projects incur enabling costs which are not considered in current programs | <b>R3.2</b> Programs should not exclude the cost of enabling activities such as service upgrades, structural issues and/or the abatement of harmful substances.                                                                                                                                                                                                                                                                                                                          |

**4. The market currently has limited awareness of how to implement deep energy retrofits.**

| <b>Key Challenges:</b>                                                                            | <b>Recommendations:</b>                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Limited education and awareness on how to undertake deep energy retrofits in homes and businesses | <b>R4.1</b> Launch a program dedicated to deep energy retrofit education and awareness. The program should facilitate the following: <ul style="list-style-type: none"> <li>• Guidance on ECM upgrade packages for different building and home archetypes.</li> <li>• Guidance on available incentives and financing options for ECM upgrade packages.</li> </ul> |
| Limited understanding of the true measure life of various deep energy retrofits                   | <b>R4.2</b> Commission further analysis to determine the measure life of various deep energy retrofit scenarios for each representative building archetype to better quantify financial return on investment and risk assessments to instill confidence in home and business owners.                                                                              |

**5. Building owners have an important role to play.**

| <b>Key Challenges:</b>                                                | <b>Recommendations:</b>                                                                                                                                                                                                                                                                                                                                                                                           |
|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Procurement strategies must include energy efficiency                 | <b>R5.1</b> When procuring engineering design services, place increased focus on the need to include energy efficiency measures and take advantage of incentive programs.                                                                                                                                                                                                                                         |
| Operational staff training for Energy Service Company (ESCO) projects | <b>R5.2</b> Buildings entering or undergoing an energy performance contract should place increased emphasis on staff training to sustain the project's energy savings and enhance the long-term cost savings of the project.                                                                                                                                                                                      |
| Planning for the long-term                                            | <b>R5.3</b> Building owners should consider the need for deep energy retrofits when planning major renovations and other activities intended to increase the building's Facility Condition Index. This should also include structural or other changes needed to make the building ready for solar PV, and including upgrades such as window replacements and exterior wall insulation during cladding retrofits. |

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| <b>Term</b>               | <b>Definition</b>                                                                                                                                           |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>ACH</b>                | Air changes per hour                                                                                                                                        |
| <b>AHU</b>                | Air Handling Unit                                                                                                                                           |
| <b>ASHP</b>               | Air-Source Heat Pump                                                                                                                                        |
| <b>BAS</b>                | Building Automation Systems                                                                                                                                 |
| <b>BAU</b>                | Business as Usual                                                                                                                                           |
| <b>Building envelope</b>  | Refers to the outer shell of the building which includes opaque assemblies (walls, ceilings) and transparent assemblies (windows, doors).                   |
| <b>C&amp;I</b>            | Commercial and Institutional                                                                                                                                |
| <b>CaGBC</b>              | Canada Green Building Council                                                                                                                               |
| <b>CCASHP</b>             | Cold climate air source heat pump                                                                                                                           |
| <b>CCHP</b>               | Cold climate heat pump                                                                                                                                      |
| <b>CCI</b>                | Consumer Confidence Index                                                                                                                                   |
| <b>CER</b>                | Canada Energy Regulatory                                                                                                                                    |
| <b>CEUD</b>               | Comprehensive energy use database                                                                                                                           |
| <b>DCV</b>                | Demand Controlled Ventilation                                                                                                                               |
| <b>DCW</b>                | Domestic Cold Water                                                                                                                                         |
| <b>DHW</b>                | Domestic Hot Water                                                                                                                                          |
| <b>DOAS</b>               | Dedicated Outdoor Air System                                                                                                                                |
| <b>DSM</b>                | Demand Side Management                                                                                                                                      |
| <b>DP</b>                 | Differential Pressure                                                                                                                                       |
| <b>E1</b>                 | EfficiencyOne                                                                                                                                               |
| <b>ECM</b>                | Energy Conservation Measure                                                                                                                                 |
| <b>EGCCRA</b>             | Environmental Goals and Climate Change Reduction Act                                                                                                        |
| <b>ENS</b>                | Efficiency Nova Scotia                                                                                                                                      |
| <b>ERV</b>                | Energy Recovery Ventilation                                                                                                                                 |
| <b>ESCO</b>               | Energy Service Company                                                                                                                                      |
| <b>EU</b>                 | European Union                                                                                                                                              |
| <b>FCI</b>                | Facility Condition Index                                                                                                                                    |
| <b>GHG</b>                | Greenhouse Gas                                                                                                                                              |
| <b>HEA</b>                | Home Energy Assessment                                                                                                                                      |
| <b>HRM</b>                | Halifax Regional Municipality                                                                                                                               |
| <b>HRV</b>                | Heat Recovery Ventilation                                                                                                                                   |
| <b>HTAP</b>               | Housing technology assessment platform                                                                                                                      |
| <b>HVAC</b>               | Heating, Ventilation, and Air Conditioning                                                                                                                  |
| <b>HW</b>                 | HomeWarming                                                                                                                                                 |
| <b>LCOC</b>               | Levelized Cost of Carbon                                                                                                                                    |
| <b>LED</b>                | Light Emitting Diode                                                                                                                                        |
| <b>Mechanical systems</b> | Equipment related to space and water conditioning, including but not limited to heat pumps, furnaces, and boilers; water heaters; and ventilation equipment |
| <b>MHEEP</b>              | Mi'kmaw Home energy Efficiency Project                                                                                                                      |
| <b>Mt</b>                 | Megatonne                                                                                                                                                   |
| <b>NEBs</b>               | Non-Energy Benefits                                                                                                                                         |
| <b>NBC</b>                | National Building Code                                                                                                                                      |

| <b>Term</b>     | <b>Definition</b>                    |
|-----------------|--------------------------------------|
| <b>NECB</b>     | National Energy Code for Buildings   |
| <b>NRCan</b>    | Natural Resources Canada             |
| <b>NREL</b>     | National Renewable Energy Laboratory |
| <b>OBPS</b>     | Output-Based Pricing System          |
| <b>Pa</b>       | Pascals of pressure                  |
| <b>RSU</b>      | Roof Top Unit                        |
| <b>SCR</b>      | Silicone Controlled Rectifier        |
| <b>Solar PV</b> | Solar Photovoltaic                   |
| <b>TRC</b>      | Total Resource Cost                  |
| <b>VAV</b>      | Variable Air Volume                  |
| <b>VFD</b>      | Variable Frequency Drive             |
| <b>WSHP</b>     | Water Sourced Heat Pump              |

## 1 Introduction

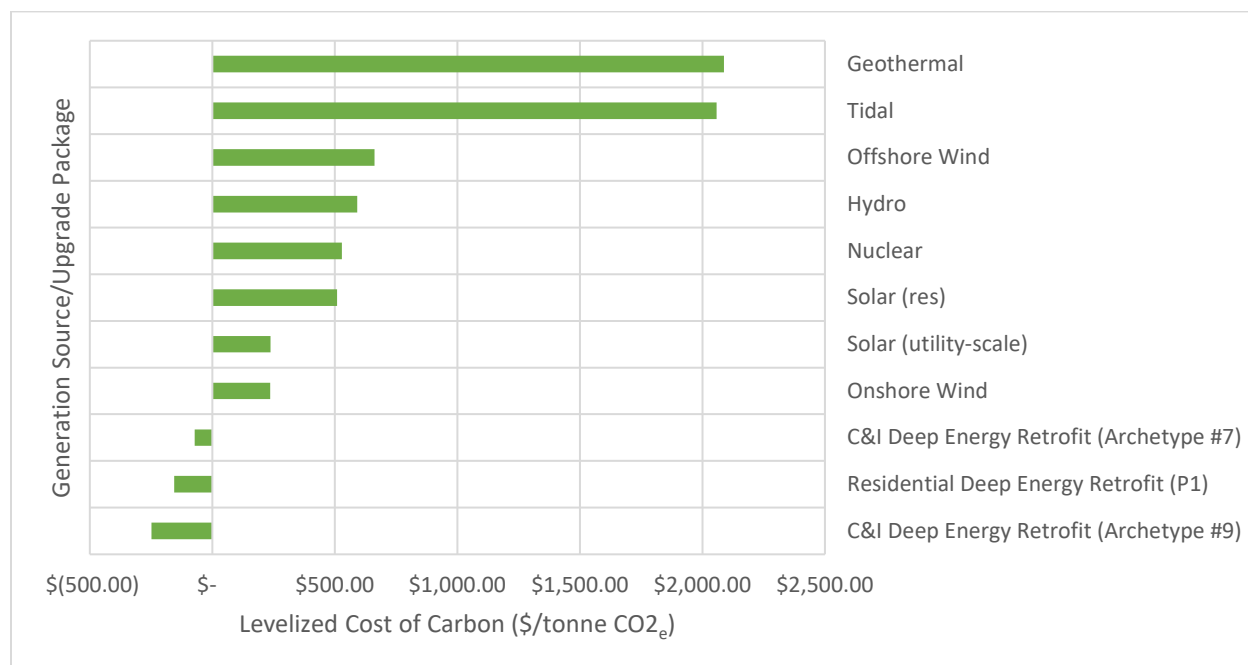
Decarbonizing buildings offer significant opportunities for scaling up industry, job creation, economic benefit, creating healthy spaces, reducing energy bills and long-term GHG reduction, but it also presents challenges. In 2020 in Nova Scotia, 45%-53% of emissions, or 6.6 to 7.7 Megatonnes (Mt) (electricity use included) was attributed to buildings. Currently, all pathways to achieve Nova Scotia's and Canada's emission reduction targets include deep and widespread energy efficiency improvements to the residential and commercial building stock. These upgrades are referred to in this paper as "deep energy retrofits"; they include energy efficiency upgrades to electrical systems, mechanical systems, and building envelopes resulting in energy savings of up to 50% or more compared to an unchanging state of operation, referred to here as business as usual (BAU). In practice, defining deep energy retrofits needs to be approached with nuance and care. The definition is expanded upon in section 3.1.

The built environment is facing increasing pressure from extreme weather and climate change; building stock climate resilience is a concern. Most buildings standing today will still be in use in 30 years. To achieve net-zero in a relatively cost-effective manner, as supported by our levelized cost of carbon (LCOC) analysis, we will need to retrofit most of them.

Many energy efficiency retrofits undertaken today do not go far enough. Home and building owners face technical, financial, and perceived barriers that need to be overcome before deep energy retrofits can be achieved at the necessary pace and scale. Overcoming these barriers offers an opportunity to reduce the cost of carbon abatement going forward.

The technical analysis portion of this paper includes estimated LCOC. This metric allows policy-makers to evaluate deep energy retrofits as a carbon mitigation strategy and compare it to other strategies in a like-for-like manner. LCOC can be determined for renewable energy generation, carbon sequestration and deep energy retrofits considering the initial investment and operating costs over the expected lifetime. Figure 1 shows that the LCOC is significantly lower for deep energy retrofits of common homes and buildings than it is for prevalent renewable energy generation technologies. In the residential space, the average LCOC for the upgrade packages examined ranged from -\$181/tonne of CO<sub>2</sub> avoided to -\$150/tonne of CO<sub>2</sub> avoided. In the commercial and institutional (C&I) space, the average for deep energy retrofits ranged from -\$277/tonne of CO<sub>2</sub> avoided to \$18/tonne of CO<sub>2</sub> avoided while renewable generation ranged from \$236/tonne of CO<sub>2</sub> to \$2089/tonne CO<sub>2</sub> avoided. The lower the LCOC the more cost-effective the carbon mitigation strategy.

Figure 1: Levelized Cost of Carbon for Deep Energy Retrofits and Renewable Energy Generation<sup>5</sup>



A key benefit for homeowners and building owners undertaking energy-efficiency retrofits is the reduction of utility bill costs. A review of deep energy retrofit lifetime utility bill savings and retrofit costs indicates savings will outpace the initial investment. For C&I buildings, the ratio of lifetime savings to retrofit cost<sup>6</sup> ranges from 110% to 310%. For example, a deep energy retrofit of a typical multi-storey office building in Nova Scotia would cost \$2.2M which would result in a 50% energy-reduction or \$4.2M saved over the lifetime of the efficient equipment. For residential buildings, four different upgrade packages were modelled across a sample of building archetypes. The average ratio of lifetime savings to retrofit costs ranges from 150% – 170%.

Retrofitting Nova Scotia’s building stock will require novel approaches to financing, building industry capacity, innovative programs, and policy changes. We need to transform government and utility programs, adopt more stringent building codes, and drive more investment toward deep decarbonization. Otherwise, we cannot achieve net-zero.

In this paper, we analyze the energy, energy cost, and utility bill savings potential and estimate costs for improving Nova Scotia's building stock using deep energy retrofits, assess the current market readiness, discuss practical considerations, and suggest policy interventions that will help accelerate the adoption of

<sup>5</sup> Nova Scotia Power. (2023). *2022 Evergreen IRP Updated Assumptions, January 26, 2023* and NS Power emissions intensity forecasts used as the basis of the renewable generation LCOC calculations. Deep retrofit LCOC calculations were calculated using E1 internal technical tables and NS Power emissions intensities.

<sup>6</sup> This ratio is of that of the first year upgrade costs to the sum of nominal annual bill savings expected to occur over the lifetime of the measures.

these measures. Our findings are based on technical analyses of relevant retrofits as well as quantitative and qualitative market research to gauge customer and industry perceptions and motivations.

Due to the limited availability of data, the vast scope of potential modeling scenarios, and the scope of the market research, various assumptions and limitations of the research and analysis discussed in this paper are highlighted. For example, the analysis did not focus on electrification of building systems or include energy storage. As well, multiple sources of data were used in some scenarios, requiring cross-referencing and author interpretation. In some cases, sufficiently granular data was not available to consider nuances in architecture and technologies, and therefore generalizations have been made. Further detail on the assumptions and limitations of the research and analysis can be found in sections 1.2.1, 1.2.2, and 1.3. Broadly speaking, the results of this paper, and recommendations, are intended to convey the types and scale of benefits, issues, and potential solutions. In practice, the approach to a deep energy retrofit must recognize the individual building and building owner's unique set of circumstances. Due to the limitations of the analysis expressed within, this paper is not intended to be used for making investment decisions.

## **1.1 Scope**

This technical analysis builds on recommendations in *2050: Net-Zero Carbon Nova Scotia*, a white paper published by EfficiencyOne in 2021. The focus is on the approach, challenges, and solutions to making Nova Scotia's existing residential and commercial/institutional building stock as energy-efficient as needed to achieve net-zero in Nova Scotia. The emphasis of this paper is on reducing the energy needed to make buildings safe and comfortable through improvements to the envelope and other major systems, that lead to substantial benefits of using less energy and reducing GHGs.

This analysis does not address buildings in the industrial sector. These facilities have unique site-specific operations, equipment, and requirements. Related topics such as electrification of building systems, onsite renewable generation, and energy storage are also outside the scope of this analysis.

Implementing deep energy retrofits at scale is a technical challenge; it must address barriers related to cost, customer motivation, perceptions about technology, building readiness, accessibility of programs, industry capacity, and other factors. The analysis combines the findings from two key sources – independent modeling of common Nova Scotian building archetypes to assess costs and savings for upgrade paths, and market research -- to identify non-technical barriers. Our approach is detailed below in sections 1.2 to 1.3.

## **1.2 Technical Research: Methodology, Assumptions, and Limitations**

Different research methodologies and assumptions were used as the basis for the C&I building stock analysis than for the residential analysis. C&I research and modelling conducted by Eastpoint Engineering consisted of using a building population assessment, defining building archetypes and characteristics, creating energy models, assessing energy conservation measures, and estimating savings. The residential analysis was based on two sources of information, energy modeling performed by Natural Resources Canada (NRCan) and Nova Scotia housing stock statistics as described in NRCan's Comprehensive Energy Use Database (CEUD).

### 1.2.1 Methodology for Commercial and Institutional Building Stock

The research and analysis methodology used for the C&I building stock was divided into four phases:

1. Categorizing C&I buildings by property type;
2. Identifying building archetypes and characteristics by property type;
3. Modeling building energy use by archetype by a third-party consultant; and
4. Estimating costs and savings for energy conservation measures (ECMs) by archetype.

The following sections summarize the objectives and methodologies of each phase. Conclusions drawn from phases 3 and 4 are found in section 3.5.

#### 1.2.1.1 Building Population Assessment

A list of property types was created that accounted for an estimated 85% of the energy used in the C&I sector. This list became the basis for building archetype definitions used in later stages. The following data sources were used to establish population estimates for Nova Scotia’s C&I building stock, the number of businesses, and energy use by business type.

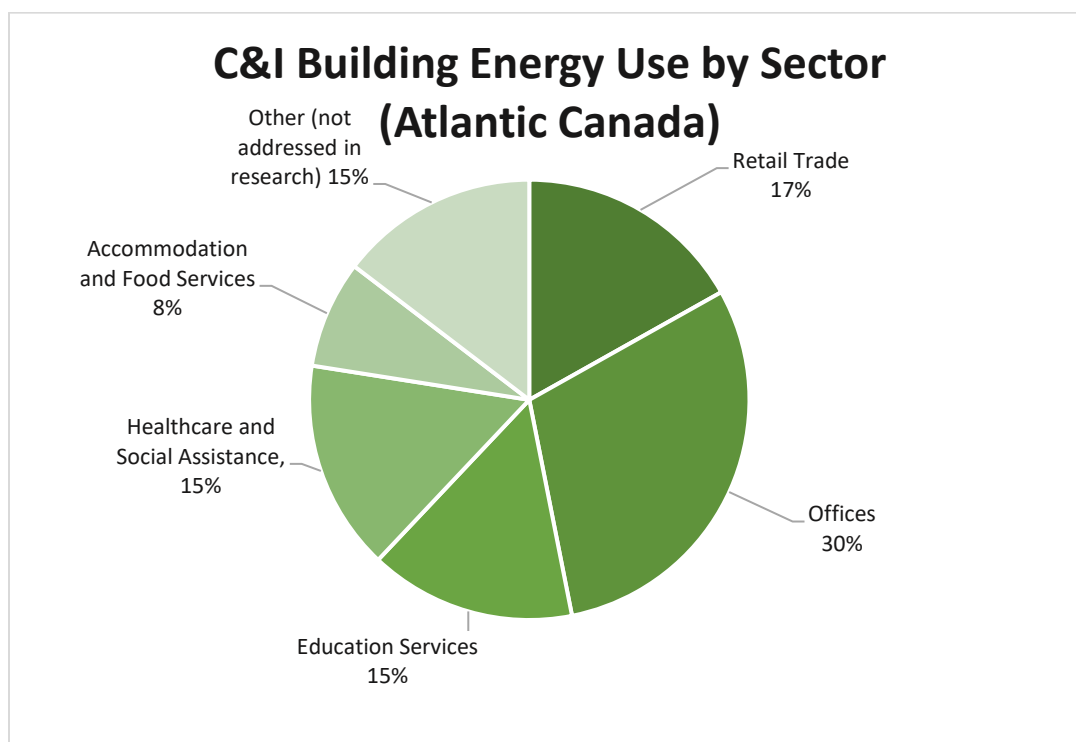
*Table 1: Data Sources used to Establish Population Estimates*

| Data Source                                                           | Considerations                                                                                                                                                                                        |
|-----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| NRCan’s comprehensive energy use dashboard (CEUD) for Atlantic Canada | <ul style="list-style-type: none"> <li>• Aggregated data for Atlantic Canada</li> <li>• Building energy use data by fuel source and business type</li> <li>• Total floor area estimates</li> </ul>    |
| Nova Scotia Power customer data (electrical energy consumption)       | <ul style="list-style-type: none"> <li>• Customers served directly by Nova Scotia Power</li> <li>• Building electrical energy consumption only</li> </ul>                                             |
| Dunn and Bradstreet Business Data                                     | <ul style="list-style-type: none"> <li>• Number of businesses by industry type</li> <li>• Detailed secondary and tertiary breakdown by business type</li> <li>• No energy consumption data</li> </ul> |

This study required energy consumption for all fuels to be accounted for within the C&I building stock. However, the Nova Scotia specific data referenced above had gaps that did not allow us to report on the consumption of all fuels in the C&I sector. The considerations noted in the previous table led us to conclude that the most reliable and accurate data source was the NRCan CUED. It had energy consumption (all fuels) tracked by industry categories and what NRCan referred to as “activity type.” (The activity types used in this study are defined later in this section). Figure 1 illustrates the building energy consumption for each activity type.

The five sectors shown in Figure 2 comprise approximately 85% of the C&I building stock energy use.

Figure 2: C&I Building Energy Use by Sector Atlantic Provinces (NRCan CUED)



Based on a review and cross-reference of data sources, we selected the property types listed in Table 2 for inclusion in a representative set of archetypes.

Table 2: NRCan Activity Type and Definition (CUED) and Selected Property Type

| NRCan Activity Type and Definition                                                                                                                                                                                                                                                     | Selected Property Type                                                                                                                    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Office</b><br>Includes activities related to: <ul style="list-style-type: none"> <li>• finance and insurance;</li> <li>• real estate, rental, and leasing;</li> <li>• professional, scientific, and technical services; and</li> <li>• public administration and others.</li> </ul> | <ul style="list-style-type: none"> <li>• Small single-storey building</li> <li>• Large multi-storey building</li> </ul>                   |
| <b>Retail</b><br>This sector comprises establishments primarily engaged in retailing merchandise, generally without transformation, and services incidental to the sale of merchandise.                                                                                                | <ul style="list-style-type: none"> <li>• Small format store (e.g., strip mall)</li> <li>• Large format store (single building)</li> </ul> |

| <i><b>NRCan Activity Type and Definition</b></i>                                                                                                                                                                                                                                                                                                                                                                                        | <i><b>Selected Property Type</b></i>                                                                                                                                  |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p><u>Educational Services</u></p> <p>This subsector comprises establishments primarily engaged in providing instruction and training in a wide variety of subjects. This is provided by specialized establishments such as public schools, colleges, universities, and training centres.</p>                                                                                                                                           | <ul style="list-style-type: none"> <li>• Small format school</li> <li>• Large format school</li> </ul>                                                                |
| <p><u>Health Care</u></p> <p>This sector comprises establishments primarily engaged in providing health care by diagnosis and treatment; providing residential care for medical and social reasons; and providing social assistance such as child protection, community housing and childcare to those requiring such assistance.</p>                                                                                                   | <ul style="list-style-type: none"> <li>• Residential care, outpatient, and senior-living community</li> </ul>                                                         |
| <p><u>Accommodations and Food Service</u></p> <p>This sector comprises establishments primarily engaged in providing short-term lodging and complementary services to travelers, vacationers, and others in facilities such as hotels, motor hotels, resorts, and cabins. This sector also comprises establishments primarily engaged in preparing meals, snacks, and beverages, for immediate consumption on and off the premises.</p> | <ul style="list-style-type: none"> <li>• Small format (i.e., stand-alone restaurant)</li> <li>• Large format (i.e., multi-storey hotel with food services)</li> </ul> |

Property types that could have specialty equipment or site-specific operational considerations, such as university buildings with lab equipment unique to a site, were excluded from the modeling. Multi-unit residential buildings are considered as well as residential care facilities but differ in many ways discussed later in this paper.

### **1.2.1.2      *Defining Building Archetypes and Characteristics***

In consideration of the cost and time to develop energy models, we limited energy modeling to two building archetypes per property type.

The following table summarizes the primary architectural, building envelope, and mechanical and electrical systems that define each building archetype.

Table 3: Building Archetype Definitions

| Characteristic                   | Parameters Modeled                                                                                                                                                                                                                    |
|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Building Size</b>             | Conditioned floor area                                                                                                                                                                                                                |
| <b>Building Envelope</b>         | Insulation values for: <ul style="list-style-type: none"> <li>• Ceiling;</li> <li>• Above grade walls;</li> <li>• Below grade walls;</li> <li>• Slabs;</li> <li>• Exposed floors;</li> <li>• Glazing; and</li> <li>• Doors</li> </ul> |
| <b>Period of Construction</b>    | Year of construction                                                                                                                                                                                                                  |
| <b>Heating System</b>            | Central heating type and zone heating type                                                                                                                                                                                            |
| <b>Ventilation System</b>        | Central ventilation type                                                                                                                                                                                                              |
| <b>Cooling System</b>            | Central cooling system type, and zone cooling system type                                                                                                                                                                             |
| <b>Domestic Hot-Water System</b> | Hot water system and fuel type most representative of the Nova Scotia building stock for a given property type                                                                                                                        |
| <b>Lighting System</b>           | Lighting technology and lighting controls (if applicable) most representative of the Nova Scotia building stock for a given property type                                                                                             |
| <b>Building Controls</b>         | Non-lighting controls and building automation systems (if applicable) most representative of the Nova Scotia building stock for a given property type                                                                                 |
| <b>Ancillary Equipment</b>       | Appliances, computing, server rooms, etc. most representative of the Nova Scotia building stock for a given property type                                                                                                             |

The specific building archetype definitions for all 10 commercial and institutional building archetypes are summarized in Appendix B. However, an example of the retail building archetypes definition is included in the following two tables.

### 1.2.1.3 Retail Building Archetype Definitions

#### Archetype 1 – Large Single-Building Retail Store

Table 4: Building Archetype Definition – Archetype 1

| Characteristic                              | Parameters Modeled                                                |
|---------------------------------------------|-------------------------------------------------------------------|
| <b>Building Size<br/>(total floor area)</b> | 15,675 m <sup>2</sup>                                             |
| <b>Occupied Schedule</b>                    | Sunday to Saturday – 7:00am to 10:00pm                            |
| <b>Building Envelope</b>                    | <ul style="list-style-type: none"> <li>• Wall Assembly</li> </ul> |

|                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                  | <ul style="list-style-type: none"> <li>○ Concrete tilt-up</li> <li>○ Assumed R-Value (<math>\text{ft}^2 \text{ } ^\circ\text{F h/BTU}</math>) of R-18</li> <li>• Roof Type <ul style="list-style-type: none"> <li>○ Modified bitumen</li> <li>○ Assumed R-Value (<math>\text{ft}^2 \text{ F h/BTU}</math>) of R-30</li> </ul> </li> <li>• Windows <ul style="list-style-type: none"> <li>○ Metal insulated double pane</li> <li>○ Assumed U-Value (<math>\text{BTU} / \text{ft}^2 \text{ } ^\circ\text{F h}</math>) of 3</li> </ul> </li> <li>• General <ul style="list-style-type: none"> <li>○ Window-to-wall ratio of 5%</li> </ul> </li> </ul> |
| <b>Period of Construction</b>    | 2000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Heating System</b>            | Propane-fired roof-top unit (RTU)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Ventilation System</b>        | Packaged roof-mounted air-handling units                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Cooling System</b>            | RTU – direct-expansion air conditioning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| <b>Domestic Hot-Water System</b> | Electric boiler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Lighting System</b>           | <ul style="list-style-type: none"> <li>• Primary lighting – fluorescent T8</li> <li>• Secondary lighting – high-pressure sodium (HPS)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

### Archetype 2 – Small Retail Store (Strip Mall)

Table 5: Building Archetype Definition – Archetype 2

| Characteristic                   | Parameters Modeled                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Building size</b>             | 7,760 $\text{m}^2$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Occupied Schedule</b>         | Sunday to Saturday – 9:00am to 9:00pm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Building Envelope</b>         | <ul style="list-style-type: none"> <li>• Wall Assembly <ul style="list-style-type: none"> <li>○ Concrete tilt-up</li> <li>○ Assumed R-Value (<math>\text{ft}^2 \text{ } ^\circ\text{F h/BTU}</math>) of R-18</li> </ul> </li> <li>• Roof Type <ul style="list-style-type: none"> <li>○ Tar and gravel roof with a metal roof deck</li> <li>○ Insulated</li> <li>○ Assumed R-Value (<math>\text{ft}^2 \text{ F h/BTU}</math>) of R-24</li> </ul> </li> <li>• Windows <ul style="list-style-type: none"> <li>○ Metal insulated double pane</li> <li>○ Assumed U-Value (<math>\text{BTU} / \text{ft}^2 \text{ } ^\circ\text{F h}</math>) of 3</li> </ul> </li> <li>• General <ul style="list-style-type: none"> <li>○ Window to Wall ratio of 5%</li> </ul> </li> </ul> |
| <b>Period of Construction</b>    | 2000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Heating System</b>            | Propane-fired RTU                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Ventilation System</b>        | Packaged roof-mounted air-handling units                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Cooling System</b>            | RTU – direct-expansion air conditioning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Domestic Hot-Water System</b> | Electric boiler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Lighting System</b>           | <ul style="list-style-type: none"> <li>• Primary lighting – fluorescent T8</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

| Characteristic | Parameters Modeled                                                                                |
|----------------|---------------------------------------------------------------------------------------------------|
|                | <ul style="list-style-type: none"> <li>Secondary lighting – high-pressure sodium (HPS)</li> </ul> |

#### **1.2.1.4 C&I Building Energy Modeling by Archetype**

C&I building archetypes were modeled using RETScreen Expert, software that identifies and assesses the financial viability of ECMs. To improve the accuracy of the energy models, a calibrated simulation of the model was performed using a comparable real-world reference building. This enabled the adjustment of the model parameters to match each model’s predicted energy consumption with utility bills for the corresponding reference building. Furthermore, climate zone 6 and representative weather station data was used to simulate the climate in Nova Scotia. Energy modeling findings are summarized in section 3.5.

#### **1.2.1.5 Estimation of ECM costs and savings by archetype**

ECM packages were built for each building type using the following scenarios:

- Shallow retrofit (30% total building energy savings)
- Deep energy retrofit, Scenario 1 (50% total building energy savings)
- Deep energy retrofit, Scenario 2 (70% total building energy savings)

Multiple scenarios were modeled for each building archetype to quantify potential energy savings, upgrade costs, specific measure packages, etc. These findings are summarized in section 3.5.

ECM upgrades were prioritized by financial viability and electrification potential for a given archetype. These priorities were drawn from the experience of our Business Development Manager (BDM) and Energy Manager (EM) teams.

#### **Levelized Cost of Carbon – C&I Buildings**

Levelized cost of carbon figures included in this paper for C&I buildings are estimated over the assumed lifetime of the upgrade packages and savings scenarios being evaluated. Lifetime savings projections were based on the respective building systems included in each archetype energy model. Lifetime savings projections were based on estimated measure lives specific to the building archetype and six different measure categories: motor, space heating, space cooling, domestic hot water, lighting, and plug-load. A discount rate of 2.5% was applied<sup>7</sup>, and all energy costs were assumed to escalate at a rate of 2% per year. Electricity emissions intensity varied annually based on Nova Scotia Power Integrated Resource Plan (IRP) results<sup>8</sup>. Maintenance costs were not included due to a lack of sufficient data; however, it should be noted that the exclusion of maintenance costs was symmetrical, i.e., both the upgrade and base case did not contain these costs.

<sup>7</sup> Bank of Canada 10 year savings bond – 2023/01/12

<sup>8</sup> CO<sub>2</sub> k tonne by year are based on Nova Scotia Power IRP Final Report Appendix F, Scenario 2.0C. Net System Requirement (load in GWh) are from NSP 10-Year System Outlook report filed with NS UARB. Assumed NSP load values for 2033-2045 by applying the forecast annual average increase of 0.3%, reference NSP 10-Year System Outlook report page 7 for 2022-2032 growth.

## Commercial and Institutional Limitations and Assumptions

Several assumptions formed the basis of the C&I research.

- Multiple sources of data were used to link building energy use with business classifications. The cross-referencing required interpretation as each data set used different terminology.
- The industrial sector was excluded because the unique characteristics of each site do not result in representative archetypal modeling.
- Different real-world buildings within each archetype have different heating and cooling equipment and building envelope characteristics. Cost estimates to implement upgrades may not reflect the initial state of each building and the specific improvements required.
- A key assumption is that C&I businesses would invest in deep energy retrofits so long as they were financially viable. This assumption was based on our experience working with businesses and was supported by market research. However, it is possible that in some scenarios a business will prioritize less financially attractive energy efficiency projects. For example, the decision might be made to replace existing windows with triple-glazed windows as part of a renovation project because the existing windows are at the end of their useful life. In this example, there could be other ECMs that are more financially attractive and readily implemented; thus, this decision is motivated as a renewal project with a focus on aesthetics and function. For this study, ECM upgrade packages were built for three savings scenarios: 1) Shallow energy retrofits (30% savings of BAU), 2) deep energy retrofits (50% savings), and 3) deep energy retrofits (70% savings). The upgrade packages are successively less financially attractive. The assumption is that the number one priority is maximizing financial return for every dollar invested in ECMs.
- Net present value evaluation was excluded from the technical results section of this paper. This is because there is limited available ECM measure life data to draw reliable and representative conclusions. The recommendations included in this paper highlight the need for further analysis of measure life for those ECMs included in each building archetype upgrade package.

### **1.2.2 Methodology for Residential Building Stock**

Two sources of information were used to analyze the savings and costs of deep energy retrofits on the existing housing stock of Nova Scotia:

1. Energy modeling previously performed by NRCan
2. Summary statistics of the provincial housing stock as described in NRCan's CEUD

Energy modeling was performed using a sample of households from NRCan and was extrapolated over the Nova Scotian housing stock to estimate the impacts of deep energy retrofits province-wide. Like within the commercial and institutional analysis, net present value evaluation was excluded from the technical results section of this paper. In particular, assessing the lifetime savings of building envelope improvements is challenging. Consider an example:

- Foam insulation is added to above-grade exterior walls as part of a deep energy retrofit
- In 15 years, the new homeowners reclad the home

While the insulation product itself could last several decades, there is a strong argument that if the new homeowner reclaims the home, future codes or changes to standard building practices would mean insulation would have been added in 15 years, and that no energy savings should be associated with the original deep energy retrofit beyond this point. Home renovations are common, so such upgrades naturally occur throughout their lifetime. In demand-side management measurement and verification, recognizing and accounting for these future changes is called a multiple baseline treatment.

There is little research on the actual lifetime of building envelope measures with these considerations. As such, the results should be viewed with this consideration in mind.

### 1.2.2.1 Energy Modeling

Comprehensive energy modeling was previously performed by NRCAN using their Housing Technology Assessment Platform (HTAP<sup>9</sup>). This modeling, done on households across Canada, was used to develop the Canada Greener Homes Grant Program. It included modeling upgrade packages for a diverse group of housing types<sup>10</sup> in each province.

We modeled results from the upgrade packages used by NRCAN that produced the highest energy savings. These packages are summarized in Table 6.

*Table 6: Residential Upgrade Packages, Canada*

| Upgrade Package Name | Upgrade Package Descriptions                                                                        | Energy Savings (%) |
|----------------------|-----------------------------------------------------------------------------------------------------|--------------------|
| <b>P1</b>            | A balanced approach, less envelope heavy than P2, adds a Cold Climate Air-Source Heat Pump (CCASHP) | 44%                |
| <b>P2</b>            | Comprehensive whole-house envelope-only retrofit                                                    | 43%                |
| <b>P3</b>            | CCASHP with attic and foundation retrofits                                                          | 52%                |
| <b>P4</b>            | Air sealing, mechanical ventilation, and CCASHP                                                     | 49%                |

The results shown in Table 6 are for all of Canada. The analysis performed for this paper uses the same dataset but isolates Nova Scotia households. Upgrade packages P2, P3, and P4 were applied to 47 archetypes. Upgrade package P1 was applied to 285 archetypes. These archetypes were chosen by NRCAN to be representative of the existing housing stock in Nova Scotia. Upgrade packages and archetypes are described in greater detail in section 3.5.1.

The residential energy modeling exercise differed from the C&I modeling:

- C&I modeling used a smaller number of archetypes and modeled custom upgrade packages for each archetype to achieve a performance target (30%, 50%, and 70% energy reduction). The

<sup>9</sup> HTAP is a collection of data and tools which can be used to perform parametric modeling using the HOT2000 energy modeling tool

<sup>10</sup> Houses in the sample vary in size; age; type, e.g., single detached, row, duplex; and configuration, e.g. heating equipment, insulation value, air-tightness.

models predicted energy savings associated with each of these three scenarios were on average within +/- 10% of the performance target.

- Because of the wealth of data available for the residential sector, more archetypes were used, and the same group of upgrade packages was applied to each. This means that for each upgrade package, savings will vary by house instead of each house achieving the same savings (30%, 50%, and 70% in the case of C&I).

Put another way, C&I modeling used fixed energy savings performance targets and variable upgrades based on the building archetype, whereas the availability of data for residential modeling allowed the use of fixed upgrades and energy savings varied.

### Levelized Cost of Carbon – Residential

Levelized cost of carbon figures are estimated over the assumed lifetime of the upgrade packages being evaluated. For upgrade packages containing a mix of HVAC and building envelope measures, a blended measure life of 21 years is assumed. For upgrade packages containing only building envelope measures, a measure life of 25 years is assumed. This is consistent with Efficiency Nova Scotia third-party evaluation results for effective useful life (EUL) of similar upgrades<sup>11</sup>. A discount rate of 2.5% was applied<sup>12</sup>, and all energy costs were assumed to escalate at a rate of 2% per year. Electricity emissions intensity varied annually based on Nova Scotia Power IRP results<sup>13</sup>. Maintenance costs were not included due to a lack of sufficient data; however, it should be noted that the exclusion of maintenance costs was symmetrical, i.e., both the upgrade and base case did not contain these costs.

### Residential Limitations and Assumptions

Actual buildings, compared to their modeled archetypes, vary by existing heating and cooling equipment, building envelope characteristics, and air tightness. Costs to implement upgrades do not necessarily reflect the initial state of the building and the precise incremental improvements required. Net present value evaluation was excluded from the technical results section of this paper. Recommendations included in this paper highlight the need for further analysis of measure life for those ECMs included in each building archetype upgrade package.

For example, consider two identical homes with the only difference being the exterior above-grade walls. One has no exterior insulation and no insulation in the wall cavities, the other has no exterior insulation but R-12 batts in the wall cavities. If both walls are upgraded to reach an effective R-value of R-27, the costs are assumed to be identical for both households. In the real world, the house with cavity insulation would have a reduced cost since only exterior insulation would be required.

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<sup>11</sup> M11071, exhibit 2, Table 182: EUL Values and Sources for non-LED Residential Measures

<sup>12</sup> Bank of Canada 10 year savings bond – 2023/01/12

<sup>13</sup> CO<sub>2</sub> k tonne by year are based on Nova Scotia Power IRP Final Report Appendix F, Scenario 2.0C. Net System Requirement (load in GWh) are from NSP 10-Year System Outlook report filed with NS UARB. Assumed NSP load values for 2033-2045 by applying the forecast annual average increase of 0.3%, reference NSP 10-Year System Outlook report page 7 for 2022-2032 growth.

Similarly, the configuration of a home's HVAC system can dramatically affect the cost of upgrading to a heat pump. For example, the P4 upgrade package contains a central CCASHP. Take three different homes, one with an oil-fired hydronic boiler, one with an oil-fired hot air furnace, and a third with a combined oil-fired hot air furnace and a mini-split heat pump. As modeled, they would all have the same estimated upgrade costs, despite having very different real-world costs due to the uniqueness of any individual building.

Accounting for such nuances for each archetype could increase the precision of results. However, precise costing data is not available, (i.e., there is no cost data available that is sufficiently granular to account for such specific sets of conditions). Additionally, this analysis attempts to balance the complexity of individual houses with the complexity of an analysis that incorporates many archetypes rather than a handful of precise ones. This allowed for more types of housing to be included in the results.

Identifying the combination of upgrades that is “optimal” for a single home is complex. It is outside the scope of this paper, and a significant undertaking to do this for the entire housing stock or even archetypal examples. As such, this paper does not recommend one upgrade package over the other. Instead, the paper is meant to illustrate the variety of possible upgrade paths, and most importantly, the magnitude of costs and savings associated with them. This information is useful in understanding the scale of deep energy retrofits broadly and the resources needed to address it. While it is tempting to choose the single upgrade package with the lowest costs and the highest savings, it's important to keep the above considerations in mind.

Also, this analysis focused exclusively on single-detached and single-attached buildings, which comprise 72% of all dwellings and roughly 95% of all part nine<sup>14</sup> buildings in Nova Scotia.

### 1.2.2.1 Housing Stock

Table 7: Existing Housing Stock, Nova Scotia, CEUD 2018

| Year of Construction | Quantity | Single Detached | Single Attached <sup>15</sup> | Apartments | Mini-Homes <sup>16</sup> |
|----------------------|----------|-----------------|-------------------------------|------------|--------------------------|
| 1900-1945            | 64,503   | 44,203          | 2,853                         | 14,710     | 2,737                    |
| 1946-1960            | 27,910   | 18,995          | 1,302                         | 6,427      | 1,186                    |
| 1961-1977            | 47,939   | 32,811          | 2,141                         | 10,952     | 2,035                    |
| 1978-1983            | 39,174   | 27,141          | 2,779                         | 7,143      | 2,111                    |
| 1984-1995            | 97,383   | 62,383          | 8,205                         | 23,591     | 3,204                    |
| 1996-2000            | 33,897   | 24,901          | 3,167                         | 4,662      | 1,168                    |
| 2001-2005            | 41,200   | 26,735          | 3,141                         | 9,721      | 1,603                    |
| 2006-2010            | 39,050   | 24,056          | 3,768                         | 9,800      | 1,427                    |

<sup>14</sup> Part 9 refers to part 9 of the National Building Code of Canada, which addresses housing and small buildings and excludes large multi-unit residential buildings.

<sup>15</sup> Single Attached refers to duplexes, triplexes, and row homes

<sup>16</sup> “Mini home” and “mobile home” are colloquial terms for single section manufactured housing

| Year of Construction | Quantity | Single Detached | Single Attached <sup>15</sup> | Apartments | Mini-Homes <sup>16</sup> |
|----------------------|----------|-----------------|-------------------------------|------------|--------------------------|
| 2011-2015            | 35,238   | 19,469          | 3,801                         | 10,817     | 1,152                    |
| 2016-2018            | 23,724   | 12,071          | 2,466                         | 8,482      | 704                      |
|                      |          | 292,765         | 33,623                        | 106,305    | 17,327                   |

### 1.3 Methodology for Market Research

We engaged Narrative Research, a market research firm based in Halifax, to conduct market research that explored Nova Scotians' perceptions of energy efficiency and the concept of deep energy retrofits. The study involved six components, including:

- Quantitative online residential surveys;
- Quantitative online business surveys;
- Qualitative residential contractor focus groups;
- Qualitative interviews with commercial engineering consulting firms;
- Qualitative residential focus groups; and,
- Qualitative in-depth business interviews.

A quantitative online survey was conducted among Nova Scotians, including residential and commercial audiences, to assess perceptions and market interest in the concept of deep energy retrofits. As well, qualitative research was completed using various approaches, including focus groups and in-depth interviews, to dig deeper into perceptions among residential and commercial ratepayers, residential renovation contractors, and engineering consulting firms.

The specific research components and the audiences consulted within each are outlined below.

#### Quantitative Survey Among Commercial and Residential Ratepayers

An online survey was conducted among a random sample of Nova Scotia Power (NSP) residential and commercial ratepayers. The survey was distributed via email. In total, 507 surveys were completed by residents and 414 surveys were completed by commercial ratepayers.

#### Qualitative Dyad/Triad Focus Groups with Residential Contractors

Three mini-group discussions were conducted online with residential contractors in July of 2022. One session involved two HVAC contractors, one included three insulation contractors, and one included three general contractors. Each focus group lasted approximately 90 minutes.

#### Remote In-Depth Interviews with Engineering Consultants

Between August 15 and September 6, 2022, eight in-depth interviews were conducted via video call with representatives from various engineering consulting firms. Each session was approximately 40 minutes in length. Narrative Research coordinated and facilitated the interviews.

### **Focus Groups with Residential Decision Makers**

In August 2022, two online focus groups were conducted with homeowners. A total of 15 participants (16 recruited) attended these sessions. Each group included a mix of gender, age, and location, and all participants were actively involved in energy-related decisions for their premises. The sessions each lasted approximately 90 minutes. Participants were recruited from the online survey respondents who expressed an interest in follow-up research.

### **In-Depth Interviews with Key Commercial and Institutional Accounts**

In September 2022, six 40-minute interviews were conducted by telephone with representatives from large commercial accounts, including four interviews with post-secondary institutions and one interview with a commercial business decision-maker.

### **Market Research Limitations and Assumptions**

The market research discussing energy-related decisions about buildings in Nova Scotia included Nova Scotia Power account holders (referred to as ratepayers throughout this paper) who were involved in making decisions about their home or building's energy use. As such, the study excludes Nova Scotians who do not hold an account with Nova Scotia Power for their home or building. For such households, the landlord or property manager was surveyed as the account holder and party responsible for decisions about energy use. Moreover, due to the scope of the research, an online methodology was used for the quantitative survey and recruitment of the qualitative focus groups and interviews. In turn, given the nature of online methodologies, a minority of ratepayers who do not have email addresses on file with Nova Scotia Power were excluded from the study. With these considerations in mind, despite attempts to reach a cross-section of the population, there is a possibility that the views and opinions of participants are not perfectly representative of the general population of Nova Scotia.

Additionally, qualitative discussions allow for an in-depth gathering of participant opinions and attitudes on a particular subject. These specialized techniques are used in market research to develop insights and direction, rather than collect quantitatively precise data or absolute measures. As such, it is important to note that the qualitative results summarized in this paper are directional only and cannot be generalized to the overall population under study.

## **1.4 Renewable Generation Levelized Cost of Carbon Methodology**

Two sources of information were used as the basis for the capital, operational, and maintenance costs for the renewable generation LCOC calculation. Costs related to tidal, solar, and both onshore and offshore generation were sourced from the 2022 Evergreen IRP<sup>17</sup> while the costs and capacity factors for

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<sup>17</sup> NS Power (2023). 2022 Evergreen IRP Updated Assumptions, January 26, 2023. [2022-Evergreen-IRP-Updated-Assumptions-January-2023-Update.pdf](https://www.nspower.ca/2022-Evergreen-IRP-Updated-Assumptions-January-2023-Update.pdf) (nspower.ca)

hydro and geothermal were sourced directly from the National Renewable Energy Laboratory (NREL) Annual Technology Baseline database<sup>18</sup>.

The following assumptions were used as part of the analysis:

- All renewable generation technologies used a discount rate equivalent to NS Power's weighted average cost of capital (WACC), 6.33%.
- The grid's emissions factor was based on the values stated in the IRP Final Report, Appendix F, Scenario 2.0C.
- The operation and maintenance costs were escalated by 2% each year.

Where geothermal and hydro were sourced directly from the NREL Annual Technology Baseline, the costs were subject to the following additional assumptions:

- The moderate innovation scenarios, scenarios where systems became moderately more efficient or cost-effective over time, were selected as the baselines for both technologies.
- Costs were assumed to use a USD-to-CAD conversion ratio of 1.35.

Once the assumptions were set, the LCOC calculation was completed by taking net present value for the costs and GHG reductions<sup>19</sup> of each technology over a 25-year time horizon.

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<sup>18</sup> NREL. (2023). Annual Technology Baseline. Retrieved July 19, 2023. <https://atb.nrel.gov/electricity/2023/about>

<sup>19</sup> If a marginalized abatement cost calculation was used instead of a LCOC the emissions reduction would not have been subject to the net present value calculation. The capital, operational, and maintenance costs, would all still be subject to the net present value calculation.

## 2 Policy Environment & Emissions in Nova Scotia

Canada and Nova Scotia have made significant commitments to reduce GHG emissions and an equally significant investment in the clean energy economy. To make well-informed decisions concerning deep energy retrofits, it is important to understand the federal, provincial, and major municipal legislation, regulations, and policy guidance that concern GHG reductions and their relationship with deep energy retrofits and the historical emissions in Nova Scotia. More details concerning the current policy environment can be found in Appendix A: Policy Guidance on GHG Reductions and Electrification.

### 2.1 Emissions Gap and Pathways Forward

Emissions in Canada were only 1% lower in 2019 than they were in 2005. Over the same period, emissions in Nova Scotia declined just over 30%.<sup>20</sup> However, progress has slowed in the last few years. Meeting emission reduction targets presents a formidable challenge that will require a step-change in the rate of emissions reductions.

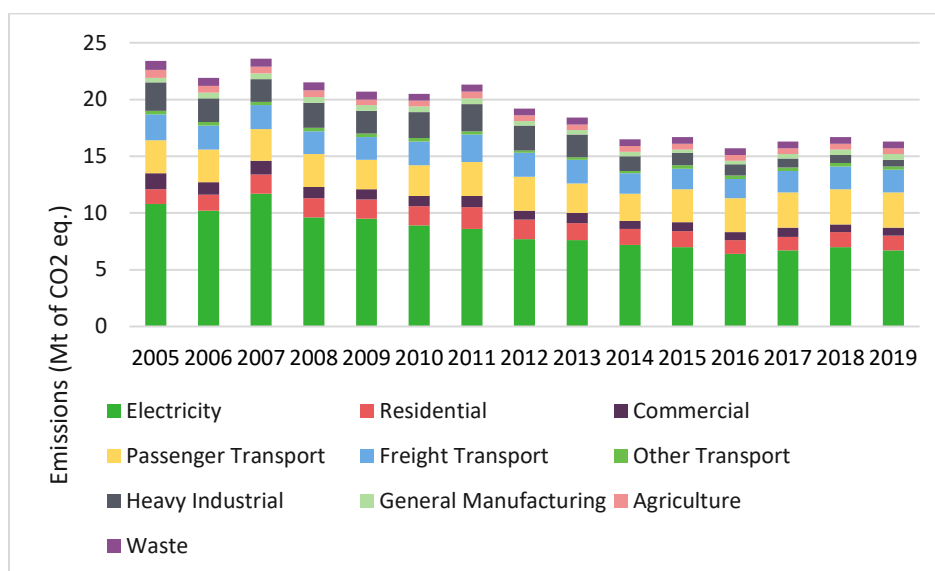
#### 2.1.1 Historical Emissions in Nova Scotia

In Nova Scotia, the majority of GHG emissions come from the tailpipes of vehicles, the stacks of power plants, and the chimneys and vents of furnaces, boilers, and water heaters in homes, commercial buildings, and industrial facilities.

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<sup>20</sup> Environment and Climate Change Canada. (n.d.). *Canada's Greenhouse Gas Emissions Projections*. 2022. Retrieved September 11, 2022, from <https://data-donnees.ec.gc.ca/data/substances/monitor/canada-s-greenhouse-gas-emissions-projections/Current-Projections-Actuelles/?lang=en>

Figure 3: Historical Emissions in Nova Scotia<sup>21</sup>



The leading sources of emissions in Nova Scotia have been power generation, transportation, and residential and commercial buildings<sup>22</sup>. Due to a combination of economic factors, energy efficiency programs, and growth in the renewable energy supply, GHG emissions in Nova Scotia are more than 30% lower in 2019 (16 Mt of CO<sub>2</sub> equivalent) than in 2005 (23 Mt of CO<sub>2</sub> equivalent)<sup>23,24</sup>.

In 2005, Nova Scotia's largest source of emissions was the electricity sector at 11 Mt per year. This was followed by the transportation sector with annual emissions of 5.5 Mt. The building sector was third with emissions of 2.7 Mt, not including their electricity use.<sup>25</sup>

By 2019, electricity sector emissions had declined 38%, to 6.7 Mt. Heavy industry<sup>26</sup> had the sharpest decline in emissions, down from 2.5 Mt in 2005 to 0.6 Mt in 2019 – a decline of nearly 80%.<sup>27</sup> Passenger transport was the only sector of the top three to show an increase in emissions between 2005 and 2019.

If building electricity use is proportionally allocated to building stock, building sector GHG emissions increase to approximately 6.6 Mt to 7.7 Mt of CO<sub>2</sub> equivalent, or 45% to 53% of the provincial GHG

<sup>21</sup> GHG emissions in 2020 were abnormally low due to the pandemic and are expected to rise in 2022. For that reason, our projections are based on 2019 emissions.

<sup>22</sup> Electricity only counted at generation, not at end use in this example.

<sup>23</sup> Environment and Climate Change Canada. (n.d.). *Canada's Greenhouse Gas Emissions Projections*. 2022. Retrieved September 11, 2022, from <https://data-donnees.ec.gc.ca/data/substances/monitor/canada-s-greenhouse-gas-emissions-projections/Current-Projections-Actuelles/?lang=en>

<sup>24</sup> For reference, the average GHG intensity for electricity generation in NS is 0.67kg CO<sub>2</sub>e/kWh as of 2020 (Canada Energy Regulator (CER), 2022) with a targeted emissions intensity of 0.05kg CO<sub>2</sub>e/kWh by 2050 (Nova Scotia Power, 2022).

<sup>25</sup> Ibid

<sup>26</sup> For the purpose of this analysis, E1 included the sectors 'Oil and Gas' and 'Coal Production' from the source data in its definition of 'Heavy Industry'

<sup>27</sup> E1 understands this sharp decline is mostly related to the closure of a Dartmouth refinery in 2013

emissions, making it the largest emitter<sup>28</sup>. As the electricity grid becomes less carbon-intensive, the GHGs related to electricity use in buildings are expected to decline.

Emissions from heavy industry and electricity generation have been declining, but as noted in our 2021 White Paper, emissions from buildings and transportation have declined only slightly over the past 15 years.

Achieving net-zero emissions in Nova Scotia will require completing the decarbonization of the electricity supply at the same time as the electrification of transportation and building systems are being pursued. This will create upward pressure on electricity demand, which emphasizes the need to optimize energy use as electricity load increases.

### **2.1.2 Emissions Gap**

It is important to acknowledge the significant work that has resulted in 2019 GHG emissions being 30% lower in Nova Scotia than they were in 2005. However, it is equally important to acknowledge the significant reduction in emissions still needed to achieve the 2050 net-zero goal. From 2005 to 2019, Nova Scotia reduced emissions by 7 Mt of CO<sub>2</sub> equivalent, or 500,000 tonnes of CO<sub>2</sub> equivalent per annum. Given the current emissions targets for Nova Scotia, an average reduction of approximately 600,000 tonnes per year will be needed between 2019<sup>29</sup> and 2030.<sup>30</sup> The level of emissions for Nova Scotia to achieve net-zero by 2050 has not been defined. Figure 4 represents the emissions projected to be reduced by 2030, and a trajectory to 2050, however, this trajectory is not yet certain.

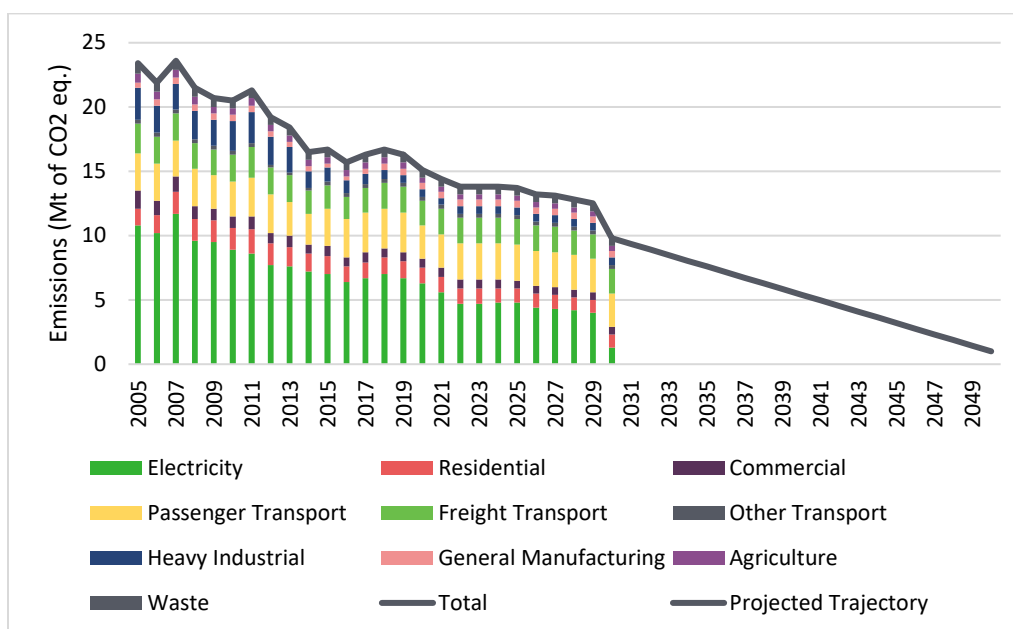
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<sup>28</sup> Estimate of electricity usage driven by building stock.

<sup>29</sup> GHG emissions in 2020 were abnormally low due to the pandemic and are expected to rise in 2022. For that reason, our projections are based on 2019 emissions.

<sup>30</sup> Environment and Climate Change Canada. (n.d.). *Canada's Greenhouse Gas Emissions Projections*. 2022. Retrieved September 11, 2022, from <https://data-donnees.ec.gc.ca/data/substances/monitor/canada-s-greenhouse-gas-emissions-projections/Current-Projections-Actuelles/?lang=en>

Figure 4: Emissions Projections for Nova Scotia<sup>31</sup>



The technological pathways for achieving emissions reductions all require the simultaneous pursuit of energy efficiency, electrification, and decarbonization of the electricity supply. The effort will require a continued focus on DSM in the form of energy efficiency and demand response, conversion of existing oil-fired building systems to electric, and higher levels of energy efficiency in building codes and standards for new construction and major retrofits.

Although overall GHG emissions in Canada have trended down since 2005, building stock emissions, excluding electricity, have increased by 6.4 Mt of CO<sub>2</sub> equivalent, or 7.6% as of 2019.<sup>32</sup> In Nova Scotia, residential building stock emissions were up 11% above 2005 levels in 2011, but dropped back down to 2005 levels by 2019 – effectively stagnating<sup>33</sup> whereas C&I building stock emissions have gone down by 700,000 tonnes, a 50% reduction. However, current projections show C&I building stock emissions only dropping by 100,000 tonnes between 2019 and 2030.<sup>34</sup> Given these projections, it is unlikely that we will achieve the required GHG and energy efficiency performance from our existing building stock without

<sup>31</sup> Historical to 2019, Projection to 2030, Pathway to net-zero 2050

<sup>32</sup> Environment and Climate Change Canada. (2022). *Canada's Official Greenhouse Gas Inventory*.

<https://data.ec.gc.ca/data/substances/monitor/canada-s-official-greenhouse-gas-inventory/E-Tables-Electricity-Canada-Provinces-Territories/?lang=en>

<sup>33</sup> Energy efficiency programs have resulted in per-home emissions reductions, as measured by independent evaluation. Identifying the factors contributing to the noted stagnation in total residential emissions was beyond the scope of this paper and could be driven by factors such as population growth.

<sup>34</sup> Environment and Climate Change Canada. (n.d.). *Canada's Greenhouse Gas Emissions Projections*. 2022. Retrieved September 11, 2022, from <https://data-donnees.ec.gc.ca/data/substances/monitor/canada-s-greenhouse-gas-emissions-projections/Current-Projections-Actuelles/?lang=en>

making significant changes to current market structures and policy approaches. Deep energy retrofits, with the typical goal of reducing energy use in buildings by 50% or more, must be part of the solution.

When considering deep energy retrofits within the perspective of an overall provincial decarbonization strategy, it is important to be aware that some metrics, such as ROI and payback periods, are not always best practice. Building owners often view few projects from the perspective of financial costs and benefits. However, from the perspective of policy-makers, projects that with less-than-ideal ROIs or payback periods, but have a negative cost of carbon abatement, should be taken into serious consideration. This differs from other decarbonization strategies such as carbon capture, which may appear to be financially attractive, but have positive abatement costs.

## 2.2 Environmental Goals

Each level of government has complementing environmental goals. For example, the federal *Canadian Net-Zero Emissions Accountability Act*<sup>35</sup> sets the highest-level GHG reduction target -- net-zero emissions by 2050 -- and establishes a framework for planning and monitoring progress towards that target.

The Government of Nova Scotia is targeting a 53% reduction in GHG emissions by 2030 and net-zero emissions by 2050. The provincial government has also legislated that 80% of electricity is supplied by renewable energy and by phasing out coal-fired electricity generation by 2030, as well as decreasing GHG emissions across government-owned buildings by 75% by 2035<sup>36</sup>. Furthermore, *Our Climate, Our Future: Nova Scotia's Climate Change Plan for Clean Growth*<sup>37</sup> is an ambitious but achievable plan put forward by the provincial government in 2022. It details 68 actions that will help Nova Scotia meet its climate change targets. The climate change plan's actions are grouped into the following areas:

1. Responding to climate impacts
2. Reducing our greenhouse gas emissions
3. Seizing opportunities for a cleaner sustainable economy
4. Reporting and evaluating progress

The goal of the climate change plan is to help more Nova Scotians reduce their emissions, save on energy bills, and prepare for the impact of climate change while supporting Nova Scotians who may struggle to participate due to affordability concerns.

Like the provincial government, various municipalities have also committed to aggressive climate action. The HRM, the largest municipality in Atlantic Canada, passed a climate action plan in June 2020 titled

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<sup>35</sup> Canadian Net-Zero Emissions Accountability Act, (2021). <https://laws-lois.justice.gc.ca/PDF/C-19.3.pdf>

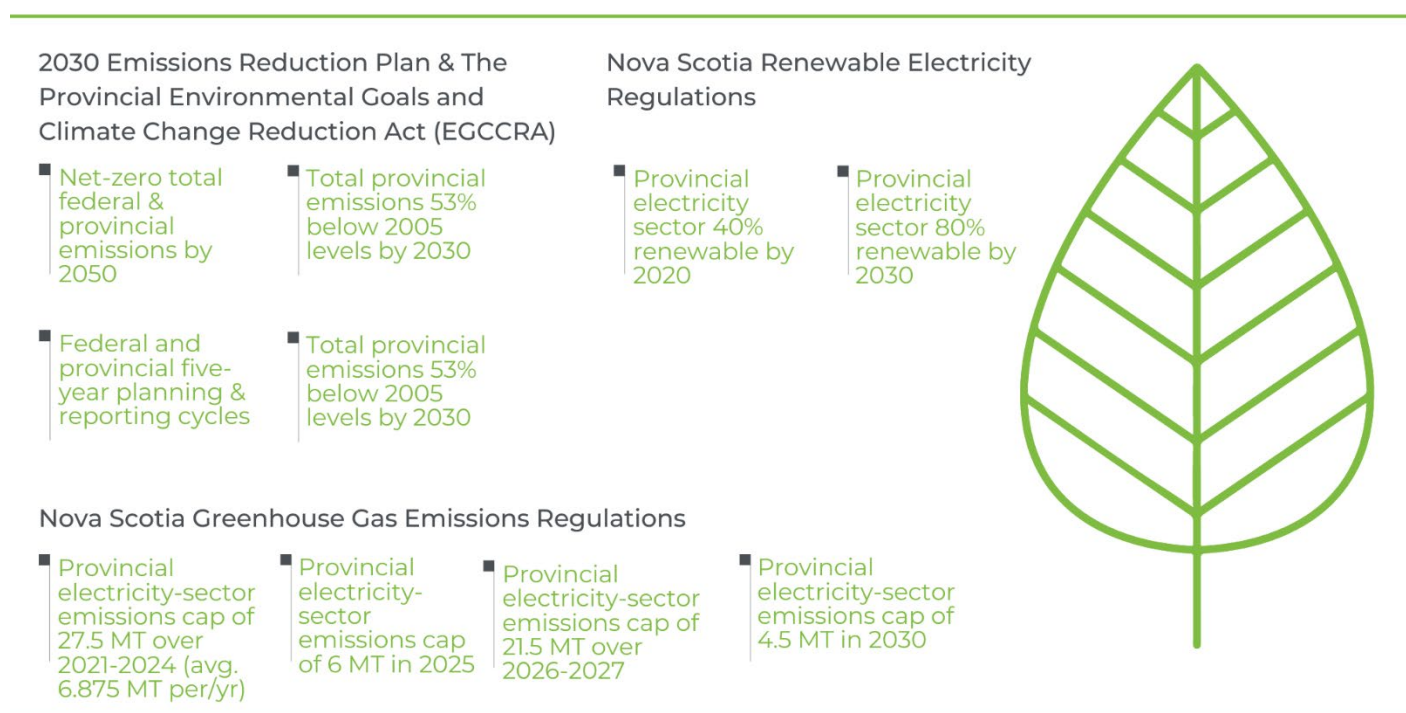
<sup>36</sup> Environmental Goals and Climate Change Reduction Act, (2021). <https://nslegislature.ca/sites/default/files/legc/statutes/environmental%20goals%20and%20climate%20change%20reduction.pdf>

<sup>37</sup> Province of Nova Scotia. (2022). *Our Climate, Our Future: Nova Scotia's Climate Change Plan for Clean Growth*. Retrieved February 6, 2023. <https://climatechange.novascotia.ca/sites/default/files/uploads/ns-climate-change-plan.pdf>

*HalifACT – Acting on Climate Change Together*<sup>38</sup>. It targets net-zero municipal operations by 2030, a community-wide emissions reduction of 75% by 2030, and net-zero emissions by 2050. This plan includes strong emphasis on reducing emissions by retrofitting existing buildings. Another example is the Municipality of the County of Antigonish. The Municipality of the County of Antigonish has established three major energy goals; reduce GHG emissions from County buildings by 35% by 2031, all new builds must be designed to be 45% more efficient than the 2017 Building Code and reduce water and sewer energy intensity by 10% by 2026.<sup>39</sup>

Together, the provincial, federal, and municipal policies specify emission caps and targets from the electricity sector, residential, commercial, and government facilities, as well as renewable electricity targets. Below are the emissions and renewable targets in effect in Nova Scotia today.

Figure 5: Federal and Provincial Policies Relating to Net-Zero and Emissions Reduction



<sup>38</sup> Halifax Regional Municipality. (2020). *HalifACT: Acting on Climate Together*.

[https://cdn.halifax.ca/sites/default/files/documents/about-the-city/energy-environment/HRM\\_HaliFACT\\_vNew%20Logo\\_.pdf](https://cdn.halifax.ca/sites/default/files/documents/about-the-city/energy-environment/HRM_HaliFACT_vNew%20Logo_.pdf)

<sup>39</sup> Efficiency Nova Scotia. (2021). *2021 Energy Management Plan: Municipality of the County of Antigonish*.

<https://antigonishcounty.ca/wp-content/uploads/2022/01/EMP-MCA-2021.pdf>

## 2.3 Deep Energy Retrofits in Policy Guidance and Building Codes

Current legislation and policies include the use of retrofits as an integral part of Canada's approach to meeting net-zero targets. Five prominent examples are:

- Nova Scotia's *Environmental Goals and Climate Change Reduction Act*<sup>40</sup> stipulates that any new build or major retrofit in government buildings, including schools and hospitals, entering the planning stage after 2022 must have net-zero energy performance and be climate resilient.
- The *2030 Emissions Reduction Plan*<sup>41</sup>, proposed by the federal government, describes the need to mobilize private sector financing to support deep energy retrofits.
- The *Pan-Canadian Framework for Green Energy and Growth*<sup>42</sup> details the need to support innovative policies. This includes establishing new retrofit codes and offering low-cost financing. The framework states that each level of government will work to develop a model code for existing buildings, with the goal that provinces and territories adopt the code. This code will help guide energy efficiency improvements when renovating buildings.
- The December 2021 mandate letter to the federal Minister of Natural Resources directed the minister to create a model retrofit code by the end of 2024.<sup>43</sup>
- The HRM, through *HalifACT*<sup>44</sup>, has set a target of 5,000 deep energy retrofits on existing residential and non-residential buildings per year until 2040.

Changes to building codes traditionally happen over long periods and in small increments—this is not compatible with the pace of retrofits envisioned by the above policy goals. Providing municipalities with the ability to adopt more stringent code requirements would allow those municipalities to increase the pace of change.

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<sup>40</sup> Province of Nova Scotia. (2021). *Environmental Goals and Climate Change Reduction Act*.

<https://nslegislature.ca/sites/default/files/legc/statutes/environmental%20goals%20and%20climate%20change%20reduction.pdf>

<sup>41</sup> Environment and Climate Change Canada. (2022). *2030 Emissions Reduction Plan: Canada's Next Steps for Clean Air and a Strong Economy*. [https://publications.gc.ca/collections/collection\\_2022/eccc/En4-460-2022-eng.pdf](https://publications.gc.ca/collections/collection_2022/eccc/En4-460-2022-eng.pdf)

<sup>42</sup> Province of Nova Scotia, Province of Newfoundland and Labrador, Province of Prince Edward Island, Province of New Brunswick, Province of Quebec, Province of Ontario, Province of Alberta, Province of British Columbia, Yukon Government, Northwest Territories, & Government of Nunavut. (n.d.). *Pan-Canadian Framework on Clean Growth and Climate Change*. Retrieved September 11, 2022, from [https://publications.gc.ca/collections/collection\\_2017/eccc/En4-294-2016-eng.pdf](https://publications.gc.ca/collections/collection_2017/eccc/En4-294-2016-eng.pdf)

<sup>43</sup> [Minister of Natural Resources Mandate Letter, December 16, 2021](#)

<sup>44</sup> Halifax Regional Municipality. (2020). *HalifACT: Acting on Climate Together*.

[https://cdn.halifax.ca/sites/default/files/documents/about-the-city/energy-environment/HRM\\_HaliFACT\\_vNew%20Logo\\_.pdf](https://cdn.halifax.ca/sites/default/files/documents/about-the-city/energy-environment/HRM_HaliFACT_vNew%20Logo_.pdf)

### 3 Deep Energy Retrofits and the State of the Market

Quantifying the benefits of deep energy retrofits is alluring, however implementation will be challenging. There is a great deal of economic uncertainty, inflation, high fuel costs, and fears of recession in the near term, which must be considered when looking at consumer perceptions of deep energy retrofits and particularly expectations of uptake, as consumers are now making more conservative financial decisions.

#### 3.1 What are Deep Energy Retrofits?

In the residential space, there is no common definition of what constitutes a deep energy retrofit. However, there are building labels that most would agree, if implemented widely, would drive substantial improvements (e.g., the Passive House EnerPHit<sup>45</sup> standard and the Canadian Home Builders' Association's Net Zero Home Labelling Program for Renovations<sup>46</sup>).

Although there is no industry consensus on the percentage, deep energy retrofits should achieve energy savings of 50% or more if we are to achieve emissions reduction targets. At the current rate, if all building stock across the entire province were subject to deep energy retrofits, it would have the same impact as taking approximately 720,000 to 837,000 fossil-fuelled vehicles off the road.<sup>47</sup>

The research and analysis conducted for this paper targeted upgrade packages that would achieve an approximate 50% reduction in energy use when applied across all houses and C&I buildings. However, it is important to note that savings potential varies widely from building to building (e.g., a 100-year-old house that consumes 50,000 kWh annually will save substantially more energy than a 20-year-old house that consumes 20,000 kWh annually if the same upgrade package is applied to both). Further information on these upgrade packages can be found in section 3.5.

#### 3.2 State of the Market

##### Residential

On average, there have been approximately 2,500 participants per year in Efficiency Nova Scotia's Home Energy Assessment (HEA), Mi'kmaw Home energy Efficiency Project (MHEEP), and HomeWarming (HW) programs combined. This number can vary significantly based on the investment in energy efficiency programs. For example, in 2022 there were over 4,000 participants in these programs; this increase is attributable almost entirely to the Federal Canada Greener Homes Grant program. On average, participating homeowners reduced their energy use by 27%, 23%, and 31%, in HEA, MHEEP, and HW, respectively. When viewing the group as a whole, the mean energy reduction for a participating household is 26% or about half of our baseline definition of deep energy retrofits.

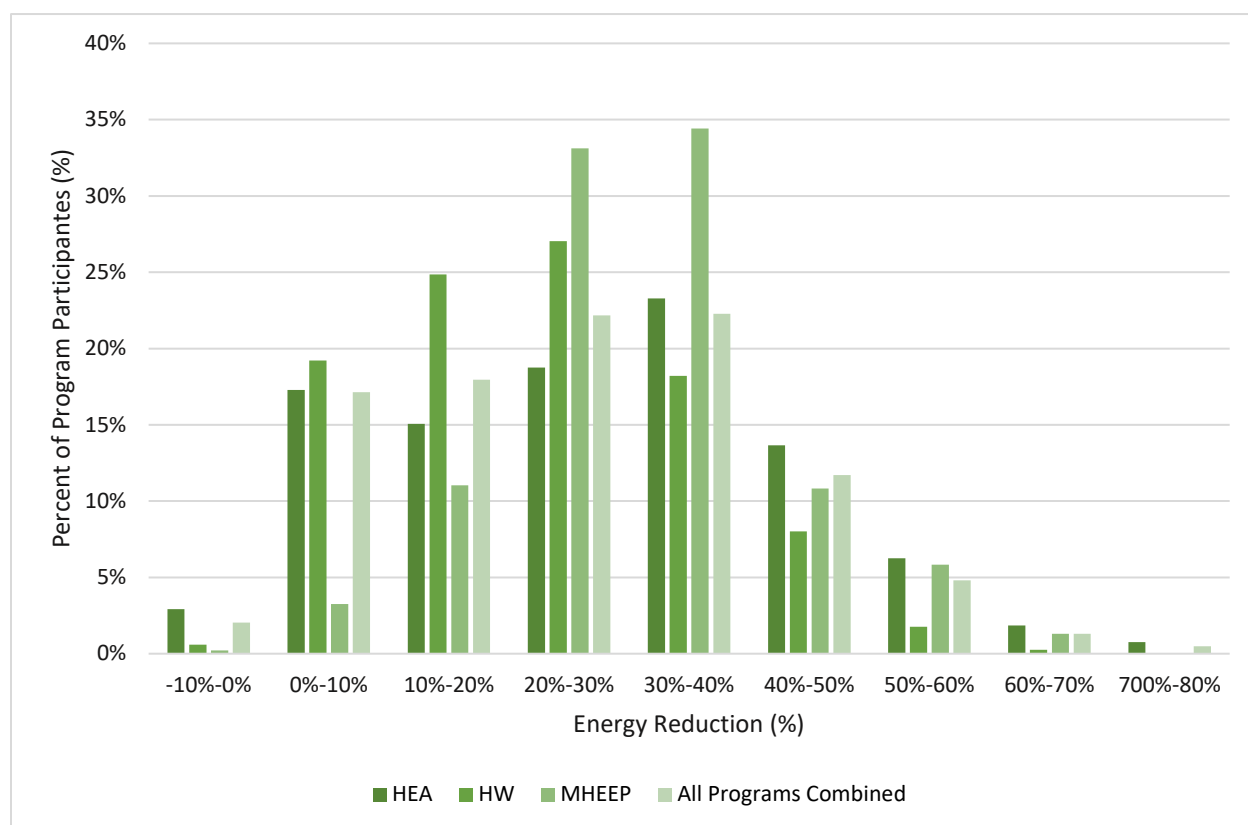
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<sup>45</sup> [Passive House Canada, EnerPHit standard](#)

<sup>46</sup> [CHBA Net Zero Renovation](#)

<sup>47</sup> Assuming 4,600 kg CO<sub>2</sub>/car/annum - United States Environmental Protection Agency (2018). *Greenhouse Gas Emissions from a Typical Passenger Vehicle*. <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100U8YT.pdf>

Figure 6: Energy Reduction from Participants in HEA, MHEEP, and HW since 2017



At 2,500 projects per year, the throughput of these three programs is equivalent to approximately 0.8% of the existing stock of single-detached and single-attached dwellings. If these programs were to continue at the current pace and achieve the current depth of per-home energy savings, current levels of energy use of Nova Scotia's existing housing stock would be reduced by only 1% by 2030; and 6% by 2050.<sup>48</sup>

### Commercial & Institutional

There are currently programs supporting deep energy retrofits within the C&I sector. Programs targeted at advancing deep energy retrofits have had success but have been limited to federal and provincial government programs that have specific project and sector eligibility requirements as well as program expiry dates. The only energy efficiency programs for businesses in Nova Scotia today are those administered by Efficiency Nova Scotia (ENS). ENS incentive programs and services are primarily targeted at electrical energy efficiency, except for one program (Small Business Energy Solutions) offered to small businesses. There is limited data on ENS business program participants' non-electric energy consumption; however, because of the exclusive focus on electrical energy efficiency, it is estimated that the existing

<sup>48</sup> Energy reduction is based on the current rate and depth of retrofits, and measures energy use reduction in single attached and single detached dwellings, i.e. multi-unit buildings are not included

programs cannot achieve greater than 30% reductions in building energy use for eligible small business customers.

### 3.3 Economic Context

There is currently a great deal of economic uncertainty in Atlantic Canada that must be considered when looking at consumer perceptions of deep energy retrofits, expectations of uptake, and industry capacity. Unprecedented world events have impacted the global economy, and as a result, inflation and the cost of living have increased significantly<sup>49</sup>. Accordingly, many consumers are now making more conservative financial decisions.

The Atlantic Consumer Confidence Index (CCI) measures the economic uncertainty in the local market. The Atlantic CCI is a metric developed by Narrative Research to measure the economic well-being and outlook of the region<sup>50</sup>. Since the pandemic began in 2020, economic mood has dropped significantly, and in Q2 of 2022, the CCI fell to a record-low score of 60.4 (a drop of approximately 35 points compared with the CCI scores for 2019)<sup>51</sup>. Consumer confidence has shown a slight rebound as of Q2 2023 (score of 71.1, up 10.7 points), suggesting that perceptions of economic conditions may be improving, albeit slowly.<sup>52</sup>

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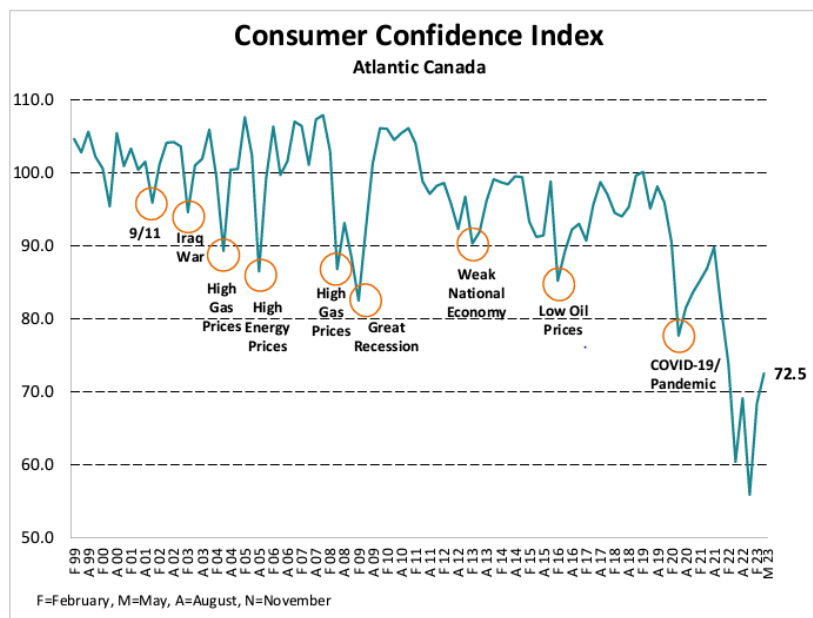
<sup>49</sup> Province of Nova Scotia. (2023). *Consumer Price Index*. Retrieved August 29, 2023.  
<https://novascotia.ca/finance/statistics/topic.asp?fto=21u&rdval=2023-07>

<sup>50</sup> Narrative Research. (2022). *2022 Deep Energy Retrofit Quantitative and Qualitative Report*.

<sup>51</sup> Narrative Research. (2022). *2022 Deep Energy Retrofit Quantitative and Qualitative Report*.

<sup>52</sup> Narrative Research. (2023). *Atlantic Quarterly Spring 2023*.

Figure 7: CCI for Atlantic Canada



### 3.4 Demographics and Firmographics

#### Demographic Profile for Nova Scotia Residents

According to Statistics Canada's 2021 census, Nova Scotia's population has an average age of 44 years. Of these residents, approximately 67% own a home. As well, approximately 30% of Nova Scotians between the ages of 25 and 64 years have a post-secondary degree, while 17% have no high school certificate<sup>53</sup>. As of Q1 of 2023, Nova Scotia is estimated to have a population of over 1,000,000.<sup>54</sup>

The Canadian Urban Sustainability Practitioners<sup>55</sup> looked at energy poverty levels across the country<sup>56</sup>. In Nova Scotia, the disparity between HRM and the rest of the province is significant, with 27% of households in the Halifax Regional Municipality (HRM), and an overall average of approximately 43% elsewhere in the province<sup>57</sup>. Moreover, Nova Scotia is the third highest-ranking province in Canada in terms of energy

<sup>53</sup> Statistics Canada. 2023. (table). Census Profile. 2021 Census of Population. Statistics Canada Catalogue no. 98-316-X2021001. Ottawa. Released November 15, 2023.

<https://www12.statcan.gc.ca/census-recensement/2021/dp-pd/prof/index.cfm?Lang=E> (accessed November 15, 2023).

<sup>54</sup> Statistics Canada. (2023). *Population Estimates, Quarterly*.

<https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000901>

<sup>55</sup> CUSP. (2019). *Energy Poverty in Canada: a CUSP Backgrounder*. <https://energypoverty.ca/backgrounder.pdf>

<sup>56</sup> Energy Poverty is defined as a household spending more than 6% of their after-tax income on energy.

<sup>57</sup> Efficiency Nova Scotia Energy Poverty Tool (referenced with cost of oil at \$1.2/L)

poverty levels, following Prince Edward Island and Newfoundland and Labrador. This highlights the need for more work to be done to ensure widespread access to programs and support for all Nova Scotians.

### Firmographic Profile of Commercial Organizations in Nova Scotia

There are approximately 53,000 businesses in Nova Scotia, with service sector businesses being most prevalent (40%), followed by retail trade (18%), and construction (8%). All other business sectors each represent approximately 7% or less of the total market. Along with business activity, our market research study revealed that approximately 90% of commercial organizations in Nova Scotia indicate an ability to make energy-related decisions about their buildings whether through ownership or lease agreements. The remaining 10% are not involved in these decisions about their buildings in terms of energy use. The bulk of the latter group rents their buildings as opposed to leasing or owning.

## 3.5 Technical Study Results

The results of residential and commercial technical studies are discussed in the following sections. Overall, the findings indicate:

### Residential

- Achieving energy reductions in the range of 50% is possible with commercially available technologies.
- The benefit of implementing deep energy retrofits province-wide would be:
  - Avoided annual GHG emissions of 2.7 Mt of CO<sub>2</sub> equivalent
- Savings potential varies widely by building and a one-size-fits-all approach is not viable. However, the simple payback period is approximately 17 years based on the P1 upgrade package described further in section 3.5.1.
- Average LCOC range for evaluated residential deep energy retrofit upgrade packages is - \$181/tonne CO<sub>2</sub> to -\$150/tonne CO<sub>2</sub>.

### Commercial and Institutional

- Achieving energy reductions of 50% is possible for most building types with available technologies and practices for optimizing existing building systems. Building types within the accommodations and food services category present a greater technical challenge.
- The LCOC was evaluated for each building archetype and three scenarios (30%, 50%, and 70% energy-reductions). The LCOC for all building archetypes and savings scenarios ranged from - \$409/tonne CO<sub>2</sub> to \$171/tonne CO<sub>2</sub>. For upgrade package 2, the package that results in a 50% energy reduction, the LCOC ranged from -\$277/tonne to \$18/tonne. This indicates that deep energy retrofits with energy reductions of 50% result in savings that often exceed the initial investment. Further energy reduction beyond 50% will often result in the initial investment outpacing the utility bill savings over the expected lifetime.
- The benefit of implementing deep energy retrofits province-wide would be:

- Avoided annual GHG emissions of 0.9 Mt of CO<sub>2</sub> equivalent.
- Compared with other greenhouse gas emission strategies, deep energy retrofits are among the most cost-effective and lowest-risk options for organizations pursuing net-zero.
- The average simple payback period of C&I deep energy retrofit projects is approximately 13 years. This simple payback period, without funding or financing support, exceeds what EfficiencyOne found to be attractive to the C&I sector. Specifically, feedback from commercial decision-makers indicated that a payback period of 5 to 10 years is preferable.

### **3.5.1 Residential Technical Study Results**

Each of the following sections describes:

- a) Archetypes modeled and how they relate to the Nova Scotian building stock
- b) Upgrades included in each package
- c) Costs and benefits associated with the upgrades

We analyzed the results from four upgrade packages modeled by NRCan (see details beginning in Section 3.5.1.1). Three of those upgrade packages (P2, P3, and P4) were modeled on a subset of between 38 and 43 houses. The upgrade packages addressed building envelope, HVAC, and DHW equipment; end uses with a smaller impact on energy use like lighting, plug loads, were not modeled by NRCan.

The P1 upgrade package is the most comprehensive modeling exercise, with 285 archetypes modeled. As such, the P1 results will be used to extrapolate across the entirety of the existing housing stock of Nova Scotia. These results give a sense of scale of the costs and savings if every household were to implement these upgrades. We consider the P1 upgrade package to be a balanced approach; it includes both envelope and mechanical system upgrades, meaning homes which have already made improvements to one and not the other will still benefit. However, it should be noted that a single upgrade package (i.e., one size fits all) is not a practicable path to achieve deep energy savings. Each home will have its own challenges and opportunities and will be subject to homeowner preferences. Existing building conditions may mean the upgrades proposed are not applicable, e.g. if a heat pump is already installed then upgrade package P4 is not a viable path to significant savings. Homeowner preference is also a significant factor, e.g., the homeowner may be focused on improving building envelope performance to reduce drafts, increase indoor air quality, etc. so upgrade package P2 is a better fit.

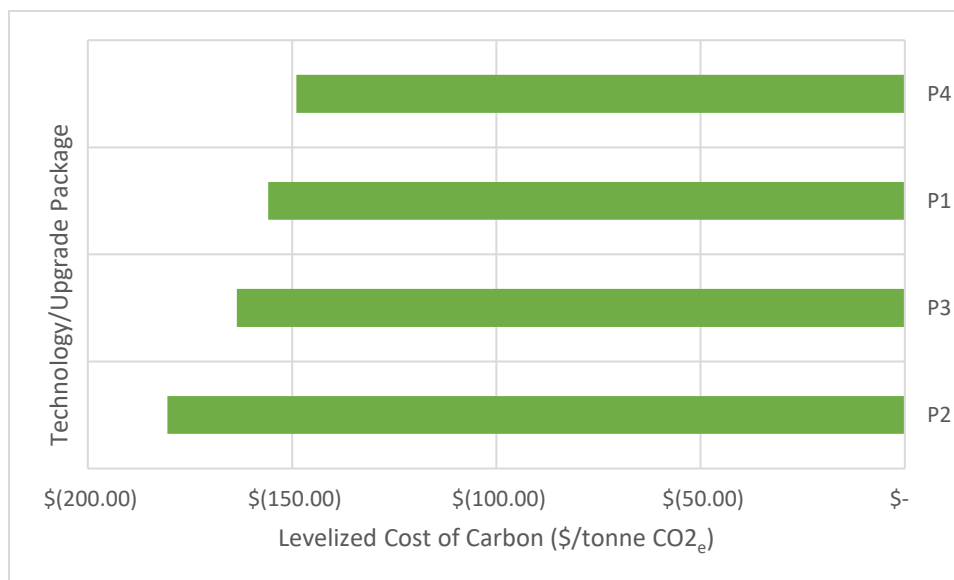
Upgrade packages P2, P3, and P4 demonstrate this variety in approaches that will be necessary to accommodate different homes and homeowners. Because these upgrade packages were modeled on a smaller subset of houses, they should not be compared directly to the results of the P1 upgrade package, which includes many more homes and is more representative of the province.

Identifying the combination of upgrades that is “optimal” for a single home is complex. It is outside the scope of this paper, and a significant undertaking, to do this for the entire housing stock or even archetypal examples. As such, this paper does not recommend one upgrade package over the other. Instead, the following sections are meant to illustrate the variety of possible upgrade paths, and most importantly, the magnitude of costs and savings associated with them. This information is useful in understanding the scale of deep energy retrofits broadly and the resources needed to address it. While it is tempting to choose

the single upgrade package with the lowest costs and the highest savings, it's important to keep the above considerations in mind.

Finally, the levelized cost of carbon was evaluated for each upgrade package according to the methodology described in section 1.2.2.1 above. The mean LCOC for every upgrade package was negative, i.e. on average the savings outweigh the costs over the lifetime of the measures. The results are summarized in the figure below.

Figure 8: Residential levelized cost of carbon



### 3.5.1.1 P1 Upgrade Package

#### Upgrades Modeled

The P1 upgrade package comprises the following upgrades:

1. Air sealing to 5.5 air changes per hour (ACH) @ 50 Pa<sup>58</sup>
2. ENERGY STAR™ doors and windows (triple pane)
3. Basement header insulation to an effective R-value of R-40
4. Basement foundation wall insulation to an effective R-value of R-10
5. Ceilings below attic insulation to an effective R-value of R-50
6. Installation of a CCASHP

<sup>58</sup> ACH @ 50 Pa is an industry standard metric used to evaluate air tightness of a building. In this example, the entire volume of air in the house leaks through the building envelope at a rate of 5.5 times per hour when subject to a constant 50 Pa of pressure between the inside and outside of the building.

This upgrade package contains moderate building envelope improvements, but it notably does not include any above-grade exterior wall upgrades or seal the building to the point where it requires mechanical ventilation. It also includes a cold climate air source heat pump sized to meet the heating needs of the building.

### Archetypes Modeled

The P1 upgrade package was the most comprehensive modeling run; 285 archetypes were modeled. Buildings in nearly all the age ranges were used in this study.

*Table 8: Count of Archetypes Modeled by Year Built, P1 Upgrade Package*

| <b>Year of Construction</b> | <b>Single Attached<br/>(Count of Archetypes)</b> | <b>Single Detached<br/>(Count of Archetypes)</b> |
|-----------------------------|--------------------------------------------------|--------------------------------------------------|
| <b>1900-1945</b>            | 2                                                | 37                                               |
| <b>1946-1960</b>            | 1                                                | 31                                               |
| <b>1961-1977</b>            | 7                                                | 56                                               |
| <b>1978-1983</b>            | 0                                                | 28                                               |
| <b>1984-1995</b>            | 7                                                | 56                                               |
| <b>1996-2000</b>            | 2                                                | 16                                               |
| <b>2001-2005</b>            | 1                                                | 16                                               |
| <b>2006-2010</b>            | 1                                                | 17                                               |
| <b>2011-2015</b>            | 1                                                | 4                                                |
| <b>2016-2018</b>            | 0                                                | 2                                                |
|                             | <b>22</b>                                        | <b>263</b>                                       |

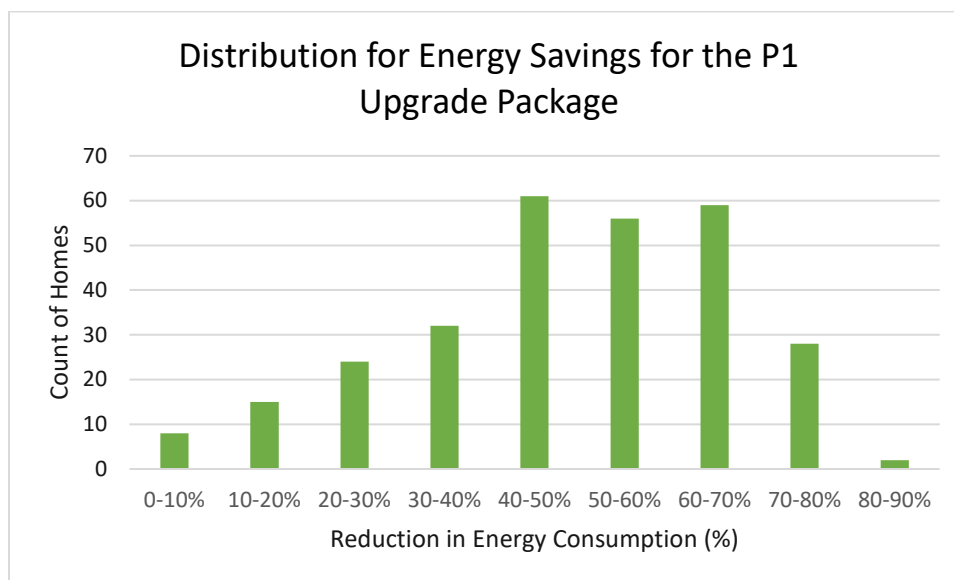
NRCan did not model archetypes for single-attached houses built in the 1978-1983 and 2016-2018 timeframes. However, homes of this vintage comprise fewer than 2% of all single-attached and single-detached houses.

### Sample Results

Following are results specific to the 285 archetypes modeled with the P1 upgrade package.

The mean energy savings was 49%. Figure 9 contains the distribution of household energy savings and shows the majority of houses achieved 40%-70% energy savings. The mean annual bill savings are \$2,300 and this distribution of bill savings is summarized in Figure 9. Over the lifetime of the measures modelled, average total bill savings are \$60k. The mean LCOC was -\$181/tonne, summarized in Figure 8.

Figure 9: Distribution of Energy Savings for the P1 Upgrade Package (n=285)



The mean retrofit project cost for P1 upgrades is \$36k. Figure 10 shows the distribution of bill savings and Figure 11 contains the distribution of retrofit project costs.

Figure 10: Distribution of Annual Bill Savings for P1 Upgrade Package

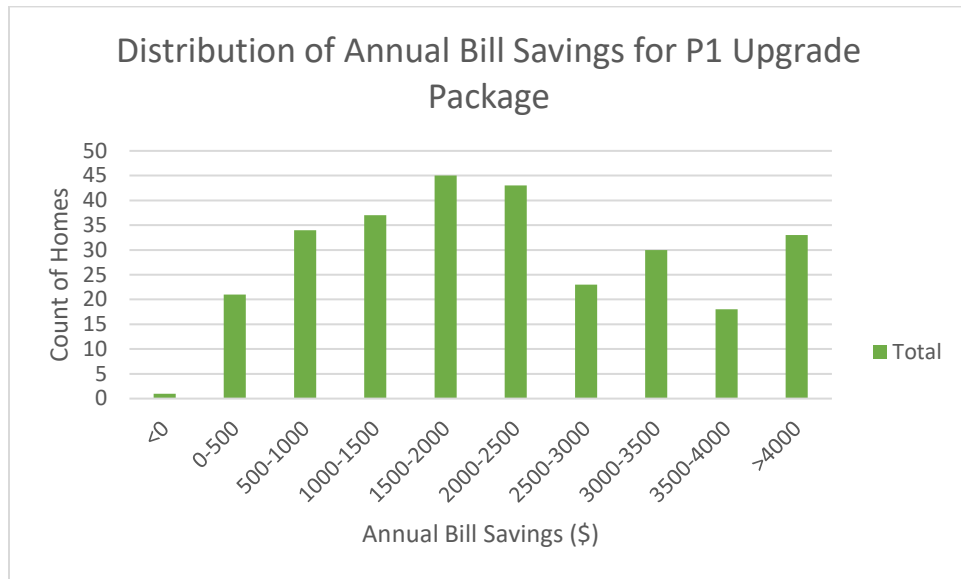
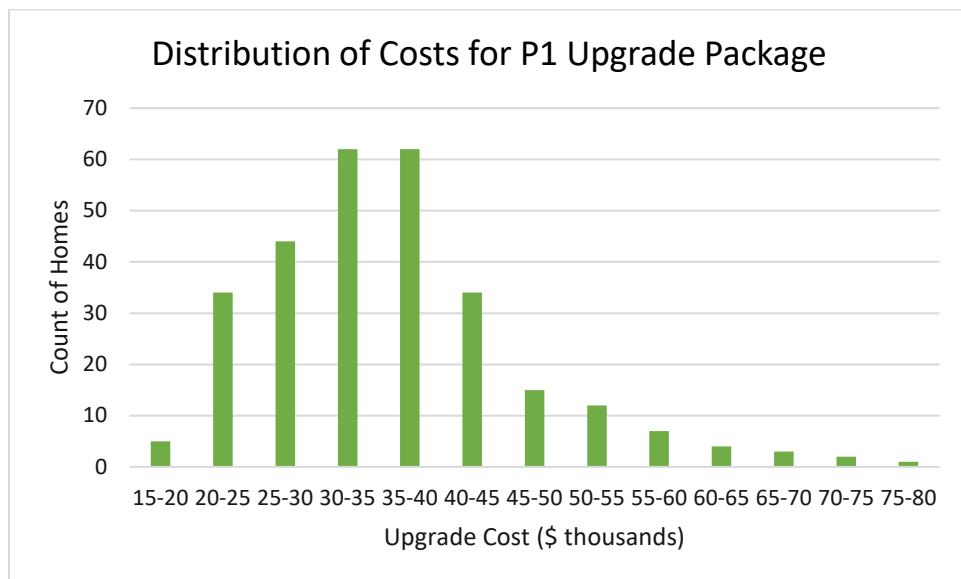


Figure 11: Distribution of costs for P1 Upgrade Package (n=285)



### 3.5.1.2 P2 Upgrade Package

#### Upgrades Modeled

The P2 upgrade package comprises the following upgrades:

1. Air sealing to 2.5 ACH @ 50 Pa

2. ENERGY STAR™ doors and windows (triple pane)
3. Exterior above-grade wall insulation to an effective R-value of R-27
4. Basement header insulation to an effective R-value of R-40
5. Basement foundation wall insulation to an effective R-value of R-22
6. Exposed floor insulation to an effective R-value of R-35
7. Ceilings below attic insulation to an effective R-value of R-50
8. Flat or cathedral ceiling insulation to an effective R-value of R-28

Unlike P1, this upgrade package focuses exclusively on the building envelope. Exterior wall upgrades come at a considerable expense, but by combining the substantial envelope upgrades, savings similar in magnitude to P1 are achieved despite no changes being made to mechanical systems.

### Archetypes Modeled

The P2 upgrade package was modeled for 47 archetypes. Most archetypes were single-detached with the majority (81%) of all archetypes built between 1961 and 1977.

*Table 10: Count of Archetypes Modeled by Year Built for the P2 Upgrade Package*

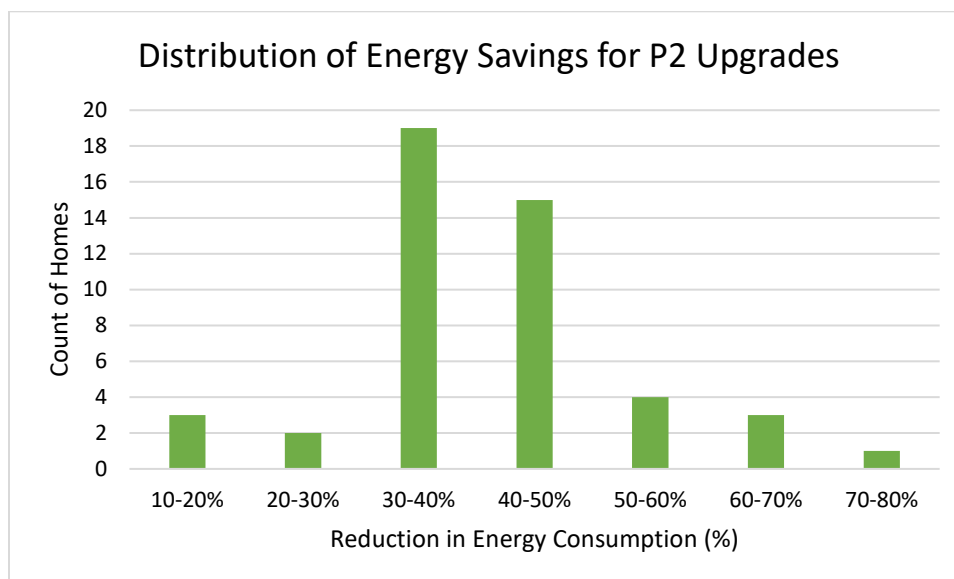
| Year of Construction | Single Attached<br>(Count of archetypes) | Single Detached<br>(Count of archetypes) |
|----------------------|------------------------------------------|------------------------------------------|
| 1900-1945            | 0                                        | 0                                        |
| 1946-1960            | 0                                        | 6                                        |
| 1961-1977            | 5                                        | 33                                       |
| 1978-1983            | 0                                        | 3                                        |
| 1984-1995            | 0                                        | 0                                        |
| 1996-2000            | 0                                        | 0                                        |
| 2001-2005            | 0                                        | 0                                        |
| 2006-2010            | 0                                        | 0                                        |
| 2011-2015            | 0                                        | 0                                        |
| 2016-2018            | 0                                        | 0                                        |
|                      | 5                                        | 42                                       |

### Sample Results

Following are results specific to the 47 archetypes that were modeled with the P2 upgrade package.

Mean energy savings was 40%. Figure 12 contains the distribution of household energy savings; most houses reduced energy use by 30%-50%. The average bill savings for this upgrade package is \$1,900 per year, as shown in Figure 13. Over the lifetime of the measures modelled, average total bill savings are \$61k. The mean LCOC was -\$156/tonne, summarized in Figure 8.

Figure 12: Distribution of Energy Savings for P2 Upgrade Packages as a Percent of Energy Saved (n=47)



The mean retrofit project cost for P2 upgrades is \$52k. Figure 14 contains the distribution of retrofit project costs. The standard deviation of project costs is approximately \$17k, which reflects significant variation driven primarily by differences in house size (i.e., how much surface area to insulate).

Figure 13: Distribution of Annual Bill Savings for the P2 Upgrade Package

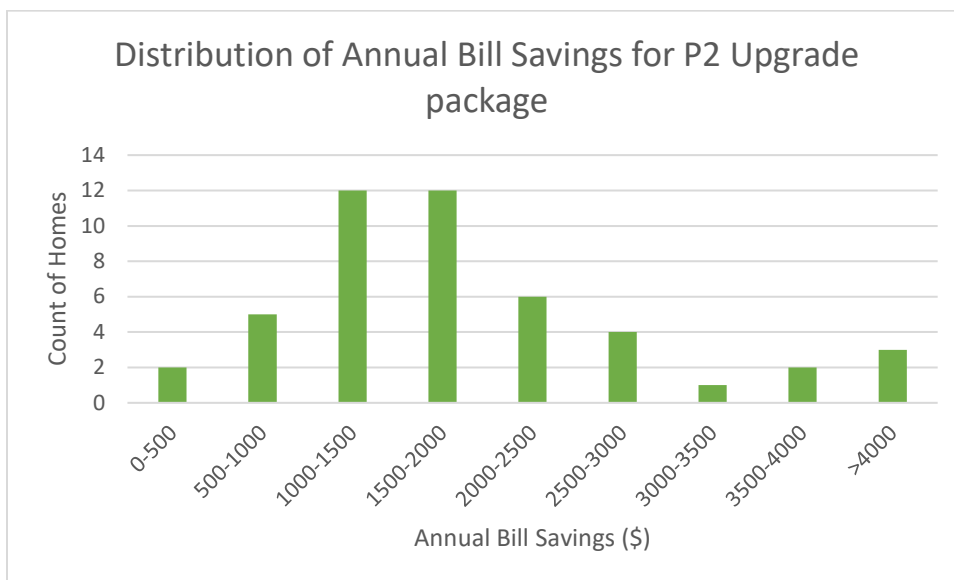
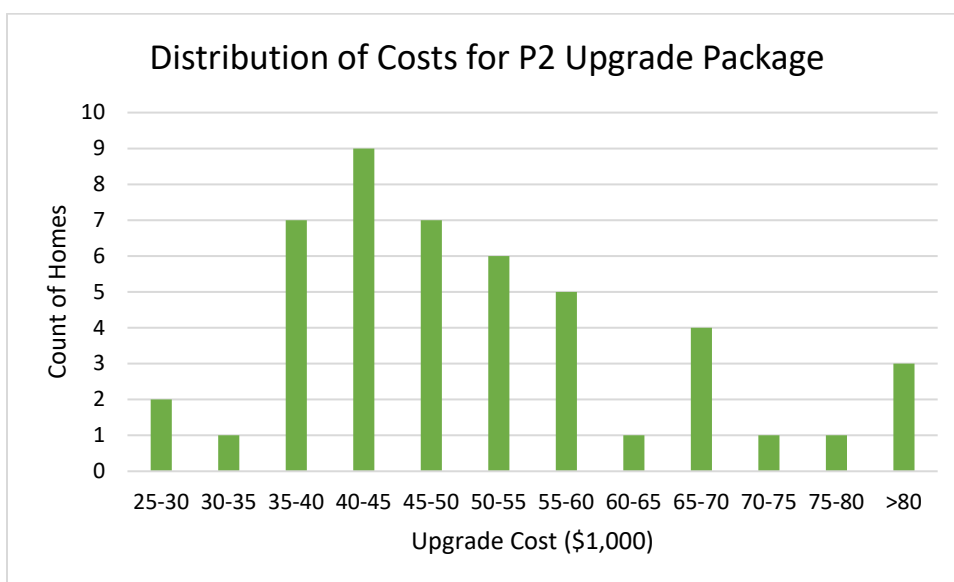


Figure 14: Distribution of Project Costs for P2 Upgrade Package (n=47)



### 3.5.1.3 P3 Upgrade Package

#### Upgrades Modeled

The P3 upgrade package is comprised of the following upgrades:

1. Air sealing to 2.5 ACH @ 50 Pa
2. Basement header insulation to an effective R-value of R-40
3. Basement foundation wall insulation to an effective R-value of R-22

4. Ceilings below attic insulation to an effective R-value of R-50
5. Flat or cathedral ceiling insulation to an effective R-value of R-28
6. Installation of a CCASHP

The P3 upgrade package is like the P1 package. However, P3 excludes relatively expensive window and door upgrades, achieves greater levels of airtightness, and includes upgrades to sloped and flat ceilings.

### Archetypes Modeled

The P3 upgrade package was modeled for 43 archetypes. Most archetypes were single-detached with the majority (82%) of all archetypes built between 1961 and 1977.

*Table 11: Count of Archetypes Modeled by Year Built for the P3 Upgrade Package*

| Year of Construction | Single Attached<br>(Count of Archetypes) | Single Detached<br>(Count of Archetypes) |
|----------------------|------------------------------------------|------------------------------------------|
| 1900-1945            | 0                                        | 0                                        |
| 1946-1960            | 0                                        | 5                                        |
| 1961-1977            | 5                                        | 30                                       |
| 1978-1983            | 0                                        | 3                                        |
| 1984-1995            | 0                                        | 0                                        |
| 1996-2000            | 0                                        | 0                                        |
| 2001-2005            | 0                                        | 0                                        |
| 2006-2010            | 0                                        | 0                                        |
| 2011-2015            | 0                                        | 0                                        |
| 2016-2018            | 0                                        | 0                                        |
|                      | <b>5</b>                                 | <b>38</b>                                |

### Sample Results

Following are results specific to the 43 archetypes modeled with the P3 upgrade package.

The mean energy savings was 45%. Figure 15 contains the distribution of household energy savings; the majority of houses reduced energy use by 30%-70%. The average bill savings for this upgrade package is \$2,100 per year. Figure 16 contains the distribution of bill savings. Over the lifetime of the measures modelled, average total bill savings are \$56k. The mean LCOC was -\$164/tonne, summarized in Figure 8.

Figure 15: Distribution of Energy Savings for the P3 Upgrade Package

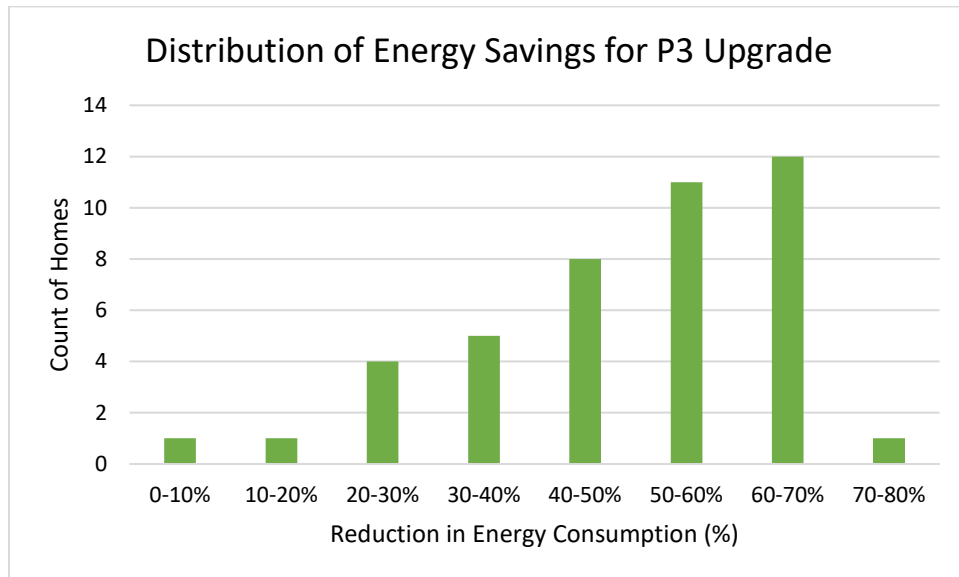
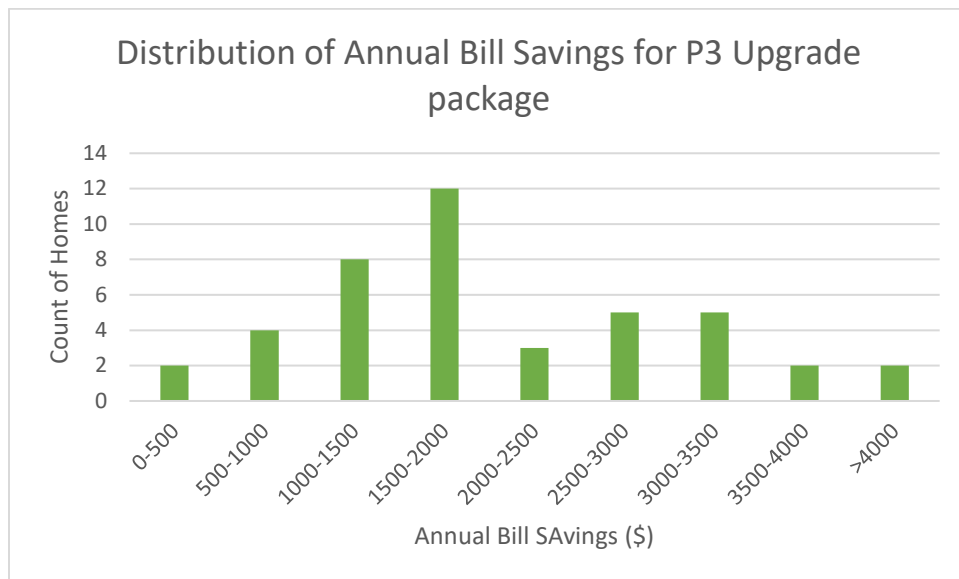
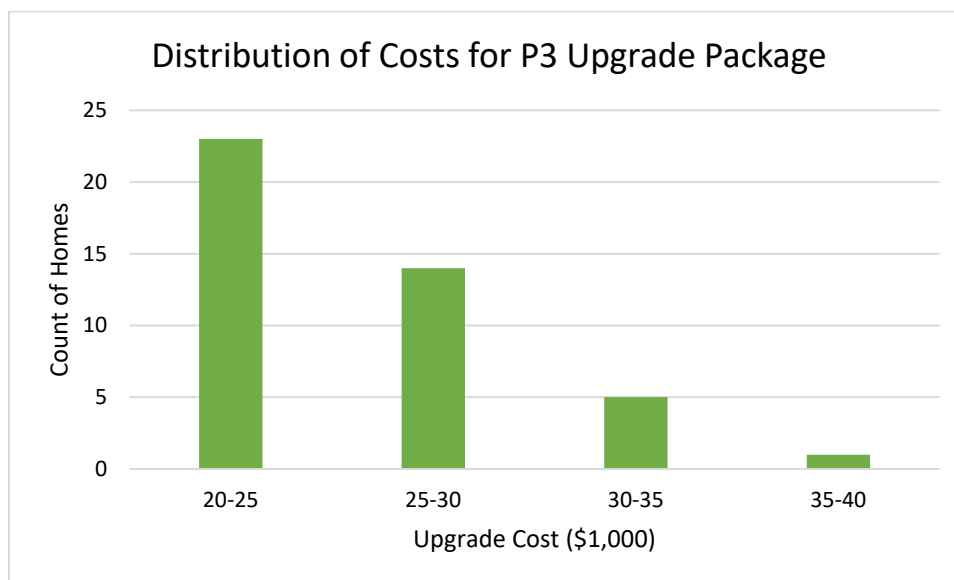


Figure 16: Distribution of Savings for the P3 Upgrade Package



The mean retrofit project cost is \$25k. Figure 17 contains the distribution of costs.

Figure 17: Distribution of Costs for the P3 Upgrade Package



### 3.5.1.3 P4 upgrade package

#### Upgrades Modeled

The P4 upgrade package comprises the following upgrades:

1. Air sealing to 2.5 ACH @ 50 Pa
2. Installation of a heat recovery ventilator (HRV)
3. Installation of a CCASHP

Unlike other upgrade packages, P4 focuses exclusively on air sealing and HVAC upgrades.

#### Archetypes Modeled

The P4 upgrade package was modeled for 47 archetypes. Most archetypes were single-detached with the majority (81%) of all archetypes built between 1961 and 1977.

Table 12: Count of Archetypes Modeled by Year Build for the P4 Upgrade Package

| Year of Construction | Single Attached<br>(Count of archetypes) | Single Detached<br>(Count of archetypes) |
|----------------------|------------------------------------------|------------------------------------------|
| 1900-1945            | 0                                        | 0                                        |

| <b>Year of Construction</b> | <b>Single Attached<br/>(Count of archetypes)</b> | <b>Single Detached<br/>(Count of archetypes)</b> |
|-----------------------------|--------------------------------------------------|--------------------------------------------------|
| <b>1946-1960</b>            | 0                                                | 6                                                |
| <b>1961-1977</b>            | 4                                                | 34                                               |
| <b>1978-1983</b>            | 0                                                | 3                                                |
| <b>1984-1995</b>            | 0                                                | 0                                                |
| <b>1996-2000</b>            | 0                                                | 0                                                |
| <b>2001-2005</b>            | 0                                                | 0                                                |
| <b>2006-2010</b>            | 0                                                | 0                                                |
| <b>2011-2015</b>            | 0                                                | 0                                                |
| <b>2016-2018</b>            | 0                                                | 0                                                |
|                             | <b>4</b>                                         | <b>43</b>                                        |

### Sample Results

The mean retrofit project cost is \$20k, with the majority of houses reducing energy use by 40%-60%. Figure 18 contains the distribution of costs. The average bill savings for this upgrade package is \$2,000 per year. Figure 19 contains the distribution of bill savings. Over the lifetime of the measures modelled, average total bill savings are \$52k. The mean LCOC was -\$150/tonne, summarized in Figure 8.

Figure 18: Distribution of Energy Savings for the P4 Upgrade Package (n=47)

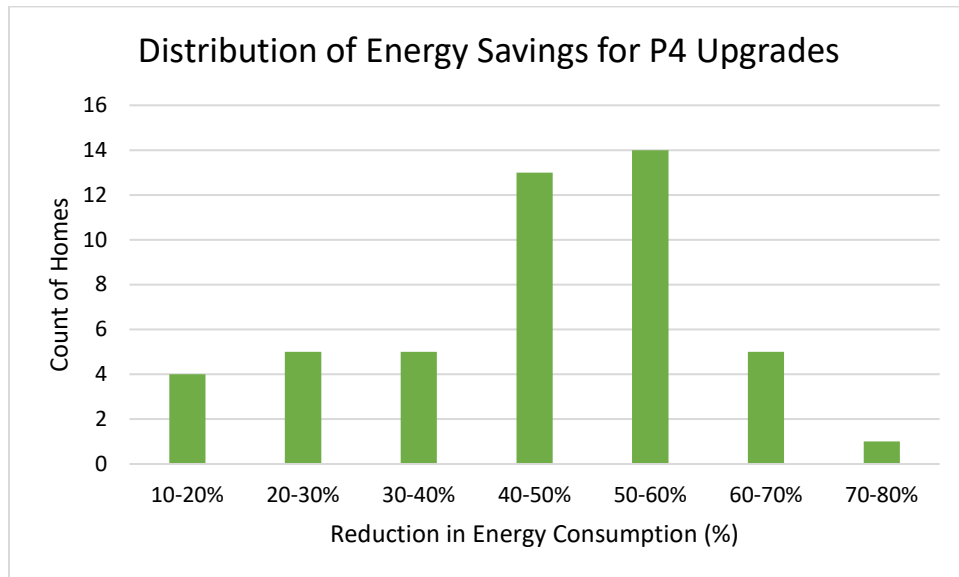


Figure 19: Distribution of Annual Bill Savings for P4 Upgrade Package

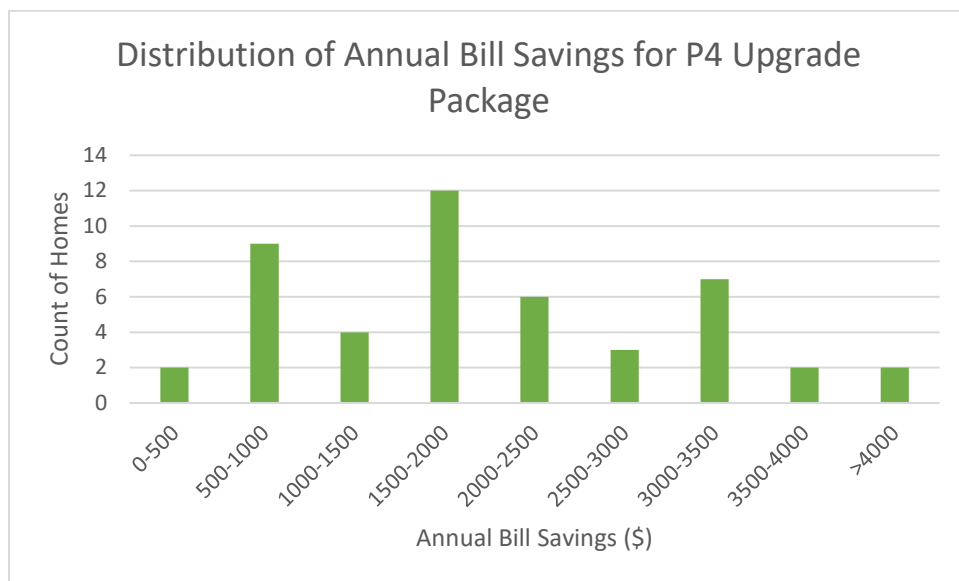
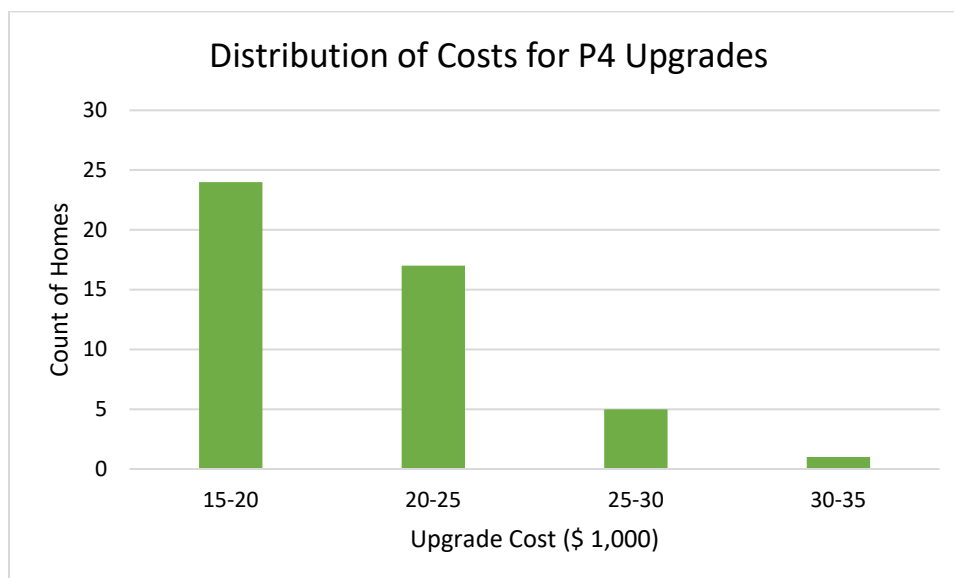


Figure 20: Distribution of Costs for the P4 Upgrade Packages (n=47)



### 3.5.2 Commercial and Institutional Technical Study Results

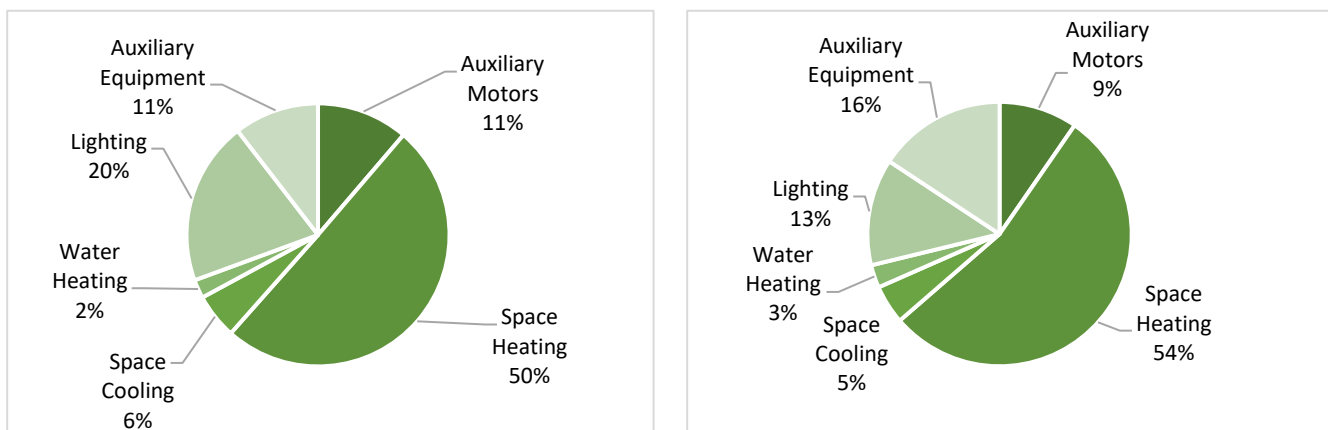
This section summarizes the findings from the calibrated energy models for C&I buildings. This includes the recommended ECM upgrade packages to achieve deep energy retrofit savings (50%+). These packages were developed to be the most cost-effective upgrades that successfully reduce energy consumption from a shallow retrofit (10% - 30% savings of BAU) to deep energy retrofits (50%+ savings over BAU).

#### 3.5.2.1 Baseline Building Archetype Energy End-Use Breakdown

Energy end-use breakdowns provide useful insights into the disaggregated energy use in a building by its respective systems and functions. Figures illustrating energy end-use are provided in Appendix B for all building archetypes modeled. These figures are based on the calibrated energy models and building archetype definitions also found in Appendix B. However, an example for the office building archetypes is included below.

## Office Building Archetype

Figure 21: Office Archetype 3 (left) and Archetype 4 (right) Energy End-Use Breakdown



Up to 80% of the predicted energy consumption for office buildings is accounted for in the space heating, auxiliary equipment, and space lighting end-use categories. This is a consistent outcome for all C&I building archetypes modeled. We used the NRCan end-use definitions where auxiliary equipment refers to any stand-alone equipment powered directly from an electrical outlet, which includes computers, commercial kitchen equipment and other plug loads.

In general, space heating represented the most significant energy end-use category, accounting for 35% - 58% of the total energy consumed. Conversely, space cooling (for building archetypes modeled with space cooling systems) represented less than 6% of the overall building energy consumption.

### 3.5.2.2 ECM – Upgrade Packages

The following example summarizes the results of the iterative energy modeling on C&I buildings. The models converged on the most cost-effective ECM upgrade packages. It should be noted that the simple payback estimates do not assume an increase in energy costs over the life of the measure and do not include other non-energy related operating and maintenance costs or benefits, yielding a conservative estimate of simple payback period. In practice, the inclusion of non-energy benefits would make these projects more financially attractive.

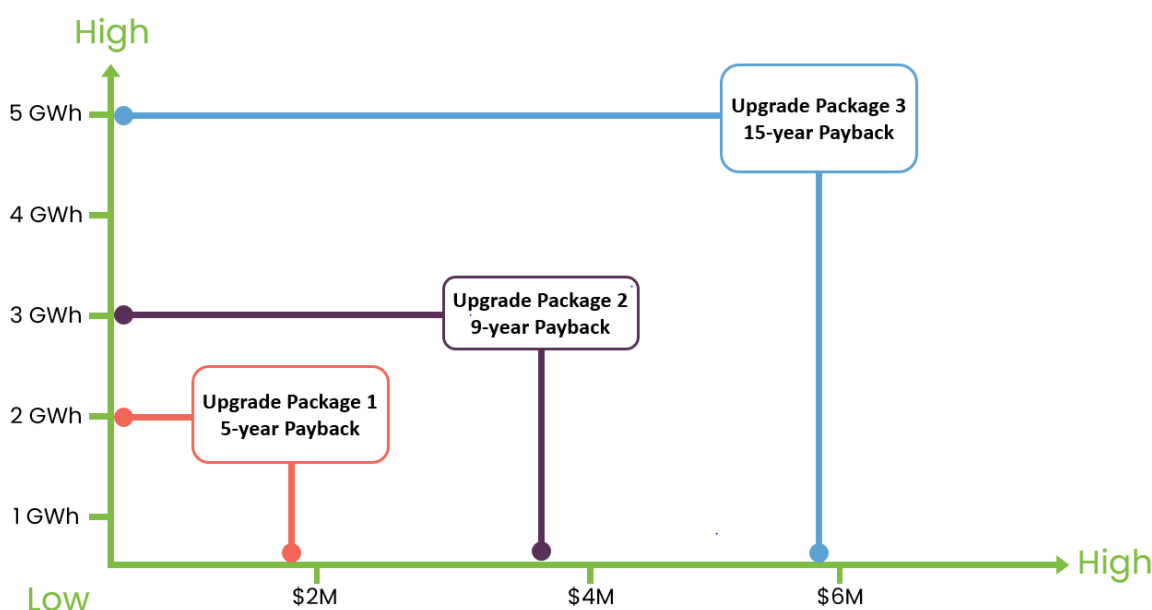
The upgrade packages and modeling outputs specific to each building archetype are summarized in Appendix B for all 10 building archetypes modeled. However, an example is provided in the figure below for Archetype 3 – multi-storey office building. Each upgrade scenario has a corresponding ECM upgrade package, simple payback period in years and a pie chart illustrating the distribution of total energy savings by end-use category. Each successive ECM upgrade package builds off the prior upgrade scenario. For example, upgrade package 3 included the ECMs from upgrade packages 1 and 2. The exception would be if an ECM is a direct replacement to the system defined in the prior upgrade package.

The distribution of energy savings by end-use shifts with each upgrade scenario. For example, lighting ECMs account for 39% of the total energy-savings Archetype 3 experiences in upgrade package 1 (30% energy-savings from BAU). Whereas in upgrade package 2 (50% energy-savings from BAU) the impact of lighting ECMs is lower (30%) as non-lighting ECMs are introduced.

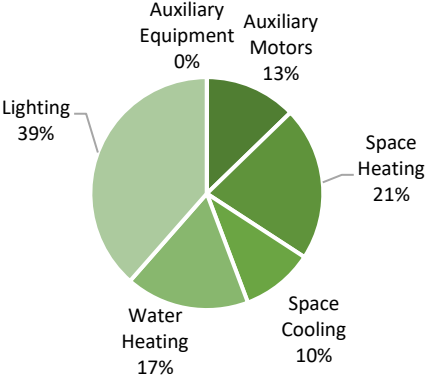
In each successive upgrade scenario, the ECMs modeled are less cost-effective, and more capital-intensive, than the previous. This is highlighted by the increasing simple payback period between upgrade packages 1 and 3. More capital-intensive measures such as these are good candidates for retrofit at the end of the equipment's useful life.

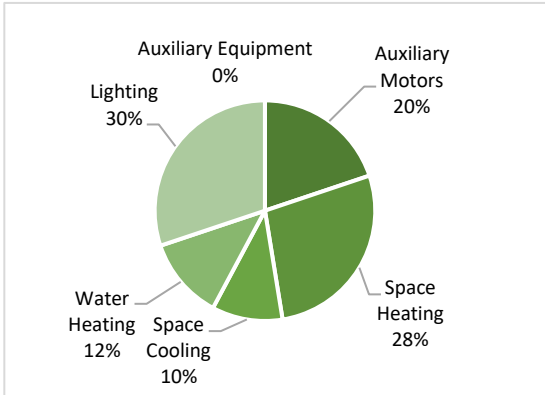
### Archetype 3

Figure 22: C&I Archetype 3 Upgrade Package Benefits Cost Diagram



The following shows the result of energy modeling for, large multi-storey office buildings in more detail.

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
|------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|----------|-----|---------------|-----|---------------|-----|---------------|-----|------------------|-----|---------------------|----|
| Upgrade Package 1: target 30% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>No upgrade</li><li>• <b>Lighting:</b><br/>LED Lighting</li><li>• <b>Heating System:</b><br/>Condensing boiler upgrade for HVAC system and temperature setbacks</li><li>• <b>Ventilation:</b><br/>Reduce runtime hours to match building occupancy</li><li>• <b>Pumps:</b><br/>VFD on DHW pumps with minimum setback<br/>Delta temperature control</li><li>• <b>Domestic Hot Water:</b><br/>Install low-flow fixtures<br/>Condensing boiler</li><li>• <b>Other:</b><br/>Schedule DHW recirculatory pump to shut off overnight<br/>Maximize use of nighttime setbacks (programmable thermostats)<br/>Reduce HVAC fan runtimes</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>2,102,000 or 31% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$188,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$3,247,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$996,000</p> | 5                             |  <table><caption>Distribution of Energy Savings by End-Use</caption><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Lighting</td><td>39%</td></tr><tr><td>Space Heating</td><td>21%</td></tr><tr><td>Water Heating</td><td>17%</td></tr><tr><td>Space Cooling</td><td>10%</td></tr><tr><td>Auxiliary Motors</td><td>13%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Lighting | 39% | Space Heating | 21% | Water Heating | 17% | Space Cooling | 10% | Auxiliary Motors | 13% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Lighting                                                   | 39%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Space Heating                                              | 21%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Water Heating                                              | 17%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Space Cooling                                              | 10%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Auxiliary Motors                                           | 13%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Upgrade Package 2: target 50% energy savings               | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof insulation (+40% R-Value from BAU)</li><li>• <b>Lighting:</b><br/>LED Lighting conversion with</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | 9                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |

| Upgrade Scenarios             | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|----------|-----|---------------|-----|------------------|-----|---------------|-----|---------------|-----|---------------------|----|
| from baseline                 | <p>occupancy sensors and scheduling of parking garage lighting</p> <ul style="list-style-type: none"><li>• <b>Heating System:</b><br/>AHU with ducted VRF heat pump coil with backup electric heater with SCR<br/>Condensing boiler upgrade for perimeter and terminal heating<br/>Maximize use of temperature setbacks</li><li>• <b>Ventilation:</b><br/>Full VAV conversion<br/>Ventilation fan speed control with VFD</li><li>• <b>Pumps:</b><br/>Pumps equipped with VFD and eliminate three-way valves<br/>Use of DP control<br/>Install variable speed DCW pumps</li><li>• <b>Domestic Hot Water:</b><br/>No additional upgrade</li><li>• <b>Other:</b><br/>Maximize use of nighttime setbacks (occupancy sensors day / night linked to BAS)</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>3,307,000 or 49% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$239,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$4,087,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$2,157,000</p> |                               |  <table><caption>Distribution of Energy Savings by End-Use</caption><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Lighting</td><td>30%</td></tr><tr><td>Space Heating</td><td>28%</td></tr><tr><td>Auxiliary Motors</td><td>20%</td></tr><tr><td>Space Cooling</td><td>10%</td></tr><tr><td>Water Heating</td><td>12%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Lighting | 30% | Space Heating | 28% | Auxiliary Motors | 20% | Space Cooling | 10% | Water Heating | 12% | Auxiliary Equipment | 0% |
| End-Use                       | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Lighting                      | 30%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Space Heating                 | 28%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Auxiliary Motors              | 20%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Space Cooling                 | 10%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Water Heating                 | 12%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Auxiliary Equipment           | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Upgrade Package 3: target 70% | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof insulation (+100% R-Value from BAU) and triple glazed</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | 15                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |

| Upgrade Scenarios            | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use                                                                                                                                                                                                                                                                                                                      |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|------------------|-----|----------|-----|---------------|-----|---------------|-----|---------------------|----|
| energy savings from baseline | <p>windows</p> <ul style="list-style-type: none"><li>• <b>Lighting:</b><br/>Incorporate daylight harvesting</li><li>• <b>Heating System:</b><br/>Geo-exchange system<br/>AHUs with WSHP ducted coil equipped with backup electric heater with SCR<br/>WSHP system for perimeter and terminal heating with electric boiler backup<br/>Maximize use of temperature setbacks<br/>ERV for washroom heat recovery linked to AHU supply</li><li>• <b>Ventilation:</b><br/>Maximize use of Demand Control Ventilation with CO2 sensor<br/>Ventilation fans equipped with VFDs<br/>Parking garage equipped with CO / NOx system</li><li>• <b>Pumps:</b><br/>Electronically Commutated Motor driven pumps with DP control (no sensor)</li><li>• <b>Domestic Hot Water:</b><br/>ASHP hot water heaters (highest efficiency option available)</li><li>• <b>Other:</b><br/>No additional upgrade</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>4,686,000 or 70% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$343,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$5,817,000</p> |                               | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>27%</td></tr><tr><td>Auxiliary Motors</td><td>20%</td></tr><tr><td>Lighting</td><td>21%</td></tr><tr><td>Water Heating</td><td>19%</td></tr><tr><td>Space Cooling</td><td>13%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 27% | Auxiliary Motors | 20% | Lighting | 21% | Water Heating | 19% | Space Cooling | 13% | Auxiliary Equipment | 0% |
| End-Use                      | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Space Heating                | 27%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Auxiliary Motors             | 20%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Lighting                     | 21%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Water Heating                | 19%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Space Cooling                | 13%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Auxiliary Equipment          | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |

| Upgrade Scenarios | ECM Upgrade Packages                     | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use |
|-------------------|------------------------------------------|-------------------------------|-------------------------------------------|
|                   | Upgrade Package Cost (\$)<br>\$5,148,000 |                               |                                           |

In the above example, the modeled energy savings expressed as a percentage reduction of BAU is near, but not exactly, aligned with the target for a given upgrade scenario. All ECM upgrade packages are known solutions based on the building systems specific to each building archetype. With each ECM added to a given upgrade package, the energy modeller aimed to get as close to the performance target (30%, 50% or 70%) as possible. Though similar ECMs were included in each building archetype energy model the savings impact will vary by building archetype. For this reason, achieving the performance target was more challenging to accomplish for some building archetypes, which is addressed in the following section and illustrated in the upgrade package figures in Appendix B. The ECMs evaluated in each building archetype are known solutions.

### Summary of Technical Research Findings (C&I)

We reviewed Efficiency Nova Scotia's business incentive program participation as part of the technical research. Since these business programs are almost exclusively focused on electrical energy efficiency, there are data gaps on the overall facility energy consumption including non-electric fuels. As a result, it is challenging to estimate the typical energy savings of program participation with respect to overall building energy consumption (all fuels). However, it is estimated that business operators are only investing in ECMs resulting in shallow energy retrofits (<30% reduction in total building energy use).

The market research responses indicated that typical business operators would not see projects with simple payback periods of greater than 10 years as financially attractive. For all building archetypes, the deep energy retrofit ECM upgrade packages (summarized in Appendix B) are greater than 10 years and thus financially unattractive; except for large multi-storey office buildings (archetype 3). Thus, ECM upgrade packages for deep energy retrofits would not typically be financially attractive without the inclusion of incentives or accounting for site-specific non-energy cost benefits (e.g., reduced maintenance costs).

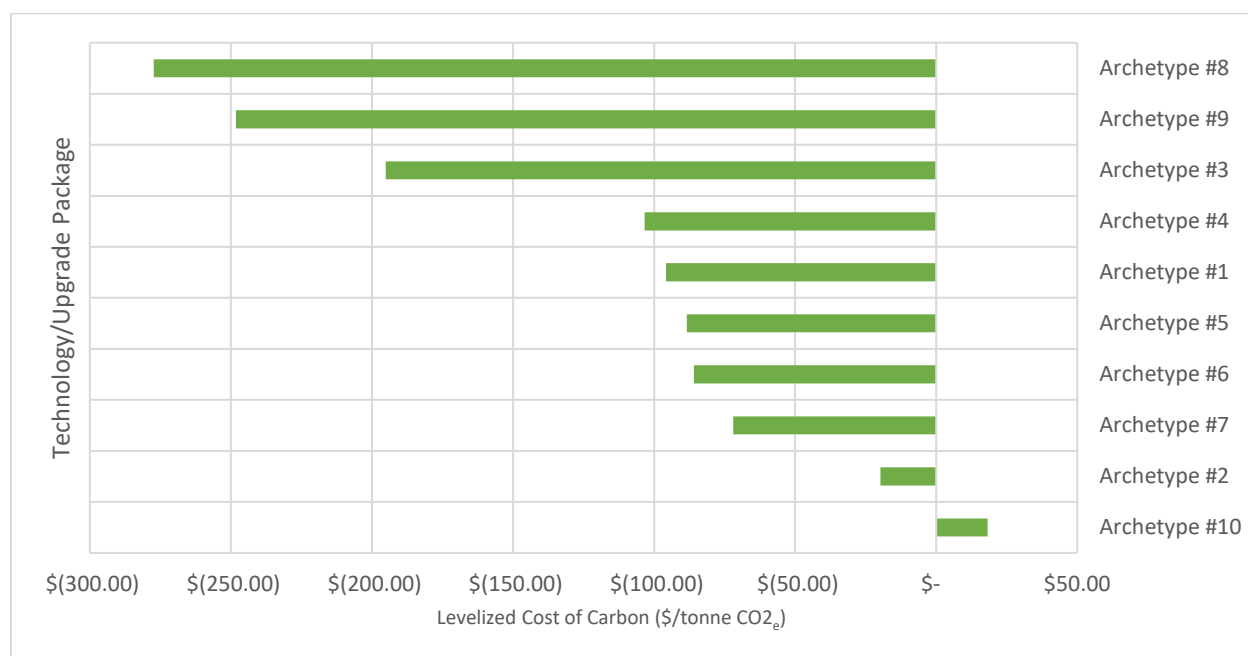
We also reviewed our energy management strategies developed for select C&I businesses with corporate commitments to achieve net-zero building operations. In these strategy documents, greenhouse gas emission reduction options were compared by evaluating upfront costs, operational costs, and implementation risk. For these C&I businesses, deep energy retrofits were a requirement to achieve net-zero building operations along with clean fuel procurement, fuel switching and carbon offsets. In the context of targeting net zero, deep energy retrofits were among the most cost-effective and lowest-risk options. In these strategy documents, deep energy retrofits were defined as a 50% energy reduction to business as usual.

Based on the literature reviews and financial evaluation of deep energy retrofit projects across the building archetypes in this study, the following needs to occur:

- Create tailored incentive programs for non-electric ECMs that would close the current gap.
- Offer deep energy retrofit incentives that cover a minimum of 30% of the upgrade and engineering costs to motivate business operators to move forward with these upgrades.
- Offer support to help customers make operational changes. Changes to equipment operating schedules, setpoints, and sequences of operations are required to achieve the level of savings associated with a deep energy retrofit project. This requires more training and technical support related to operational energy management.
- Achieving the performance target (70%) was not achievable for three of the building archetypes without changes to typical occupancy and process demand. These three archetypes were those in the food services and hospitality categories. Here, changes to process demand refer to reducing hours of operation for the commercial kitchen and other auxiliary equipment unique to these building archetypes. Furthermore, deep energy retrofits with energy reductions beyond 50% do not lead to favourable LCOC.
- If C&I organizations are pursuing energy efficiency to achieve net-zero building operations, deep energy retrofits (specifically 50% energy reduction to BAU) are an attractive option when compared with other greenhouse gas emission strategies. Pursuing greater energy reductions to BAU should be evaluated on a case-by-case basis as there can be site-specific barriers to exceeding this performance target, including 1) diminishing returns for further investment with some ECMs (e.g. increasing building envelope insulation value), and 2) specific building types that have significant process loads (e.g. commercial kitchen equipment) that are significant energy end-uses.

The research found that deep energy retrofits, 50% energy reduction to business as usual, is technically feasible for all C&I building archetypes modelled. These are technically feasible given that this performance target can be met with the implementation of readily available products and operational energy management practices. However, when comparing the simple payback of modelled ECM upgrades with the market research we found most businesses will require increased incentives and other forms of support to make these upgrades happen at the needed pace and scale.

Figure 23: C&I Levelized Cost of Carbon



## 4 Practical Considerations for Deep Energy Retrofits

Reaching substantial levels of deep energy retrofit market penetration requires several different technologies and funding mechanisms to overcome barriers to adoption. Overcoming these barriers is essential to meeting climate change reduction targets and achieving net zero.

This section discusses other factors that must be considered when planning how to remove barriers to entry and deliver affordable retrofits at scale. Differences in housing and building types and technologies; the perceptions held by stakeholders; the availability of data; regulatory constraints; and the current industry capacity will all need to be considered.

### 4.1 Residential

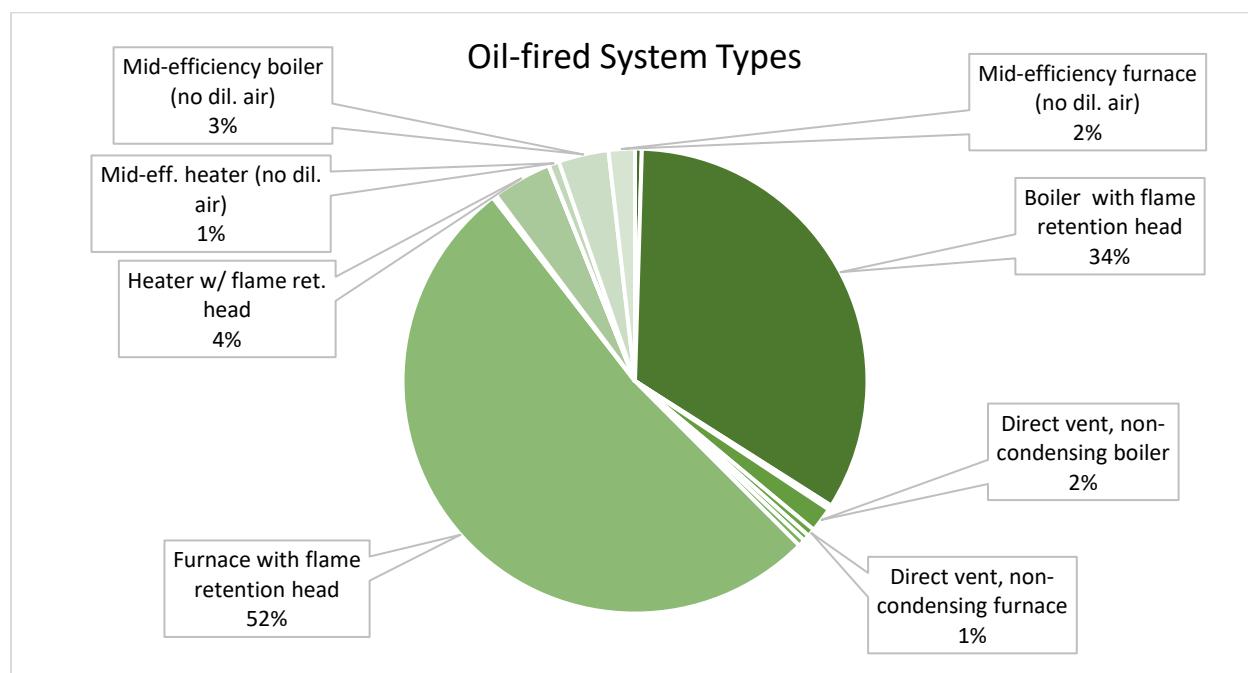
The upgrades explored in the technical study results are founded on general assumptions about costs. These broadly assume that all upgrades can be implemented in any house. However, it should be noted that many considerations will affect the cost and/or strategy for approaching a deep energy retrofit for a given building. If we are to implement deep energy retrofits at scale, it is important to consider the distribution of energy end-uses, the prevalent source of heat loss, the availability of project management and oversight, and the other enabling costs that residential customers might face.

#### 4.1.1 Existing Space and Water-Heating Equipment

##### Space Heating Equipment

Based on energy audit data from ENS programs, approximately 60% of participating households have a central, oil-fired heating system. Among those, roughly 40% have an oil-fired boiler and 60% have an oil-fired furnace (Figure 24).

Figure 24: Distribution of Primary Heating System Types in Households Heated by Oil (n=13,369). Systems with Shares of less than 1% are not shown.



Heat pumps can replace oil-fired furnaces, though such a replacement is not without its challenges. The supply air temperature of an oil-fired furnace is higher than that of a heat pump system, and the ducts in existing homes are sized accordingly — typically, they are smaller than what is ideal for the lower temperature/higher airflows needed for heat pumps.

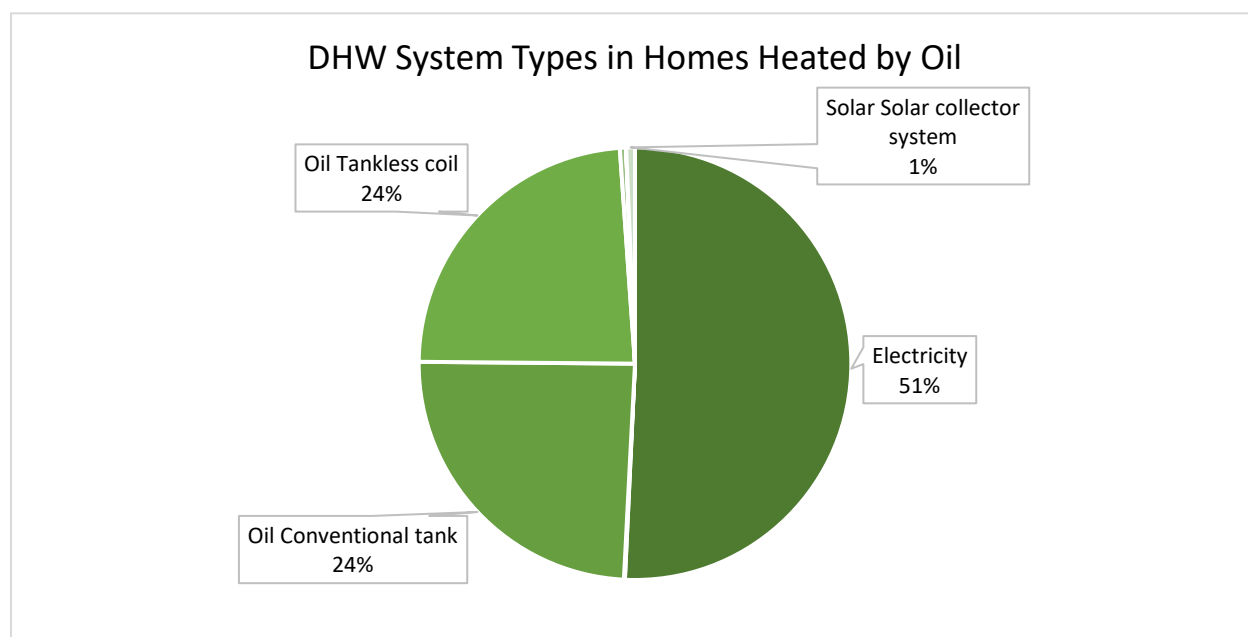
Oil-fired boilers offer more significant challenges; existing radiators are typically not suitable for the lower-temperature water supplied by an air-to-water heat pump. Similarly, the piping supplying those radiators can be undersized.

A qualified HVAC designer should ensure the existing distribution system and radiators can be used and make any necessary modifications.

## Existing Domestic Water-Heating Equipment

Based on energy audit data collected through ENS programs (n=13,369), 49% of oil-heated homes use oil to heat domestic water. Of those households, half use a conventional tank and half use a tankless coil.<sup>59</sup> The current market presents an opportunity to decarbonize water-heating technologies as long as industry has the needed capacity and skills.

Figure 25: Domestic Hot Water (DHW) System Types in Homes Heated by Oil (n=13,369)



### 4.1.2 Exterior Facade

Above-grade exterior walls account for approximately 20% of all heat loss, as do windows and doors. This is based on pre-retrofit assessment data of 8,895 ENS program participants (Figure 22).

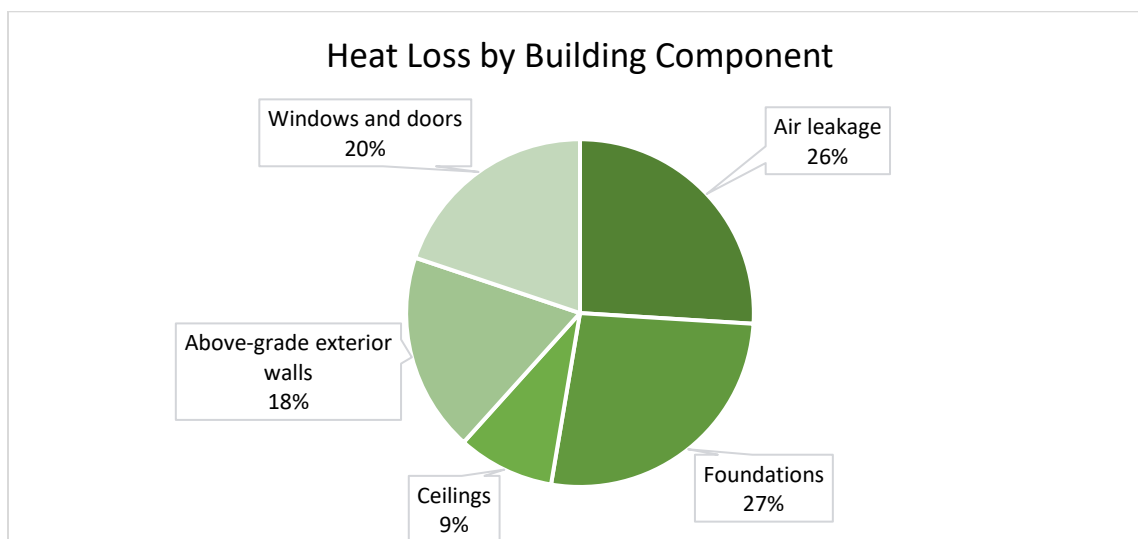
It's worth noting that transparent building assemblies like windows and doors necessarily have limited upgrade potential when compared to opaque assemblies like walls and ceilings. For example, an uninsulated 2x4 wall (approximately R-4 to R-5) can add blown-in cavity insulation and exterior rigid insulation and achieve an R-value of R-22+. A single-pane window could have an R-value of ~R-1 and upgrading it to an ENERGY STAR™ replacement would bring it to ~R-4. Even high-performance Passive House-certified windows reach R-5 up to R-14 at the extreme<sup>60</sup> (i.e., the best performing windows will generally be on par with the worst performing walls and will always be a significant source of heat loss

<sup>59</sup> The “oil conventional tank” category includes tanks with standalone burners and indirect water heaters. Indirect water heaters and tankless coils both tie into the oil-fired boiler used for space heating. Replacing the heating system necessitates replacing the water heater in these cases.

<sup>60</sup> [Passive House Component Database min and max U<sub>w</sub>](#)

regardless of whether they've been upgraded). That said, conductive losses are not the only source of heat loss from windows and doors; a poorly installed or otherwise compromised window installation can be a significant source of air leakage, and a properly installed replacement can reduce heat loss from air leakage.

Figure 26: Heat Loss by Building Component Based on Pre-Retrofit Energy Audits (n=8,895)



Options are limited for upgrading exterior walls without incurring the prohibitive cost of removing cladding. Stud cavities in older homes are 3.5-4.0 inches deep, so cavity insulation alone cannot produce a high R-value wall assembly. Stud bays can be furred out to create a deeper cavity, but this requires gutting the interior living space and doesn't address thermal bridging via studs. Adding insulation between the exterior sheathing and cladding is often the most practical and effective option but replacing cladding and detailing windows for the newly increased wall thickness adds significant cost.

Together, all elements of the exterior facade account for the largest portion of heat loss in a house (i.e., windows, doors, and walls total 38% of heat loss). These are also the most expensive upgrades explored in this study. Every opportunity should be taken to make such upgrades more economical (i.e., when it's time for windows to be replaced, add exterior insulation at the same time (and vice versa for when the cladding needs to be replaced)). Doing window, door, and exterior wall upgrades concurrently also means critical connections to vapor-, air-, and weather-control layers of the building envelope can be detailed properly. This is a significant opportunity to reduce heat loss due to air infiltration, the single greatest source of heat loss in existing houses (26% of all heat loss).

Approaches such as the Energiesprong initiative may simplify and make facade retrofits more cost-effective, using prefabricated panelized envelope upgrades. Such a model could be applied on a

community-wide basis to achieve economies of scale. This concept is explored further in Efficiency Canada's report entitled "Canada's Retrofit Mission".<sup>61</sup>

#### **4.1.3 Project Management and Oversight**

Deep energy retrofits involve modifications to multiple building components and systems and therefore require different trades and coordination of those trades. For example, replacing an oil-fired boiler with a heat pump requires an HVAC designer, a heat pump installer, an electrician, a plumber, and a company qualified to remove oil tanks. A deep energy retrofit of such a house would include these trades and services in addition to those needed to perform building envelope upgrades. Coordinating such a project is a substantial undertaking. It is not something most homeowners are qualified or willing to take on themselves. A core tenet of energy efficiency programs and retrofit projects is the house-as-a-system concept, described by NRCan as follows<sup>62</sup>.

A HOUSE OPERATES AS A SYSTEM. ALL THE ELEMENTS OF A HOUSE, THE ENVIRONMENT, ENVELOPE, MECHANICAL SYSTEMS AND OCCUPANT ACTIVITIES AFFECT EACH OTHER, AND THE RESULT AFFECTS THE PERFORMANCE OF THE HOUSE AS A WHOLE.

Complex projects which make changes to multiple aspects of a building must therefore consider the ways in which those changes interact with other building systems and components. A common example is increasing the airtightness of a home that does not contain a mechanical ventilation system; if air leakage is reduced substantially, humidity levels in the home will rise, which can promote mould growth, degrade building materials, and reduce indoor air quality.

#### **4.1.4 Enabling Costs**

Major renovations often encounter unforeseen costs or will require additional scope items to perform the work in a safe, technically sound, and aesthetically pleasing way. This can include but is not limited to:

- Abatement of hazardous materials, e.g. asbestos, lead paint
- Upgrades to dated or unsafe infrastructure, e.g. lead and galvanized pipes, knob and tube wiring
- Decommissioning oil equipment
- Electrical service upgrades
- Cosmetic upgrades, e.g. new cladding or interior finishes
- Water management, e.g. installing an interior or exterior drainage system
- Added external costs, such as to move tenants during disruptive upgrades

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<sup>61</sup> Haley, B., & Torrie, R. (2021). *Canada's Climate Retrofit Mission: Why the climate emergency demands and innovation-oriented policy for building retrofits*. Retrieved on December 2, 2022 from <https://www.energycanada.org/wp-content/uploads/2021/06/Retrofit-Mission-FINAL-2021-06-16.pdf>

<sup>62</sup> [Keeping the heat in, §2.1.7, Natural Resources Canada](#)

These costs are not currently eligible for incentives under existing efficiency programs in Nova Scotia. Financial support to address these barriers would enable more deep energy retrofits to happen, particularly for families living in energy poverty.

## **4.2 Commercial and Institutional**

The technical research provides guidance on the ECM upgrades to achieve deep energy retrofits based on the Nova Scotian C&I building stock. As outlined earlier in this document, the technical research is based on archetypal energy modeling. Although these building archetypes are representations of “typical” buildings, the estimated project costs and ECM packages might not be applicable in all cases. Therefore, the ECM packages, costs, and other findings from this technical research should be considered an informed starting point for how to achieve deep energy retrofits. This section addresses some of the real-world considerations based on our market research and experience working with industry and businesses to undertake energy efficiency projects.

### **4.2.1 Industry Capacity and Expertise**

Since 2020, federal and provincial investments in energy efficiency and GHG reduction programs have increased. This has motivated eligible businesses to invest in energy efficiency projects and placed increased demand on industry to support projects. Examples of industry support include energy auditing, engineering design services, project management, and equipment commissioning. From our experience, there are capacity and expertise challenges in meeting the current market demand. Increasing project timeline delays and a small pool of firms bidding on energy efficiency projects are examples of these challenges in practice. The latter has been observed as a key barrier for building optimization (recommissioning) projects where there are a limited number of firms in Nova Scotia with this expertise. For building optimization projects, firms must perform energy audits and address equipment scheduling, setpoint and sequence of operation changes that when implemented could reduce operating energy consumption. All these challenges would be exacerbated if the market demand shifts to undertake more deep energy retrofit projects, meaning that more capacity will be needed to sustain all energy efficiency initiatives that must be undertaken to achieve net zero.

### **4.2.2 Project Considerations**

The following are considerations for businesses planning or executing energy efficiency projects within their owned or rented buildings:

- Procurement – Businesses have a major influence over the scope of the bids they receive, which are often in response to a request for proposals (RFP). When procuring engineering design services, the RFP requirements should include the necessity for bidders to build energy efficiency measures into the design and in the case of a design/build process, facilitate available funding from open programs (e.g., DSM incentive programs).
- Energy Services Companies (ESCOs) and operating and maintenance (O&M) – Businesses with an energy performance contract should require their ESCO to perform O&M training for their

employees. If this is performed well, the energy savings outcomes of the contract can be maintained.

- Energy efficiency as part of Facility Condition Index (FCI)<sup>63</sup> improvements – Integrating energy management and facility condition improvements can minimize overall costs to a business. Furthermore, the utility savings can be reinvested in other projects (infrastructure, renewal etc.) or other areas of the business. Some ECMs are capital-intensive, including the replacement of a heating system and building envelope improvements. These ECMs often have a simple payback exceeding 10 years, based on our program experience that corroborates the market research.
- Minimizing disturbances to building tenants – Deep energy retrofits should be implemented through longer-term capital project planning. The impact on the use and functionality of the building may affect the scope of the renovations but also timing. The work could be done at certain times of the year during multiple consecutive years to minimize disturbances.

#### **4.2.3      *ECM Considerations***

The following are considerations for businesses when reviewing the ECM upgrade packages outlined in this paper:

- Scheduling equipment – Any scheduling of HVAC and DHW systems outlined in the ECM upgrade packages needs to be evaluated by site. Specific comfort or operational requirements could limit the scope of equipment and temperature setback schedules. This can be addressed by working closely with building managers and tenants.
- Making a building solar photovoltaic (solar PV) ready - When retrofitting or replacing a roof, perform the structural evaluation that would be required for a solar PV project and make any needed structural upgrades during the roof retrofit. This minimizes the overall costs associated with a roof-mounted solar PV installation. These costs were not quantified in the technical analysis.
- Retail lighting requirements – ECM upgrade packages for the retail sector assumed all lighting could adopt LED technology and that lighting design would ensure over-lit areas are minimal. The technical research referenced the IES-recommended lighting levels to estimate the power per square unit of space. However, there might be customer requirements for additional overhead lighting or specialized lighting that was not accounted for in the energy modeling. Examples of this additional overhead lighting could be spotlights or downlights that highlight products in the store. If so, the real-world lighting savings and the payback period would vary from what is summarized in the technical results section of this paper.
- Backup electric heat – Air-source heat pumps (ASHP) are an attractive and efficient heating system option but require backup electric heat. Water-source heat pumps (WSHPs) and geo-exchange heating systems should be evaluated on a project-by-project basis as they are more efficient than ASHPs and do not have the same backup electric heating requirements. These systems do have a higher initial cost in most cases.

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<sup>63</sup> FCI is used by facility managers to benchmark the condition of facilities in a portfolio of buildings.

- Dedicated outdoor-air system (DOAS) – DOAS was only modeled for the healthcare building archetypes. However, these systems are growing in popularity and could create opportunities for increased heat recovery, so they should be evaluated in buildings where the following benefits are priorities:
  - Improved indoor air quality
  - Reduced ventilation energy consumption
  - Opportunity to downsize other HVAC equipment at its end of useful life
  - Reduce mold and other moisture-related problems in buildings

#### **4.2.4      *Enabling Costs***

Like the residential sector, all major retrofit projects in the commercial and institutional sectors will encounter unforeseen costs and impacts to retrofit timelines. Examples of this can include but are not limited to:

- Abatement of hazardous materials typically encountered in building envelope upgrade projects
- Installation of a building automation system where there is none
- Adding setpoints and metering to the building automation system where required
- Decommissioning old equipment
- Electrical services upgrades and costs associated with in situ backup generation requirements
- Lost rentals and costs to displace tenants for disruptive upgrades
- Cosmetic upgrades
- Resolving repairs associated with deferred maintenance

### **4.3      *Customer Perceptions***

To assess sentiment around energy efficiency, E1 regularly conducts quarterly research among the general population of Nova Scotia. As of Q1 2023, 63% of residents believe that energy efficiency upgrades can help offset the rising cost of living, 61% agree that the rising cost of living has made their household give more thought to energy efficiency, and 59% are willing to spend money, time, and effort to become more energy efficient<sup>64</sup>.

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<sup>64</sup> Narrative Research. *Atlantic Quarterly Commissioned Results for Efficiency One*. (Q1 2023).

## Statements on Energy Efficiency

A recent survey conducted for EfficiencyOne by Narrative Research found the following:

**63%** agree or strongly agree that energy efficiency upgrades can help offset the rising cost of living.

**61%** agree or strongly agree that the rising cost of living has made their household give more thought to the energy efficiency of their home.

**59%** agree or strongly agree that they are willing to spend money, time, and effort to become energy efficient.

In addition, to better understand how customers perceive deep energy retrofits, consultants, residential decision-makers, and key C&I customers were invited to take part in surveys, discussions, in-depth interviews, and focus groups. We spoke to residential customers, held three residential contractor focus groups, had eight in-depth conversations with engineering consultants, held two online consultations with residential decision makers, conducted two online focus groups with homeowners, and had six individual in-depth interviews with key C&I accounts. Feedback from consumers suggests that there is interest in deep energy retrofits in the Nova Scotia market, but there are clear concerns regarding financial viability. Nonetheless, the benefits of deep energy retrofits are apparent to residents and businesses despite the price tag. There is a strong recognition of the various advantages of deep energy retrofits, including reduced energy costs, improved comfort, and better air quality, to name a few.

### Expected Benefits of Deep Retrofits

Over 85% of residents and organizations expect to see reduced energy bills as a result of deep retrofits according to a recent survey completed by Narrative Research for EfficiencyOne. Here are some of the other expected benefits:



improved comfort



better indoor air quality



more resilient buildings



increased property value

Before being presented with the associated costs of deep energy retrofit projects, most residents and businesses felt the renovations were a worthwhile investment for building owners. In fact, the concept (without cost factors considered) appealed to 39% of residents and 29% of businesses, with those interested in completing a deep energy retrofit primarily being drawn to the prospective cost savings and environmental benefits. After being presented with the estimated costs of deep energy retrofits (based on building type), the likelihood of completing such a project in the near future dropped to 14% among residents and 13% among businesses.

When considering a deep energy retrofit, financial concerns are a significant obstacle for residents and businesses. Specifically, when asked what factors might prevent them from completing a deep retrofit, the top two barriers mentioned relate to cost (59% of both homeowners and businesses indicated that they simply do not have the money, and 46% of homeowners and 49% of businesses mentioned that there are no financial incentive programs available to help with costs). A lack of interest or prioritization of completing energy efficiency upgrades was only indicated by a small portion, including 17% of residents and 36% of businesses mentioning that they have too many other priorities, while only 4% of homeowners and 3% of businesses said that deep retrofits are not worth it. Based on this information, this suggests that there is strong interest in the market to undertake deep retrofits, but they simply cannot afford it. There is also a strong desire to avoid debt and to pay for the projects out of pocket, though financing options such as home equity loans and repayable commercial bank loans are also reasonable and likely necessary options for many. Indeed, most residents would not be able to afford an additional monthly cost of \$200 or more to fund the renovations. This is not surprising given the portion of Nova Scotians living in energy poverty today (27% in HRM, and 43% elsewhere in the province, depending on commodity energy prices). On average, households that implement upgrade package P1 as described in section 3.5.1 would incur monthly costs of \$200 or less if upgrades were financed over 10 years or more at an annual interest rate of 5%. However, it should be noted that the average simple payback (without incentives from efficiency programs) for upgrade package P1 is 17 years. This means net monthly cash flows are negative for most loan term lengths (<21 years assuming an interest rate of 5% APR), as shown in Table 13.

*Table 13: Average Net Monthly Cashflow for Upgrade Package P1*

| <b>Borrowing Rate (APR)</b> | <b>Term (years)</b> | <b>Monthly Loan Payment (\$)</b> | <b>Average Monthly Bill Savings (\$)<sup>65</sup></b> | <b>Cumulative bill savings (\$)<sup>66</sup></b> | <b>Average Net Monthly Cost (\$)</b> |
|-----------------------------|---------------------|----------------------------------|-------------------------------------------------------|--------------------------------------------------|--------------------------------------|
| 5%                          | 5                   | -\$686                           | \$189                                                 | \$12,021                                         | -\$497                               |
|                             | 10                  | -\$386                           | \$199                                                 | \$25,293                                         | -\$187                               |
|                             | 25                  | -\$213                           | \$232                                                 | \$73,988                                         | \$20                                 |

It should be noted that four in ten residents expressing a likelihood to complete deep energy retrofits would be willing to take out a loan with a term of 5 to 9 years, while over a third would not take out a

<sup>65</sup> Monthly bill savings assumes a 2% annual increase due to changes in fuel costs over time.

<sup>66</sup> *ibid*

loan for more than five years – making the average net monthly cost hard for some homeowners to manage.

Among businesses, just 13% would be able to dedicate a maximum of 25% of their capital expenditures towards efficiency projects, whereas nearly 75% are unsure what they would be able to commit in terms of capital expenditures. In terms of payback period, the bulk of commercial decision makers indicating a likelihood to undertake deep energy retrofits would expect a loan term of less than 10 years, and nearly three in ten expect a loan term between 10 and 14 years. Fewer than one in ten would be willing to take out a loan for 15 years or more.

Beyond financial considerations, residential and commercial building owners cite a strong preference to choose the contractors and professionals that would do the work. While the majority of both audiences feel they have a general understanding of the kinds of upgrades their buildings need, most would require guidance in determining what specific work needs to be done and in accessing the expertise of contractors in carrying out and managing these potentially complicated projects. As well, insights from the qualitative research suggest that given the significance of the investment required to complete a deep energy retrofit, consumers would be hesitant to receive guidance and expertise from an organization that would be expected to profit from the project.

Although there is significant interest in deep energy retrofits, there are also concerns about financial viability despite the advantages. It is important that we find ways to address these concerns if we are to reach net-zero emissions.

#### **4.4 Access to Programs and Support**

Given the high cost of deep energy retrofits and the prevalence of energy poverty, it is unlikely that incentives alone will ensure widespread access to programs and support. It is important that we overcome financial barriers by establishing and marketing programs that directly support those experiencing energy poverty. ENS currently offers programs doing this (HW, Affordable Multi-Family Housing, and MHEEP), but not at the scale required to eliminate energy poverty.

Access to programs and support for deep energy retrofits is an important goal when assessing their applicability in the province. These projects are expensive, so barriers to entry must be addressed if we want to realize the emissions reduction potential these projects can offer.

#### **4.5 Industry Capacity**

Research conducted in Q2 of 2021 by the Canada Green Building Council (CaGBC) estimates that to meet climate goals over the next decade, upwards of 1.5 million green building sector professionals would be required – a threefold increase in the current workforce – resulting in a total of more than 31,000 direct jobs in Nova Scotia by 2030 (Canada Green Building Council, 2020). Meanwhile, over the past two years, job vacancies, particularly in the construction sector, continue to rise dramatically.

Since the start of the pandemic in early 2020, the number of unfilled positions in Canada has increased by nearly 75%. In Nova Scotia, vacant positions reached a new all-time high as of Q2 2022, with labour

shortages in the construction industry being among the highest across all sectors.<sup>67</sup> Paired with increased market demand in the green building construction and retrofitting sector, industry capacity poses a significant challenge to meeting GHG reduction targets.<sup>68</sup>

Based on our market research, there is interest among industry members to undertake more intensive energy efficiency projects. However, renovation contractors do not have the capacity to educate and inform customers about the benefits of energy efficiency when responding to renovation requests. Meanwhile, engineering consultants highlight a need to offer strong financial incentives to motivate customers to complete deep energy retrofits given the costs.

Beyond a focus on workforce shortages in the building sector, those within the green building sector must be equipped with the technical skills and knowledge required to carry out deep energy retrofits.<sup>69</sup>

Addressing industry capacity for wide-scale deep energy retrofits calls for significant investment in zero carbon training and education to reduce relevant gaps among trades and industry professionals such as engineers, architects, and renewable energy specialists.<sup>70</sup> Moreover, complex deep energy retrofit projects require oversight and project management to ensure the coordination of various trades and professionals.

Market research indicates that most contractors responsible for individual measures (e.g., installation of heat pumps) are not interested in managing entire deep energy retrofit projects. General contractors who do have this project management experience and skillset are reluctant to take on what amounts to a high-risk project (i.e., significant learning curve, removing key building systems, and displacement of homeowners) at a time when they cannot meet demand for their other services.

Building industry capacity to deliver deep energy retrofits will be an iterative cycle. Funding and programs will increase market demand, while contractors will need to invest in physical assets, hire new people and train them to meet that demand. They will only do so if demand for their services is expected to be sustained over their long-term investment horizons.

### 4.6 Availability of Data

The cost estimates produced in this study are approximations that are useful to understand the magnitude of investment required for deep energy retrofits. However, the availability and granularity of retrofit cost data is a significant opportunity for improvement. For example, detailed costing information was not

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<sup>67</sup> Statistics Canada. (2022). *Job vacancies, first quarter 2022. The Daily*. <https://www150.statcan.gc.ca/n1/daily-quotidien/220621/dq220621b-eng.htm>

<sup>68</sup> Canada Green Building Council. (2020). *Canada's Green Building Engine: Market Impact and Opportunities in a Critical Decade*. <https://pdfslide.net/download/link/canadaas-green-building-engine-since-the-first-edition-of-this-market-assessment>

<sup>69</sup> Agar, B. (2020). *Training up for Deep Retrofits: Skilled Trades Are Key to Transforming Canada's Building Sector*. Pembina Institute. <https://www.pembina.org/reports/deep-retrofit-skills-training-2020.pdf>

<sup>70</sup> Agar, B. (2020). *Training up for Deep Retrofits: Skilled Trades Are Key to Transforming Canada's Building Sector*. Pembina Institute. <https://www.pembina.org/reports/deep-retrofit-skills-training-2020.pdf>

available for all ECMs as applied to all C&I archetypes, but we recognize costs will vary by building and by archetype.

This study relied upon pre-pandemic costing information, and most ECMs would now cost more due to recent price increases.

Not considered here are costs related to project management and enabling activities (such as mitigation of asbestos), meaning that these projects will often cost more than estimated here. Research to gather more detailed information on these costs would be helpful to inform the design of future deep energy retrofit programs.

Further research to quantify recent ECM and other project costs by building type should be undertaken when deep energy retrofit programs are being developed.

Limited information is available on the non-electrical energy use of C&I building archetypes in Nova Scotia. Absent a province-wide reporting mechanism or mandatory building performance labeling (both of which are beyond the scope of this paper), research to gather this information should be undertaken when planning new deep energy retrofit programs.

#### **4.7 Funding**

The ENS HEA program pays approximately \$1.2 million per year in rebates to homeowners. However, this current rate of spending does not stimulate retrofits at either the required pace or depth.

Additional investments would need to be shared between businesses and other parties (government programs, external financing, and DSM program incentives). Most incentive programs available to businesses today only address electrical energy efficiency and typically reduce the cost of these upgrades by 10% - 30%, with businesses paying for the remaining 70% - 90%. The technical research identified the need to focus on non-electric space heating ECMs to achieve deep energy retrofit levels of savings in most buildings. Thus, to realize scalable deep energy retrofit investments, program incentives would need to be increased and expanded to include non-electric funding.

#### **4.8 Cost-Effectiveness Testing for DSM**

In Nova Scotia, the current electricity ratepayer-funded efficiency programs must pass the Total Resource Cost (TRC) test, which is widely used in the industry. The TRC test is a ratio of the benefits and costs for an energy efficiency measure, program, or portfolio of programs. If the benefits outweigh the costs, the investment is considered to have passed the test and is therefore a worthwhile investment of ratepayer funds.

The benefits currently included are avoided utility costs, such as fuel for generators and capital investments for new infrastructure, which can be reduced or eliminated through energy efficiency upgrades. However, customer benefits such as reduced maintenance costs, improved productivity, etc. are not included. Costs used in the TRC test include all customer costs and all ENS program administration costs.

Due to the relatively high cost of deep energy retrofits for most buildings, many of these projects are unlikely to pass the TRC test, which limits the level of investment ENS can offer in support of these upgrades. More deep energy retrofit projects would pass the TRC test if all customer benefits (e.g., improved productivity, reduced maintenance, etc.) were accounted for in the test.

## 5 Conclusions and Recommendations

### 5.1 Conclusions

Decarbonizing buildings offers significant opportunities to scale industry, create jobs, and reduce energy bills and GHG emissions all while creating healthy and comfortable spaces for people to live and work. Nova Scotia has led the country in reducing GHG emissions. These reductions have primarily been achieved by adding renewable energy to the electricity supply and through energy efficiency programs. As electricity delivery continues to become less carbon intensive, increasing focus on energy efficiency will be necessary to achieve net zero. Completing deep energy efficiency retrofits at scale can make a substantial contribution to this effort.

The upgrades, referred to in this paper as deep energy retrofits, include energy efficiency upgrades to electrical systems, mechanical systems, and building envelopes resulting in energy savings of up to 50% or more compared to an unchanging state of operation, or BAU.

Historical energy savings and volumes of activity in programs show that these programs are not achieving energy savings at the level required for deep energy retrofits, and the volume of retrofits is less than one percent of the scale required. Aside from support for small businesses, programs do not offer incentives for retrofits to commercial, institutional, and industrial customers that save non-electrical energy. Deep energy retrofits to electrically heated buildings will not typically pass a DSM-related cost-effectiveness test as currently applied, making them difficult to justify when funded by electricity ratepayers. More projects would pass this test if non-energy benefits could be included.

For homeowners and business owners, evidence indicates that the utility bill savings will outpace the initial investment of a deep energy retrofit over the expected lifetime of upgrades. When comparing deep energy retrofits to other carbon mitigation strategies like renewable energy generation the evaluation of levelized cost of carbon (LCOC) is useful. LCOC indicates the cost-effectiveness of avoiding GHG emissions with the lower LCOC being more favorable. The cost of reducing one tonne of CO<sub>2</sub> through deep energy retrofits is estimated to fall within the range of -\$277 to \$18 per tonne of CO<sub>2</sub> for C&I and -\$180 to -\$150 per tonne of CO<sub>2</sub> for residential. In comparison, renewable energy generation methods like onshore wind, offshore wind, utility-scale solar photovoltaic, hydro, tidal, and geothermal are estimated to cost between \$236 and \$2089 per tonne of CO<sub>2</sub>. Building owners often view projects from the perspective of financial costs and benefits. However, from the perspective of policy-makers, projects with less-than-ideal return on investment or payback periods, but have a negative cost of carbon abatement, should be taken into serious consideration. This differs from other decarbonization strategies such as carbon capture that have positive abatement costs. This makes deep energy retrofits both a beneficial financial investment for energy consumers and for government and utilities pursuing GHG emission reductions on the path to net zero.

Many home and business owners are eager to embrace deep energy retrofits. They understand that deep energy retrofits offer an opportunity to improve comfort, improve indoor air quality, and increase property value. Many also agree that these energy efficiency upgrades can help combat the rising costs of living. However, many are generally unable to bear the cost of implementing deep energy retrofits, which is intensified by uncertainty about the economy. Affordability is particularly challenging for Nova Scotians living in energy poverty. Deep energy retrofits often require added upgrades (such as mould remediation) that are not currently eligible for rebates. Fewer than 13% of homeowners and 15% of commercial and institutional decision makers would be willing or able to make the needed investment without innovative financing solutions, increased monetary incentives, and other forms of support.

Deep energy retrofits are complex projects, requiring multiple trades, advanced planning and design, and close coordination of on-site activity. Many home and business owners lack the time, expertise, or money to pay for project management support; a barrier that must be overcome by future programs.

Achieving deep energy retrofits at the needed pace and scale will require more capacity in the trades and professions implementing the upgrades. Contractors are already over capacity, and most are unable or unwilling to sell or manage projects that they perceive to be high-risk and challenging. Creating the needed capacity will require that demand is created for these new services and that businesses will have confidence in the long-term stability of this demand.

Commercial and institutional building owners have a role to play. They can build energy efficiency into their procurement practices, train staff to sustain energy savings, and place increased focus on energy efficiency when planning major renovations. Increasingly stringent building codes and a future retrofit code will be needed to ensure this happens within long-term planning cycles to avoid the need for further upgrades to achieve net zero. Providing municipalities with the authority to mandate more aggressive building and retrofit codes could also increase market capacity and awareness.

There are many benefits to deep energy retrofits; delivering them at the needed scale and pace can only be achieved through cross-sector collaboration. Stakeholders from all levels of government, utilities, the investment community, ENS, and the buildings sector must work together to demonstrate the available technical pathways to deep energy retrofits, raise market awareness, increase demand, grow industry capacity, and overcome financial barriers.

## 5.2 Recommendations

1. ***Deep energy retrofit projects are cost prohibitive to both homeowners and business owners. Multiple initiatives are required to improve the core economic factors for Nova Scotians to undertake deep energy retrofits.***

| <b><i>Key Challenges:</i></b>              | <b><i>Recommendations:</i></b>                                                                                                      |
|--------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| High cost of deep energy retrofit projects | <b>R1.1</b> Substantially increase incentives to help alleviate the costs of deep energy retrofits for Nova Scotia building owners. |
| Lack of economic incentives                | <b>R1.2</b> Investigate tax strategies to drive the needed pace of deep energy retrofits (tax-based economic drivers could          |

| <b>Key Challenges:</b>                                                                                                                                                                  | <b>Recommendations:</b>                                                                                                                                                                                                                                                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                                                                                                         | be an effective form of incentive along with program rebates).                                                                                                                                                                                                                                                                                                                                       |
| Lack of existing economical upgrade packages for exterior facade retrofits                                                                                                              | <b>R1.3</b> Provide support for exterior-facade retrofits (financial, marketing, education, training) and incentivize large-scale community retrofits to minimize per-project costs.                                                                                                                                                                                                                 |
| Availability of costing information                                                                                                                                                     | <b>R1.4</b> Conduct additional research to quantify and refine updated Energy Conservation Measure (ECM) costs by building type and other enabling project costs when deep energy retrofit programs are being developed. This information will help refine estimates for the levels of incentives needed to increase program uptake and build a database of knowledge to be shared with contractors. |
| Detailed non-electrical energy consumption data for commercial, industrial, and institutional buildings in Nova Scotia would be helpful in the design of a deep energy retrofit program | <b>R1.5</b> Absent is a requirement for mandatory reporting or building performance labeling, conduct research to gather this information by archetype, for all non-electric energy consumption.                                                                                                                                                                                                     |
| Lack of financing options                                                                                                                                                               | <b>R1.6</b> Government innovative financing program for deep energy retrofit costs at attractive interest rates that have repayment terms of more than 15 years. One option could be to share risk with project owners by creating a loan-loss recovery fund.                                                                                                                                        |
| Limited awareness and understanding of deep energy retrofits among consumers                                                                                                            | <b>R1.7</b> Invest in education and awareness programs and services that advance consumer knowledge of the economic benefits, energy benefits, emission reductions, and non-energy benefits (NEBs) associated with deep energy retrofits.                                                                                                                                                            |
| Limited incentives for saving non-electrical energy in commercial, industrial, and institutional buildings                                                                              | <b>R1.8</b> Future programs for these sectors should provide incentives for deep energy retrofits that save non-electrical energy.                                                                                                                                                                                                                                                                   |

**2. There is a need for more industry capacity to undertake wide scale deep energy retrofit projects.**

| <b>Key Challenges:</b>                                               | <b>Recommendations:</b>                                                                                                                                                    |
|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Limited project management capacity, equipment, and trade experience | <b>R2.1</b> Build capacity by investing in specialized project management and trades programs as well as the tools and equipment needed to complete these projects. Future |

| <i>Key Challenges:</i>                                                                              | <i>Recommendations:</i>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                     | programs and policies should create a stable, predictable investment climate that encourages private industry to grow capacity and increase the number of qualified professionals willing to deliver deep energy retrofits.                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Building codes must continue to drive improvements in construction practices                        | <p><b>R2.2</b> Adoption of tiered building codes and a future retrofit code as early as possible will heighten industry focus on developing the needed skills and building designs to implement deep energy retrofits.</p> <p>All municipalities in Nova Scotia should use the same codes (i.e., NBC, NECB, and any future retrofit code) to ensure continuity in the market, but the provincial government should set an energy performance tier floor and afford municipalities the discretion to require higher tiers within those codes if desired.</p>                                                                                                                            |
| Deep energy retrofits are rare, custom, one-off projects that are not appealing to many contractors | <b>R2.3</b> Reducing costs via incentives and economies of scale by incentivizing large-scale, community retrofits that would enable bulk pricing for that community and create a compelling business case for contractors.                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| Technical solutions are well-known, but new delivery models are needed to succeed                   | <p><b>R2.4</b> Exterior facade retrofits are extremely costly. If the cladding on a building is being replaced, the incremental cost of adding insulation and replacing windows is the lowest it will ever be. Programs that provide incentives to encourage comprehensive exterior facade retrofits whenever cladding or window replacement projects occur will leverage this advantage and maximize savings potential of otherwise costly upgrades.</p> <p>Combining such programs with investments in scalable, repeatable solutions such as the Energiesprong-inspired ReCover initiative could simplify and make facade retrofits more economical through economies of scale.</p> |

**3. Deep energy retrofits do not pass the current cost-effectiveness test for electricity ratepayer-funded energy efficiency programs.**

| <i>Key Challenges:</i>                                                                | <i>Recommendations:</i>                                                                                                                                                                                                      |
|---------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Limited scope of cost-effectiveness testing for electricity ratepayer-funded programs | <b>R3.1</b> Expand the scope of the current cost-effectiveness test used for DSM programs. Focus should be placed on added non-energy benefits, such as improved health and safety, reduced operating and maintenance costs, |

| <b>Key Challenges:</b>                                                                          | <b>Recommendations:</b>                                                                                                                                                                                                                                     |
|-------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                 | auxiliary costs, increased comfort, and reduced carrying costs to the utility system. Without considering these benefits, it may limit the ability to design and deliver innovative pilot programs that could reduce the barriers to deep energy retrofits. |
| Deep energy retrofit projects incur enabling costs which are not considered in current programs | <b>R3.2</b> Programs should not exclude the cost of enabling activities such as service upgrades, structural issues and/or the abatement of harmful substances.                                                                                             |

**4. The market currently has limited awareness of how to implement deep energy retrofits.**

| <b>Key Challenges:</b>                                                                            | <b>Recommendations:</b>                                                                                                                                                                                                                                                                                                                                           |
|---------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Limited education and awareness on how to undertake deep energy retrofits in homes and businesses | <b>R4.1</b> Launch a program dedicated to deep energy retrofit education and awareness. The program should facilitate the following: <ul style="list-style-type: none"> <li>• Guidance on ECM upgrade packages for different building and home archetypes.</li> <li>• Guidance on available incentives and financing options for ECM upgrade packages.</li> </ul> |
| Limited understanding of the true measure life of various deep energy retrofits                   | <b>R4.2</b> Commission further analysis to determine the measure life of various deep energy retrofit scenarios for each representative building archetype to better quantify financial return on investment and risk assessments to instill confidence in home and business owners.                                                                              |

**5. Building owners have an important role to play.**

| <b>Key Challenges:</b>                                                | <b>Recommendations:</b>                                                                                                                                                                                                                                                                            |
|-----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Procurement strategies must include energy efficiency                 | <b>R5.1</b> When procuring engineering design services, place increased focus on the need to include energy efficiency measures and take advantage of incentive programs.                                                                                                                          |
| Operational staff training for Energy Service Company (ESCO) projects | <b>R5.2</b> Buildings entering or undergoing an energy performance contract should place increased emphasis on staff training to sustain the project's energy savings and enhance the long-term cost savings of the project.                                                                       |
| Planning for the long term                                            | <b>R5.3</b> Building owners should consider the need for deep energy retrofits when planning major renovations and other activities intended to increase the building's Facility Condition Index. This should also include structural or other changes needed to make the building ready for solar |

| <i>Key Challenges:</i> | <i>Recommendations:</i>                                                                                        |
|------------------------|----------------------------------------------------------------------------------------------------------------|
|                        | PV, and including upgrades such as window replacements and exterior wall insulation during cladding retrofits. |

## 6 References

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## Appendix A: Policy Guidance on GHG Reductions and Electrification

### A.1 GHG Reduction Targets

This section provides a summary of the federal and provincial acts and regulations that impact GHG reduction targets over the next several decades.

#### A.1.1 Federal Guidance

##### **Canadian Net-Zero Emissions Accountability Act**

The Canadian Net-Zero Emissions Accountability Act established the Government of Canada's commitment to achieve net-zero GHG emissions by 2050 and provides a framework of accountability and transparency to deliver it.

The Act establishes a legally binding process to set five-year national emissions reduction targets as well as develop emissions reduction plans. It establishes the 2030 GHG emissions reduction targets and the requirement to set national emissions reduction targets for 2035, 2040, and 2045, ten years in advance.

Each emissions reduction plan must contain:

- The GHG emissions target for the year to which the plan relates;
- A summary of Canada's most recent GHG emissions inventory (National Inventory Report) and information relevant to the plan that Canada submitted under its international climate change commitments;
- A description of the key emissions reduction measures the Government of Canada intends to take to achieve the target;
- A description of how Canada's international commitments on climate change are taken into account in the plan;
- A description of any relevant sectoral strategies;
- A description of emissions reduction strategies for federal government operations;
- A projected timetable for implementation;
- GHG emissions projections resulting from the measures and strategies; and,
- A summary of key cooperative measures or agreements with provinces, territories, and other governments in Canada

##### **2030 Emissions Reduction Plan**

The 2030 Emissions Reduction Plan describes the many actions that are driving significant reductions in Canadian GHG emissions as well as the new measures that will ensure that Canada is able to reduce emissions across the entire economy to reach our long-term emissions reduction targets. The plan includes \$9.1 billion in new investments and reflects economy-wide measures such as carbon pricing and clean fuels while also targeting actions including buildings, vehicles, industry, and agriculture.

The 2030 plan was designed to be a comprehensive roadmap that reflects the high levels of ambition needed to guide emissions reduction efforts. It was the first emissions reduction plan issued under the Canadian Net-Zero Emissions Accountability Act.

In the plan, the Government of Canada planned to take the following actions:

- Helping to reduce energy costs for homes and buildings;
- Empowering communities to take climate action;
- Making it easier for Canadian to switch to EVs;
- Driving down carbon pollution from the oil and gas sector;
- Powering the economy with renewable electricity;
- Helping industries develop and adopt clean technology;
- Investing in nature and natural climate solutions;
- Supporting farmers as partners in building a clean, prosperous future; and
- Maintaining Canada's approach to pricing pollution

#### **National Building Code of Canada and National Energy Code of Canada for Buildings**

The 2020 National Building Code (NBC) and 2020 National Energy Code for Buildings (NECB) provide improved standards with the aim of achieving higher energy efficiency in incremental steps called “tiers”. In the past, building codes established the minimum standard of construction. Tiered codes offer a progressive series of performance-based improvements. With each tier, building energy performance incrementally improves.

The 2020 NBC and NECB provide compliance paths that allow Provinces and Territories to bypass the tiers if desired. Provinces and Territories may choose to mandate use of the tiers and create supporting policy or amendments to the building code that establishes a roadmap to prepare for future changes. Each Province and territory has their own process for adoption as the federal government does not enforce the codes directly. Adoption timelines can be decided at the provincial and territorial level. In Nova Scotia, the Office of the Fire Marshall is expected to initiate a public consultation to address code adoption, but the timing of this is currently unknown.

#### **Canada Green Buildings Strategy**

The goal of the Canada Green Buildings Strategy is to develop a net-zero emissions and climate-resilient buildings sector by 2050, with an interim goal of a 37% emissions reduction from 2005 levels by 2030.

To reach net-zero in the buildings sector, potential outcomes for the strategy could include:

- Building net-zero and climate-resilient buildings from the start;
- Accelerating deep, climate-resilient, building retrofits; and
- Transforming space and water heating to cleaner energy sources

As of October 2022, the Canada Green Buildings Strategy is still in development.

#### **Pan-Canadian Framework on Clean Growth and Climate Change**

The Pan-Canadian Framework on Clean Growth and Climate Change is a collective commitment from the federal, provincial, and territorial governments to grow the Canadian economy while reducing GHG

emissions and strengthening resilience to a changing climate. The framework is a national approach to pricing carbon pollution, with measures to achieve pollution reductions across all sectors of the economy.

### **Greenhouse Gas Pollution Pricing Act**

The Greenhouse Gas Pollution Pricing Act was enacted as part of the Government of Canada's plan to implement a federal carbon pollution pricing system. The Act consists of two parts. Part 1, administered by the Canada Revenue Agency (CRA), applies a fuel charge on 21 types of fuel and combustible waste when a registered organization holds \$1,000 or more of that fuel. Part 2, administered by Environment and Climate Change Canada, introduces an output-based pricing system for industrial facilities.

As of January 1<sup>st</sup>, 2020, Manitoba, Ontario, Saskatchewan, Alberta, Nunavut, and Yukon are all subject to this Act. Nova Scotia, British Columbia, Quebec, Northwest Territories, and Newfoundland and Labrador implemented their own carbon pollution pricing systems that intended to meet the federal benchmark. However, in August 2022, the federal Minister of Environment and Climate Change stated that Nova Scotia's current cap-and-trade program did not align with the minimum national criteria, and if changes are not made the federal backstop pricing system will be applied (Nova Scotia Office of the Premier, 2022).

### **A.1.2 Provincial Guidance**

#### **Environmental Goals and Climate Change Reduction Act**

The Environmental Goals and Climate Change Reduction Act set 28 targets related to provincial environmental goals. Some of the key goals of the act include:

- a 53% reduction of GHG emissions below 2005 levels by 2030 and subsequent net-zero emissions by 2050;
- adopting the 2020 NECB within 18 months of the Act's publication date;
- targets for the reduction of government building emissions;
- support, strengthening, and setting targets for energy efficiency programs; and
- phasing out coal fired power generation and supplying 80% renewable energy by 2030.

#### **Greenhouse Gas Emissions Regulations (Environment Act)**

Unlike the Environmental Goals and Climate Change Reduction Act which broadly defines the provincial environmental goals, the GHG Emissions Regulations directly target any set of buildings, structures, generation units, set of equipment or stationary items that functions as a single integrated site for supplying electricity (facilities). Any facility in the province that emits greater than 10,000 tonnes of CO<sub>2</sub> equivalent GHG in a calendar year is subject to, cumulative of all facilities, an emissions cap that will decrease annually. The total cap will decrease from 19 million tonnes in 2010 to 4.5 million tonnes by 2030.

#### **Cap and Trade Program Regulations (Environment Act)**

The Government of Nova Scotia implemented a cap-and-trade program in 2019. It set yearly limits on the total amount of GHG emissions allowed by the province from 2019-2022. Each year, the province set total emissions allowances equal to that year's cap and distributed most of the allowances to mandatory participants. Some allowances were sold through auction, while others were set aside for sale through a government reserve. Participants could also buy emissions allowances on the secondary market. Each year the cap declined, effectively reducing the allowable emissions from participants.

The cap-and-trade program was put in place to support the Pan-Canadian Framework's commitment to price carbon pollution across Canada. It was applied to all carbon emitters over a certain threshold (50,000 tonnes or greater) by facility. It also applied to petroleum product suppliers, natural gas distributors, and electricity importers.

**Output-Based Pricing System Regulations**

The Output-Based Pricing System (OBPS), established under Part 2 of the Greenhouse Gas Pollution Act, was designed to ensure there is a price incentive for industrial emitters to reduce their GHG emissions and spur innovation while maintaining competitiveness and protecting against the risk of industrial facilities moving from one region to another to avoid paying a price on carbon pollution.

Under the OBPS, persons responsible for covered facilities are required to compensate for GHG emissions that exceed an annual facility emissions limit. In accordance with the Green Gas Pollution Pricing Act and OBPS Regulations, the Minister of the Environment will issue surplus credits to persons responsible for covered facilities that emit GHGs in a quantity that is below the facility's emissions limit. This creates an ongoing financial incentive for facilities to reduce their emission intensity.

## Appendix B: C&I Archetype Detailed Breakdown

### B.1 Building Archetypes Definition

#### Archetype 1 – Large Single-Building Retail Store

Table 14: Building Archetype Definition – Archetype 1

| Characteristic                              | Parameters Modeled                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|---------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Building Size<br/>(total floor area)</b> | 15,675 m <sup>2</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Occupied Schedule</b>                    | Sunday to Saturday – 7:00am to 10:00pm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Building Envelope</b>                    | <ul style="list-style-type: none"> <li>• Wall Assembly               <ul style="list-style-type: none"> <li>○ Concrete tilt-up</li> <li>○ Assumed R-Value (ft<sup>2</sup> °F h/BTU) of R-18</li> </ul> </li> <li>• Roof Type               <ul style="list-style-type: none"> <li>○ Modified bitumen</li> <li>○ Assumed R-Value (ft<sup>2</sup> F h/BTU) of R-30</li> </ul> </li> <li>• Windows               <ul style="list-style-type: none"> <li>○ Metal insulated double pane</li> <li>○ Assumed U-Value (BTU / ft<sup>2</sup> °F h) of 3</li> </ul> </li> <li>• General               <ul style="list-style-type: none"> <li>○ Window-to-wall ratio of 5%</li> </ul> </li> </ul> |
| <b>Period of Construction</b>               | 2000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Heating System</b>                       | Propane-fired roof-top unit (RTU)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Ventilation System</b>                   | Packaged roof-mounted air-handling units                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Cooling System</b>                       | RTU – direct-expansion air conditioning                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Domestic Hot-Water System</b>            | Electric boiler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Lighting System</b>                      | <ul style="list-style-type: none"> <li>• Primary lighting – fluorescent T8</li> <li>• Secondary lighting – high-pressure sodium (HPS)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |

#### Archetype 2 – Small Retail Store (Strip Mall)

Table 15: Building Archetype Definition – Archetype 2

| Characteristic           | Parameters Modeled                                                                                                                                                                                                                                                                                                                                    |
|--------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Building Size</b>     | 7,760 m <sup>2</sup>                                                                                                                                                                                                                                                                                                                                  |
| <b>Occupied Schedule</b> | Sunday to Saturday – 9:00am to 9:00pm                                                                                                                                                                                                                                                                                                                 |
| <b>Building Envelope</b> | <ul style="list-style-type: none"> <li>• Wall Assembly               <ul style="list-style-type: none"> <li>○ Concrete tilt-up</li> <li>○ Assumed R-Value (ft<sup>2</sup> °F h/BTU) of R-18</li> </ul> </li> <li>• Roof Type               <ul style="list-style-type: none"> <li>○ Tar and gravel roof with a metal roof deck</li> </ul> </li> </ul> |

| Characteristic             | Parameters Modeled                                                                                                                                                                                                                                                                                                                                                                           |
|----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                            | <ul style="list-style-type: none"> <li>○ Insulated</li> <li>○ Assumed R-Value (ft<sup>2</sup> F h/BTU) of R-24</li> <li>• Windows <ul style="list-style-type: none"> <li>○ Metal insulated double pane</li> <li>○ Assumed U-Value (BTU / ft<sup>2</sup> °F h) of 3</li> </ul> </li> <li>• General <ul style="list-style-type: none"> <li>○ Window-to-wall ratio of 5%</li> </ul> </li> </ul> |
| Period of Construction     | 2000                                                                                                                                                                                                                                                                                                                                                                                         |
| Heating System             | Propane fired RTU                                                                                                                                                                                                                                                                                                                                                                            |
| Ventilation System         | Packaged roof-mounted air-handling units                                                                                                                                                                                                                                                                                                                                                     |
| Cooling System             | RTU – direct-expansion air conditioning                                                                                                                                                                                                                                                                                                                                                      |
| Domestic Hot -Water System | Electric boiler                                                                                                                                                                                                                                                                                                                                                                              |
| Lighting System            | <ul style="list-style-type: none"> <li>• Primary lighting – fluorescent T8</li> <li>• Secondary lighting – high-pressure sodium (HPS)</li> </ul>                                                                                                                                                                                                                                             |

### Archetype 3 – Large-Format Multi-Storey Office Building

Table 16: Building Archetype Definition – Archetype 3

| Characteristic            | Parameters Modeled                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Building Size             | 22,290 m <sup>2</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Occupied Schedule         | Monday to Friday – 7:00am to 6:00pm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Building Envelope         | <ul style="list-style-type: none"> <li>• Wall Assembly <ul style="list-style-type: none"> <li>○ Conventional brick rain-screen system</li> <li>○ Assumed R-Value (ft<sup>2</sup> °F h/BTU) of R-18</li> </ul> </li> <li>• Roof Type <ul style="list-style-type: none"> <li>○ Tar and gravel roof</li> <li>○ Insulated metal roof deck</li> <li>○ Assumed R-Value (ft<sup>2</sup> F h/BTU) of R-24</li> </ul> </li> <li>• Windows <ul style="list-style-type: none"> <li>○ Metal insulated double pane</li> <li>○ Assumed U-Value (BTU / ft<sup>2</sup> °F h) of 3</li> </ul> </li> <li>• General <ul style="list-style-type: none"> <li>○ Window-to-wall ratio of 35%</li> </ul> </li> </ul> |
| Period of Construction    | 1977                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Heating System            | <ul style="list-style-type: none"> <li>• Hydronic heating perimeter heating</li> <li>• Natural gas boilers</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| Ventilation System        | Packed roof mounted air handling units                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| Cooling System            | Chilled water system with cooling tower                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Domestic Hot-Water System | Natural gas boiler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| Lighting System           | <ul style="list-style-type: none"> <li>• Primary lighting are fluorescent T8</li> <li>• High-pressure sodium</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

#### Archetype 4 – Small-Format Single-Storey Office Building

Table 17: Building Archetype Definition – Archetype 4

| Characteristic            | Parameters Modeled                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Building Size             | 2,180 m <sup>2</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Occupied Schedule         | Monday to Friday – 7:00am to 6:00pm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| Building Envelope         | <ul style="list-style-type: none"> <li>• Wall Assembly <ul style="list-style-type: none"> <li>○ Concrete tilt-up</li> <li>○ Assumed R-value (ft<sup>2</sup> °F h/BTU) of R-18</li> </ul> </li> <li>• Roof Type <ul style="list-style-type: none"> <li>○ Tar and gravel roof</li> <li>○ Insulated metal roof deck</li> <li>○ Assumed R-Value (ft<sup>2</sup> F h/BTU) of R-30</li> </ul> </li> <li>• Windows <ul style="list-style-type: none"> <li>○ Metal insulated double pane</li> <li>○ Assumed U-value (BTU / ft<sup>2</sup> °F h) of 3</li> </ul> </li> <li>• General <ul style="list-style-type: none"> <li>○ Window-to-wall ratio of 20%</li> </ul> </li> </ul> |
| Period of Construction    | 2001                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Heating System            | Propane fired RTUs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| Ventilation System        | Via RTUs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Cooling System            | RTU direct expansion                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Domestic Hot-Water System | Electric boiler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Lighting System           | <ul style="list-style-type: none"> <li>• Primary lighting – fluorescent T8</li> <li>• Secondary lighting – high-pressure sodium (HPS)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

#### Archetype 5 – Large-Format School

Table 18: Building Archetype Definition – Archetype 5

| Characteristic    | Parameters Modeled                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Building Size     | 12,100 m <sup>2</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| Occupied Schedule | Monday to Friday – 7:00am to 5:00pm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| Building Envelope | <ul style="list-style-type: none"> <li>• Wall Assembly <ul style="list-style-type: none"> <li>○ Conventional brick rain-screen system</li> <li>○ Assumed R-Value (ft<sup>2</sup> °F h/BTU) of R-18</li> </ul> </li> <li>• Roof Type <ul style="list-style-type: none"> <li>○ Loose-laid ballasted extremely durable synthetic rubber roofing (EPDM)</li> <li>○ Assumed R-value (ft<sup>2</sup> F h/BTU) of R-30</li> </ul> </li> <li>• Windows <ul style="list-style-type: none"> <li>○ Metal insulated double pane</li> <li>○ Assumed U-value (BTU / ft<sup>2</sup> °F h) of 3</li> </ul> </li> </ul> |

| Characteristic            | Parameters Modeled                                                                                                                                                                                          |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                           | <ul style="list-style-type: none"> <li>General <ul style="list-style-type: none"> <li>Window-to-wall ratio of 50%</li> </ul> </li> </ul>                                                                    |
| Period of Construction    | 1995                                                                                                                                                                                                        |
| Heating System            | <ul style="list-style-type: none"> <li>Hydronic heating</li> <li>Natural gas boilers</li> <li>No variable-frequency drives on boiler and circulation pumps</li> <li>Perimeter heating with pumps</li> </ul> |
| Ventilation System        | <ul style="list-style-type: none"> <li>Interior air-handling units</li> <li>Mixed-air units not equipped variable frequency drives</li> </ul>                                                               |
| Cooling System            | No cooling                                                                                                                                                                                                  |
| Domestic Hot-Water System | Electric boiler                                                                                                                                                                                             |
| Lighting System           | <ul style="list-style-type: none"> <li>Primary lighting in classes, administration and hallways are fluorescent T8</li> <li>High-pressure sodium</li> </ul>                                                 |

#### Archetype 6 – Small-Format School

Table 19: Building Archetype Definition – Archetype 6

| Characteristic            | Parameters Modeled                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|---------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Building Size             | 1,900 m <sup>2</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Occupied Schedule         | Monday to Friday – 7:00am to 5:00pm                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| Building Envelope         | <ul style="list-style-type: none"> <li>Wall Assembly <ul style="list-style-type: none"> <li>Conventional brick rain-screen system</li> <li>Assumed R-Value (ft<sup>2</sup> °F h/BTU) of R-18</li> </ul> </li> <li>Roof Type <ul style="list-style-type: none"> <li>Modified bitumen roof</li> <li>Assumed R-value (ft<sup>2</sup> F h/BTU) of R-24</li> </ul> </li> <li>Windows <ul style="list-style-type: none"> <li>Metal insulated double pane</li> <li>Assumed U-value (BTU / ft<sup>2</sup> °F h) of 3</li> </ul> </li> <li>General <ul style="list-style-type: none"> <li>Window-to-wall ratio of 20%</li> </ul> </li> </ul> |
| Period of Construction    | 2000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Heating System            | <ul style="list-style-type: none"> <li>Hydronic heating</li> <li>Oil fired boilers</li> <li>No variable-frequency drives on pumps</li> <li>Perimeter heating with electric baseboards and cabinet heaters</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                |
| Ventilation System        | Interior air-handling units                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Cooling System            | No cooling                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| Domestic Hot Water System | Electric boiler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

| Characteristic         | Parameters Modeled                                                                                                                                           |
|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Lighting System</b> | <ul style="list-style-type: none"> <li>Primary lighting in classes, administration, and hallways are fluorescent T8</li> <li>High-pressure sodium</li> </ul> |

### Archetype 7 – Long-Term-Care Residential Building

Given the complexity and site-specific equipment in hospitals and other healthcare facilities, the only healthcare facility modeled in this study was a long-term-care facility, a multi-residential building. The building archetype definition is summarized in the following table.

Table 20: Building Archetype Definition – Long-Term Care Residential Building - Archetype 7

| Characteristic                   | Parameters Modeled                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Building Size</b>             | 4,680 m <sup>2</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Occupied Schedule</b>         | 24/7 operation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Building Envelope</b>         | <ul style="list-style-type: none"> <li>Wall Assembly <ul style="list-style-type: none"> <li>Conventional brick rain-screen system</li> <li>Assumed R-value (ft<sup>2</sup> °F h/BTU) of R-18</li> </ul> </li> <li>Roof Type <ul style="list-style-type: none"> <li>Asphalt shingles</li> <li>Assumed R-value (ft<sup>2</sup> °F h/BTU) of R-22</li> </ul> </li> <li>Windows <ul style="list-style-type: none"> <li>Metal insulated double pane</li> <li>Assumed U-value (BTU / ft<sup>2</sup> °F h) of 3.2</li> </ul> </li> <li>General <ul style="list-style-type: none"> <li>Window-to-wall ratio of 50%</li> </ul> </li> </ul> |
| <b>Period of Construction</b>    | 1981                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| <b>Heating System</b>            | Electric baseboard                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| <b>Ventilation System</b>        | <ul style="list-style-type: none"> <li>100% fresh air air-handling units</li> <li>Mixed-air units not equipped variable frequency drives</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Cooling System</b>            | No cooling                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Domestic Hot Water System</b> | Natural gas                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| <b>Lighting System</b>           | <ul style="list-style-type: none"> <li>Primary lighting – fluorescent T8</li> <li>Secondary lighting – high-pressure sodium (HPS)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

### Archetype 8 – Large-Format Multi-Storey Hotel with Restaurant (non-electric heating archetype)

Table 21: Building Archetype Definition – Archetype 8

| Characteristic           | Parameters Modeled    |
|--------------------------|-----------------------|
| <b>Building size</b>     | 20,600 m <sup>2</sup> |
| <b>Occupied Schedule</b> | 24/7 operation        |

|                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Building Envelope</b>         | <ul style="list-style-type: none"> <li>• Wall Assembly <ul style="list-style-type: none"> <li>○ Combination of brick walls and metal siding</li> <li>○ Assumed R-value (<math>\text{ft}^2 \text{ } ^\circ\text{F h/BTU}</math>) of R-13</li> </ul> </li> <li>• Roof Type <ul style="list-style-type: none"> <li>○ Modified bitumen</li> <li>○ Assumed R-value (<math>\text{ft}^2 \text{ F h/BTU}</math>) of R-30</li> </ul> </li> <li>• Windows <ul style="list-style-type: none"> <li>○ Wood and metal framed windows</li> <li>○ Combination of double pane and uninsulated single pane</li> <li>○ Assumed U-Value (<math>\text{BTU} / \text{ft}^2 \text{ } ^\circ\text{F h}</math>) of up to 4</li> </ul> </li> <li>• General <ul style="list-style-type: none"> <li>○ Window-to-wall ratio of 65%</li> </ul> </li> </ul> |
| <b>Period of Construction</b>    | 2000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Heating System</b>            | <ul style="list-style-type: none"> <li>• Fan Coil Units (Room)</li> <li>• Makeup air units with natural gas boiler</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Ventilation System</b>        | <ul style="list-style-type: none"> <li>• Mixed-air units not equipped variable frequency drives</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Cooling System</b>            | Direct Expansion (DX) cooling                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Domestic Hot-Water System</b> | Natural gas                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Lighting System</b>           | <ul style="list-style-type: none"> <li>• Primary lighting – fluorescent T8</li> <li>• Secondary lighting – high-pressure sodium (HPS)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

**Archetype 9 – Large-Format Multi-Storey Hotel with Restaurant and Room-packaged Terminal Air-conditioning Units (electric heating archetype)**

*Table 22: Building Archetype Definition – Archetype 9*

| Characteristic           | Parameters Modeled                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|--------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Building size</b>     | 20,600 $\text{m}^2$                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Occupied Schedule</b> | 24/7 operation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Building Envelope</b> | <ul style="list-style-type: none"> <li>• Wall Assembly <ul style="list-style-type: none"> <li>○ Combination of brick walls and metal siding</li> <li>○ Assumed R-value (<math>\text{ft}^2 \text{ } ^\circ\text{F h/BTU}</math>) of R-13</li> </ul> </li> <li>• Roof Type <ul style="list-style-type: none"> <li>○ Modified bitumen</li> <li>○ Assumed R-value (<math>\text{ft}^2 \text{ F h/BTU}</math>) of R-30</li> </ul> </li> <li>• Windows <ul style="list-style-type: none"> <li>○ Wood and metal framed windows</li> <li>○ Combination of double pane and uninsulated single pane</li> <li>○ Assumed U-Value (<math>\text{BTU} / \text{ft}^2 \text{ } ^\circ\text{F h}</math>) of up to 4</li> </ul> </li> <li>• General</li> </ul> |

|                                  |                                                                                                                                                         |
|----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                  | <ul style="list-style-type: none"> <li>○ Window-to-wall ratio of 65%</li> </ul>                                                                         |
| <b>Period of Construction</b>    | 2000                                                                                                                                                    |
| <b>Heating System</b>            | <ul style="list-style-type: none"> <li>• Packaged Terminal Air Conditioning (PTAC) Units</li> <li>• Makeup air units with natural gas boiler</li> </ul> |
| <b>Ventilation System</b>        | <ul style="list-style-type: none"> <li>• Mixed-air units not equipped variable frequency drives</li> </ul>                                              |
| <b>Cooling System</b>            | Direct Expansion (DX) cooling                                                                                                                           |
| <b>Domestic Hot-Water System</b> | Natural gas                                                                                                                                             |
| <b>Lighting System</b>           | <ul style="list-style-type: none"> <li>• Primary lighting – fluorescent T8</li> <li>• Secondary lighting – high-pressure sodium (HPS)</li> </ul>        |

### Archetype 10 – Food Services Stand-Alone Restaurant

Table 23: Building Archetype Definition – Archetype 10

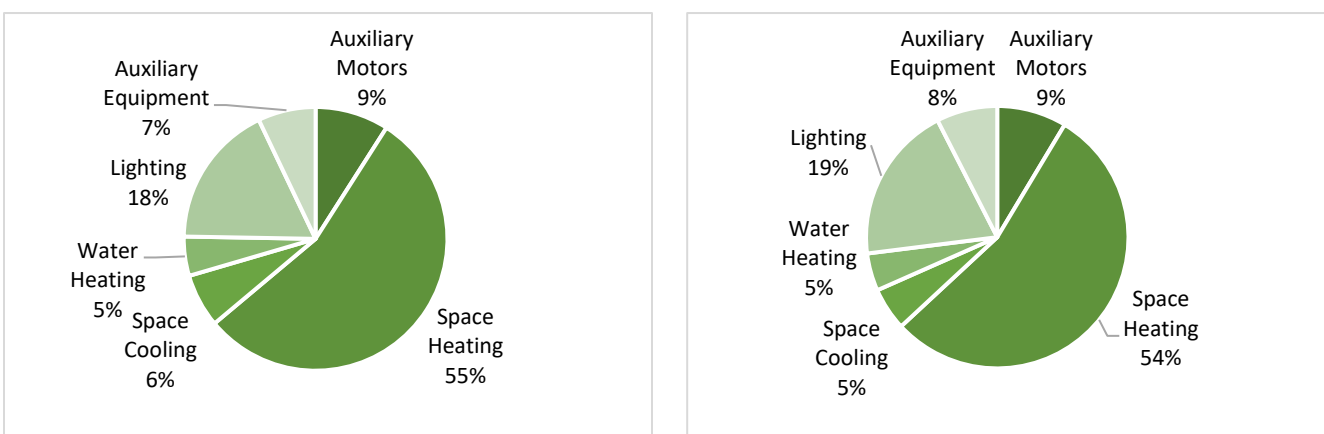
| Characteristic                   | Parameters Modeled                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Building Size</b>             | 500 m <sup>2</sup>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| <b>Occupied Schedule</b>         | Saturday to Sunday – 6:00am to 10:00pm<br>Drive thru 24/7 operation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Building Envelope</b>         | <ul style="list-style-type: none"> <li>• Wall Assembly <ul style="list-style-type: none"> <li>○ Conventional brick rain-screen system</li> <li>○ Assumed R-value (ft<sup>2</sup> °F h/BTU) of R-18</li> </ul> </li> <li>• Roof Type <ul style="list-style-type: none"> <li>○ Modified bitumen</li> <li>○ Assumed R-value (ft<sup>2</sup> F h/BTU) of R-30</li> </ul> </li> <li>• Windows <ul style="list-style-type: none"> <li>○ Metal insulated double pane</li> <li>○ Assumed U-Value (BTU / ft<sup>2</sup> °F h) of 3</li> </ul> </li> <li>• General <ul style="list-style-type: none"> <li>○ Window to Wall ratio of 30%</li> </ul> </li> </ul> |
| <b>Period of Construction</b>    | 2003                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Heating System</b>            | Natural gas fired RTUs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <b>Ventilation System</b>        | Via RTUs                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Cooling System</b>            | Direct expansion (DX) cooling                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| <b>Domestic Hot-Water System</b> | Electric boiler                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Lighting System</b>           | <ul style="list-style-type: none"> <li>• Primary lighting – fluorescent T8</li> <li>• Secondary lighting – high-pressure sodium (HPS)</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |

## B.2 Baseline Building Archetype Energy End-Use Breakdown

The following figures illustrate the differences in energy end-use between the 10 C&I building archetypes modeled in this study. The detailed definition of each archetype can be found in Appendix B. Each energy model's predicted energy use was calibrated with the actual utility energy consumption of a reference building by adjusting operational variables (i.e., occupancy schedules).

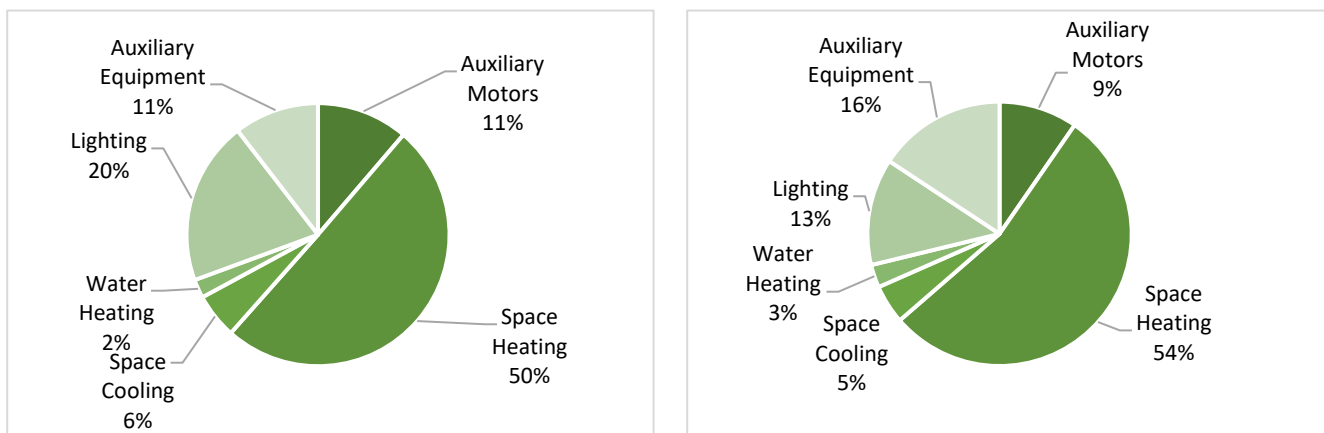
### Retail Store Building Archetypes

Figure 24: Retail Archetype 1 (left) and Archetype 2 (right) Energy End-Use Breakdown



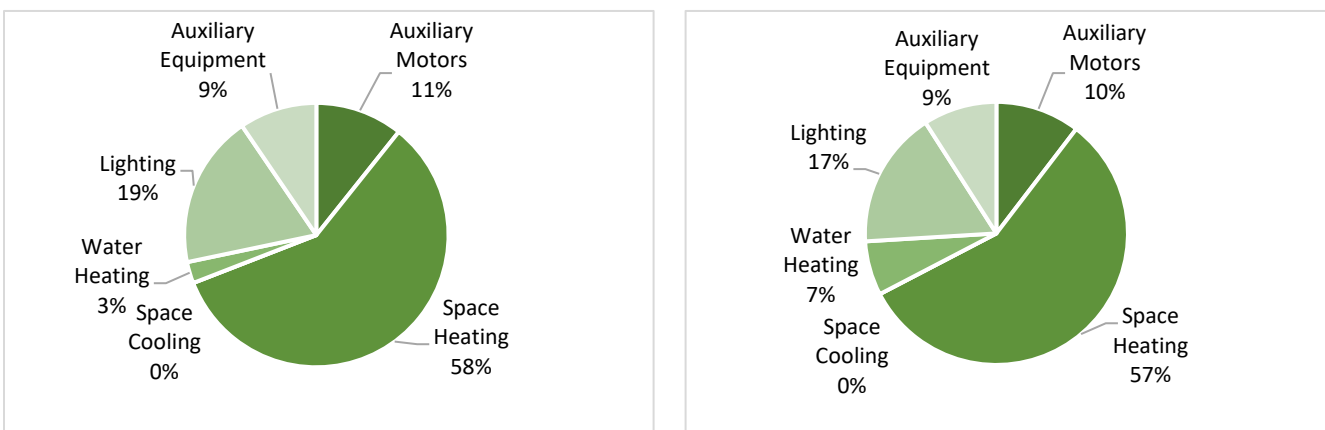
### Office Building Archetype

Figure 25: Office Archetype 3 (left) and Archetype 4 (right) Energy End-Use Breakdown



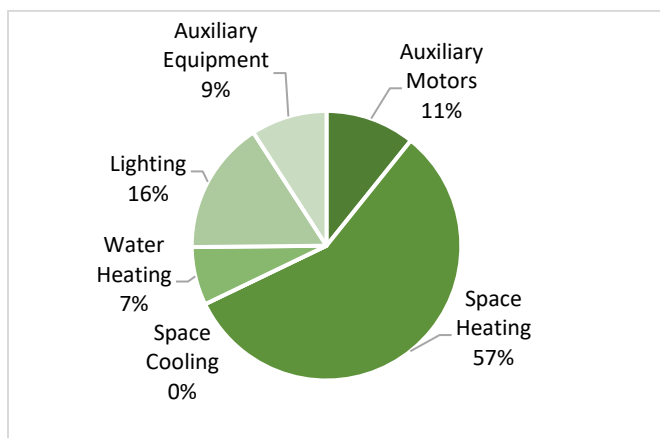
## Educational Building Archetype

Figure 26: Education Archetype 5 (left) and Archetype 6 (right) Energy End-Use Breakdown



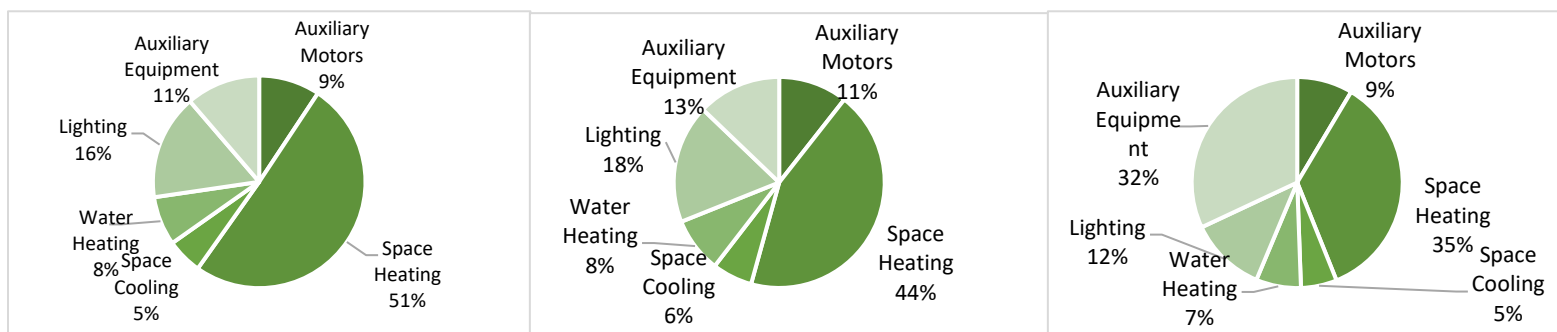
## Healthcare Building Archetype

Figure 27: Healthcare Archetype 7 Energy End-Use Breakdown



## Food Services and Accommodations Building Archetypes

Figure 28: Food and Accommodation Archetype 8 (left), Archetype 9 (middle), and Archetype 10 (right)



The dominant energy end-use is space heating, followed by lighting for most of the commercial and institutional building archetypes modeled. The exception to this is single-storey office buildings and food services where auxiliary-equipment energy use is more significant than that of lighting. For office buildings, auxiliary equipment includes plug loads. For food and accommodations, this includes commercial kitchen equipment.

### B.3 ECM Upgrade Packages

The following figures summarize the results of iterative energy modeling performed to converge on upgrade packages that minimized capital cost. These figures provide guidance, by building archetype, on which upgrades are most cost-effective to achieve the three performance targets ranging from shallow retrofit (10% - 30% savings of BAU) to deep energy retrofits (50%+ savings over BAU). It should be noted that the simple payback estimates from all energy models do not assume an increase in energy costs over the life of the measure and do not include other non-energy-related operating and maintenance cost benefits. This yields a conservative estimate, where in practice the inclusion of these benefits would make these projects more financially attractive.

#### Archetype 1

The following figure is the result of energy modeling for Archetype 1, large single-building retail stores.

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                             |         |            |               |     |          |     |               |     |               |    |                  |    |                     |    |
|------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|----------|-----|---------------|-----|---------------|----|------------------|----|---------------------|----|
| Upgrade Package 1: target 30% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>No upgrade</li><li>• <b>Lighting:</b><br/>LED Lighting</li><li>• <b>Heating System:</b><br/>Temperature Setbacks</li><li>• <b>Ventilation:</b><br/>Reduce runtime hours to match building occupancy</li><li>• <b>Pumps:</b><br/>VFD on DHW Recirculator Pump</li><li>• <b>Domestic Hot Water:</b><br/>Install low flow fixture.<br/>ASHP HW heaters with electric backup</li><li>• <b>Other:</b><br/>Schedule DHW recirc to shut off overnight<br/>Maximize use of night setbacks (programmable thermostats)<br/>Reduce HVAC fan runtimes</li></ul> <p><u>Summary</u></p> <p>Annual Energy Savings (ekWh)</p> | 4                             | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Water Heating</td><td>40%</td></tr><tr><td>Lighting</td><td>36%</td></tr><tr><td>Space Cooling</td><td>14%</td></tr><tr><td>Space Heating</td><td>6%</td></tr><tr><td>Auxiliary Motors</td><td>4%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Water Heating | 40% | Lighting | 36% | Space Cooling | 14% | Space Heating | 6% | Auxiliary Motors | 4% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |               |    |                  |    |                     |    |
| Water Heating                                              | 40%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |               |    |                  |    |                     |    |
| Lighting                                                   | 36%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |               |    |                  |    |                     |    |
| Space Cooling                                              | 14%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |               |    |                  |    |                     |    |
| Space Heating                                              | 6%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |               |    |                  |    |                     |    |
| Auxiliary Motors                                           | 4%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |               |    |                  |    |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |               |    |                  |    |                     |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                               |         |            |                     |    |          |     |               |     |               |     |               |     |                  |     |
|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------------|----|----------|-----|---------------|-----|---------------|-----|---------------|-----|------------------|-----|
|                                                            | <p>1,177,000 or 21% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$68,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$1,173,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$449,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |                     |    |          |     |               |     |               |     |               |     |                  |     |
| Upgrade Package 2: target 50% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+20% R-Value from BAU)</li><li>• <b>Lighting:</b><br/>LED Lighting conversion with occupancy sensors in warehouse</li><li>• <b>Heating System:</b><br/>Heat pump RTU with electric backup</li><li>• <b>Ventilation:</b><br/>Full VAV conversion<br/>Ventilation fan speed control with VFD.</li><li>• <b>Pumps:</b><br/>No additional upgrade.</li><li>• <b>Domestic Hot Water:</b><br/>No additional upgrade.</li><li>• <b>Other:</b><br/>Maximize use of night setbacks (occupancy sensors day / night linked to BAS)</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>3,272,000 or 59% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b></p> | 12                            | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Auxiliary Equipment</td><td>0%</td></tr><tr><td>Lighting</td><td>22%</td></tr><tr><td>Water Heating</td><td>24%</td></tr><tr><td>Space Cooling</td><td>11%</td></tr><tr><td>Space Heating</td><td>27%</td></tr><tr><td>Auxiliary Motors</td><td>16%</td></tr></tbody></table> | End-Use | Percentage | Auxiliary Equipment | 0% | Lighting | 22% | Water Heating | 24% | Space Cooling | 11% | Space Heating | 27% | Auxiliary Motors | 16% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |                     |    |          |     |               |     |               |     |               |     |                  |     |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |                     |    |          |     |               |     |               |     |               |     |                  |     |
| Lighting                                                   | 22%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |                     |    |          |     |               |     |               |     |               |     |                  |     |
| Water Heating                                              | 24%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |                     |    |          |     |               |     |               |     |               |     |                  |     |
| Space Cooling                                              | 11%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |                     |    |          |     |               |     |               |     |               |     |                  |     |
| Space Heating                                              | 27%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |                     |    |          |     |               |     |               |     |               |     |                  |     |
| Auxiliary Motors                                           | 16%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |                     |    |          |     |               |     |               |     |               |     |                  |     |

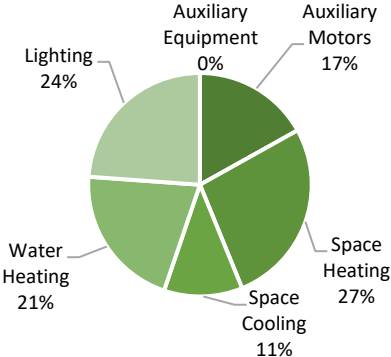
| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                               |         |            |               |     |                  |     |               |     |          |     |               |     |                     |    |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|------------------|-----|---------------|-----|----------|-----|---------------|-----|---------------------|----|
|                                                            | <p>\$175,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$2,955,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$2,046,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |               |     |          |     |               |     |                     |    |
| Upgrade Package 3: target 70% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+100% R-Value from BAU)</li><li>• <b>Lighting:</b><br/>Incorporate daylight harvesting</li><li>• <b>Heating System:</b><br/>Cold Climate Heat pump RTU with electric backup<br/>Washroom HRV</li><li>• <b>Ventilation:</b><br/>Maximize use of DCV with CO2 sensor in return duct or zone</li><li>• <b>Pumps:</b><br/>No additional upgrade</li><li>• <b>Domestic Hot Water:</b><br/>No additional upgrade</li><li>• <b>Other:</b><br/>If applicable heat recovery on refrigeration system<br/>Reduce HVAC fan runtimes</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>3,689,000 or 66% reduction to BAU</p> | 15                            | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>26%</td></tr><tr><td>Auxiliary Motors</td><td>21%</td></tr><tr><td>Water Heating</td><td>21%</td></tr><tr><td>Lighting</td><td>20%</td></tr><tr><td>Space Cooling</td><td>12%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 26% | Auxiliary Motors | 21% | Water Heating | 21% | Lighting | 20% | Space Cooling | 12% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |               |     |          |     |               |     |                     |    |
| Space Heating                                              | 26%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |               |     |          |     |               |     |                     |    |
| Auxiliary Motors                                           | 21%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |               |     |          |     |               |     |                     |    |
| Water Heating                                              | 21%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |               |     |          |     |               |     |                     |    |
| Lighting                                                   | 20%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |               |     |          |     |               |     |                     |    |
| Space Cooling                                              | 12%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |               |     |          |     |               |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |               |     |          |     |               |     |                     |    |

| Upgrade Scenarios | ECM Upgrade Packages                                                                                                                                        | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU) |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------|
|                   | <b>Annual Bill Savings (\$)</b><br>\$229,000<br><br><b>Lifetime Bill Savings (\$)</b><br>\$3,856,000<br><br><b>Upgrade Package Cost (\$)</b><br>\$3,375,000 |                               |                                                                  |

**Archetype 2**

The following figure is the result of energy modeling for Archetype 2, smaller format retail stores based on a strip mall.

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                              |         |            |          |     |               |     |               |     |                  |     |               |    |                     |    |
|------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|----------|-----|---------------|-----|---------------|-----|------------------|-----|---------------|----|---------------------|----|
| Upgrade Package 1: target 30% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>No upgrade</li><li>• <b>Lighting:</b><br/>LED Lighting</li><li>• <b>Heating System:</b><br/>Temperature Setbacks</li><li>• <b>Ventilation:</b><br/>Reduce runtime hours to match building occupancy</li><li>• <b>Pumps:</b><br/>VFD on DHW Recirculator Pump</li><li>• <b>Domestic Hot Water:</b><br/>Install low flow fixtures.<br/>ASHP HW heaters with electric backup</li><li>• <b>Other:</b><br/>Schedule DHW recirc to shut off overnight<br/>Maximize use of night setbacks (programmable thermostats)<br/>Reduce HVAC fan runtimes</li></ul> <p><u>Summary</u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>761,000 or 25% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$71,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$1,231,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$258,000</p> | 4                             | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Lighting</td><td>34%</td></tr><tr><td>Water Heating</td><td>33%</td></tr><tr><td>Space Cooling</td><td>13%</td></tr><tr><td>Auxiliary Motors</td><td>11%</td></tr><tr><td>Space Heating</td><td>9%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Lighting | 34% | Water Heating | 33% | Space Cooling | 13% | Auxiliary Motors | 11% | Space Heating | 9% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |               |    |                     |    |
| Lighting                                                   | 34%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |               |    |                     |    |
| Water Heating                                              | 33%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |               |    |                     |    |
| Space Cooling                                              | 13%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |               |    |                     |    |
| Auxiliary Motors                                           | 11%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |               |    |                     |    |
| Space Heating                                              | 9%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |               |    |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |               |    |                     |    |

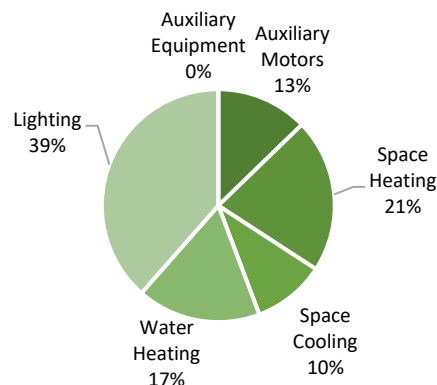
| Upgrade Scenarios                                             | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                                                                                                                    |         |            |               |     |          |     |               |     |                  |     |               |     |                     |    |
|---------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|----------|-----|---------------|-----|------------------|-----|---------------|-----|---------------------|----|
| Upgrade Package 2:<br>target 50% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+20% R-Value from BAU)</li><li>• <b>Lighting:</b><br/>LED Lighting conversion with occupancy sensors in warehouse</li><li>• <b>Heating System:</b><br/>Heat pump RTU with electric backup</li><li>• <b>Ventilation:</b><br/>Full VAV conversion<br/>Ventilation fan speed control with VFD.</li><li>• <b>Pumps:</b><br/>No additional upgrade.</li><li>• <b>Domestic Hot Water:</b><br/>No additional upgrade.</li><li>• <b>Other:</b><br/>Maximize use of night setbacks (occupancy sensors day / night linked to BAS)</li></ul> <p><u>Summary</u></p> <p>Annual Energy Savings (ekWh)</p> | 16                            |  <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>27%</td></tr><tr><td>Lighting</td><td>24%</td></tr><tr><td>Water Heating</td><td>21%</td></tr><tr><td>Auxiliary Motors</td><td>17%</td></tr><tr><td>Space Cooling</td><td>11%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 27% | Lighting | 24% | Water Heating | 21% | Auxiliary Motors | 17% | Space Cooling | 11% | Auxiliary Equipment | 0% |
| End-Use                                                       | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |          |     |               |     |                  |     |               |     |                     |    |
| Space Heating                                                 | 27%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |          |     |               |     |                  |     |               |     |                     |    |
| Lighting                                                      | 24%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |          |     |               |     |                  |     |               |     |                     |    |
| Water Heating                                                 | 21%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |          |     |               |     |                  |     |               |     |                     |    |
| Auxiliary Motors                                              | 17%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |          |     |               |     |                  |     |               |     |                     |    |
| Space Cooling                                                 | 11%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |          |     |               |     |                  |     |               |     |                     |    |
| Auxiliary Equipment                                           | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |          |     |               |     |                  |     |               |     |                     |    |

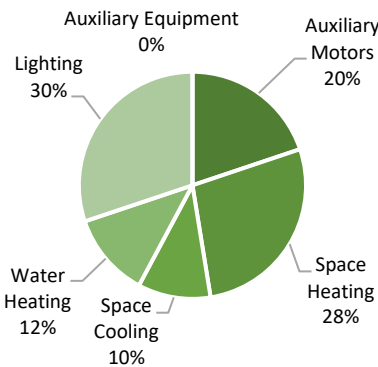
| Upgrade Scenarios                                             | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                               |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
|---------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|------------------|-----|----------|-----|---------------|-----|---------------|-----|---------------------|----|
|                                                               | <p>1,841,000 or 60% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$104,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$1,757,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$1,696,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Upgrade Package 3:<br>target 70% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+100% R-Value from BAU)<br/>Triple glazed windows</li><li>• <b>Lighting:</b><br/>Incorporate daylight harvesting</li><li>• <b>Heating System:</b><br/>Cold Climate Heat pump RTU with electric backup<br/>Washroom HRV</li><li>• <b>Ventilation:</b><br/>Maximize use of Demand Control Ventilation with CO2 sensor in return duct or zone</li><li>• <b>Pumps:</b><br/>No additional upgrade</li><li>• <b>Domestic Hot Water:</b><br/>No additional upgrade</li><li>• <b>Other:</b><br/>No additional upgrade</li></ul> <p><u>Summary</u></p> | 20                            | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>27%</td></tr><tr><td>Auxiliary Motors</td><td>20%</td></tr><tr><td>Lighting</td><td>22%</td></tr><tr><td>Water Heating</td><td>18%</td></tr><tr><td>Space Cooling</td><td>13%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 27% | Auxiliary Motors | 20% | Lighting | 22% | Water Heating | 18% | Space Cooling | 13% | Auxiliary Equipment | 0% |
| End-Use                                                       | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Space Heating                                                 | 27%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Auxiliary Motors                                              | 20%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Lighting                                                      | 22%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Water Heating                                                 | 18%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Space Cooling                                                 | 13%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Auxiliary Equipment                                           | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |

| Upgrade Scenarios | ECM Upgrade Packages                                                                                                                                                                                                                        | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU) |
|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------|
|                   | <b>Annual Energy Savings (ekWh)</b><br>2,073,000 or 68% reduction to BAU<br><br><b>Annual Bill Savings (\$)</b><br>\$134,000<br><br><b>Lifetime Bill Savings (\$)</b><br>\$2,264,000<br><br><b>Upgrade Package Cost (\$)</b><br>\$2,677,000 |                               |                                                                  |

### Archetype 3

The following figure is the result of energy modeling for Archetype 3, large multi-storey office buildings.

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|----------|-----|---------------|-----|------------------|-----|---------------|-----|---------------|-----|---------------------|----|
| Upgrade Package 1: target 30% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>No upgrade</li><li>• <b>Lighting:</b><br/>LED Lighting</li><li>• <b>Heating System:</b><br/>Condensing boiler upgrade for HVAC system and temperature setbacks</li><li>• <b>Ventilation:</b><br/>Reduce runtime hours to match building occupancy</li><li>• <b>Pumps:</b><br/>VFD on DHW pumps with minimum setback<br/>Delta temperature control</li><li>• <b>Domestic Hot Water:</b><br/>Install low flow fixtures<br/>Condensing boiler</li><li>• <b>Other:</b><br/>Schedule DHW recirculatory pump to shut off overnight<br/>Maximize use of night time setbacks (programmable thermostats)<br/>Reduce HVAC fan runtimes</li></ul> <p><u><b>Summary</b></u></p> <p><b>Annual Energy Savings (ekWh)</b></p> | 5                             |  <table><caption>Distribution of Energy Savings by End-Use</caption><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Lighting</td><td>39%</td></tr><tr><td>Space Heating</td><td>21%</td></tr><tr><td>Auxiliary Motors</td><td>13%</td></tr><tr><td>Space Cooling</td><td>10%</td></tr><tr><td>Water Heating</td><td>17%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Lighting | 39% | Space Heating | 21% | Auxiliary Motors | 13% | Space Cooling | 10% | Water Heating | 17% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Lighting                                                   | 39%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Space Heating                                              | 21%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Auxiliary Motors                                           | 13%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Space Cooling                                              | 10%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Water Heating                                              | 17%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |          |     |               |     |                  |     |               |     |               |     |                     |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use                                                                                                                                                                                                                                                                                                                                                                                                            |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
|------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|----------|-----|------------------|-----|---------------|-----|---------------|-----|---------------------|----|
|                                                            | <p>2,102,000 or 31% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$188,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$3,247,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$996,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Upgrade Package 2: target 50% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof insulation (+40% R-Value from BAU)</li><li>• <b>Lighting:</b><br/>LED Lighting conversion with occupancy sensors and scheduling of parking garage lighting</li><li>• <b>Heating System:</b><br/>AHU with ducted VRF heat pump coil with backup electric heater with SCR<br/>Condensing boiler upgrade for perimeter and terminal heating<br/>Maximize use of temperature setbacks</li><li>• <b>Ventilation:</b><br/>Full VAV conversion<br/>Ventilation fan speed control with VFD</li><li>• <b>Pumps:</b><br/>Pumps equipped with VFD and eliminate three-way valves<br/>Use of DP control<br/>Install variable speed DCW pumps</li><li>• <b>Domestic Hot Water:</b><br/>No additional upgrade</li><li>• <b>Other:</b><br/>Maximize use of night time setbacks (occupancy sensors day / night linked to BAS)</li></ul> | 9                             |  <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>28%</td></tr><tr><td>Lighting</td><td>30%</td></tr><tr><td>Auxiliary Motors</td><td>20%</td></tr><tr><td>Water Heating</td><td>12%</td></tr><tr><td>Space Cooling</td><td>10%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 28% | Lighting | 30% | Auxiliary Motors | 20% | Water Heating | 12% | Space Cooling | 10% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Space Heating                                              | 28%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Lighting                                                   | 30%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Auxiliary Motors                                           | 20%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Water Heating                                              | 12%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Space Cooling                                              | 10%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use                                                                                                                                                                                                                                                                                                                      |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|------------------|-----|----------|-----|---------------|-----|---------------|-----|---------------------|----|
|                                                            | <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>3,307,000 or 49% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$239,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$4,087,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$2,157,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Upgrade Package 3: target 70% energy savings from baseline | <p>• <b>Insulation:</b><br/>Additional roof insulation (+100% R-Value from BAU) and triple glazed windows</p> <p>• <b>Lighting:</b><br/>Incorporate daylight harvesting</p> <p>• <b>Heating System:</b><br/>Geo-exchange system<br/>AHUs with WSHP ducted coil equipped with backup electric heater with SCR<br/>WSHP system for perimeter and terminal heating with electric boiler backup<br/>Maximize use of temperature setbacks<br/>ERV for washroom heat recovery linked to AHU supply</p> <p>• <b>Ventilation:</b><br/>Maximize use of Demand Control Ventilation with CO2 sensor<br/>Ventilation fans equipped with VFDs<br/>Parking garage equipped with CO / NOx system</p> <p>• <b>Pumps:</b><br/>Electronically Commutated Motor driven pumps with DP control (no</p> | 15                            | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>27%</td></tr><tr><td>Auxiliary Motors</td><td>20%</td></tr><tr><td>Lighting</td><td>21%</td></tr><tr><td>Water Heating</td><td>19%</td></tr><tr><td>Space Cooling</td><td>13%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 27% | Auxiliary Motors | 20% | Lighting | 21% | Water Heating | 19% | Space Cooling | 13% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Space Heating                                              | 27%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Auxiliary Motors                                           | 20%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Lighting                                                   | 21%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Water Heating                                              | 19%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Space Cooling                                              | 13%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |

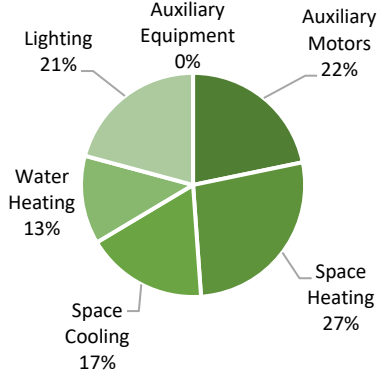
| Upgrade Scenarios | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-------------------------------------------|
|                   | sensor)<br><b>• Domestic Hot Water:</b><br>ASHP hot water heaters (highest efficiency option available)<br><b>• Other:</b><br>No additional upgrade<br><br><b><u>Summary</u></b><br><br><b>Annual Energy Savings (ekWh)</b><br>4,686,000 or 70% reduction to BAU<br><br><b>Annual Bill Savings (\$)</b><br>\$343,000<br><br><b>Lifetime Bill Savings (\$)</b><br>\$5,817,000<br><br><b>Upgrade Package Cost (\$)</b><br>\$5,148,000 |                               |                                           |

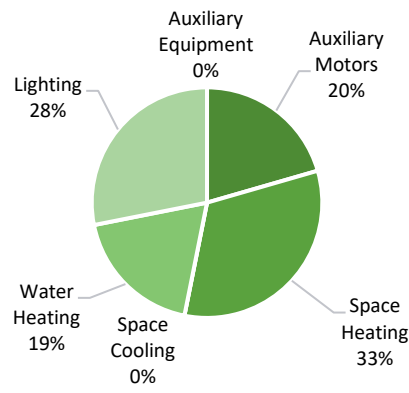
**Archetype 4**

The following figure is the result of energy modeling for Archetype 4, the single-storey office building archetype.

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                       | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU) |
|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------|
| Upgrade Package 1: target 30% energy savings from baseline | <b>• Insulation:</b><br>No upgrade<br><b>• Lighting:</b><br>LED Lighting<br><b>• Heating System:</b><br>Condensing boiler upgrade for HVAC system<br>Maximize use of temperature setbacks<br><b>• Ventilation:</b><br>Reduce runtime hours to match building occupancy<br><b>• Pumps:</b><br>VFD on DHW pumps with minimum | 7                             |                                                                  |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
|------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|----------|-----|---------------|-----|---------------|-----|---------------|-----|------------------|-----|---------------------|----|
|                                                            | <p>setback<br/>Delta temperature control</p> <ul style="list-style-type: none"><li>• <b>Domestic Hot Water:</b><br/>Install low flow fixtures<br/>Condensing boiler</li><li>• <b>Other:</b><br/>Schedule DHW recirculatory pump to shut off overnight<br/>Maximize use of night time setbacks (programmable thermostats)<br/>Reduce HVAC fan runtimes</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>185,000 or 26% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$15,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$288,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$107,000</p> |                               | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Lighting</td><td>42%</td></tr><tr><td>Space Heating</td><td>21%</td></tr><tr><td>Water Heating</td><td>14%</td></tr><tr><td>Space Cooling</td><td>10%</td></tr><tr><td>Auxiliary Motors</td><td>13%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Lighting | 42% | Space Heating | 21% | Water Heating | 14% | Space Cooling | 10% | Auxiliary Motors | 13% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Lighting                                                   | 42%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Space Heating                                              | 21%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Water Heating                                              | 14%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Space Cooling                                              | 10%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Auxiliary Motors                                           | 13%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Upgrade Package 2: target 50% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+20% R-Value from BAU)</li><li>• <b>Lighting:</b><br/>LED Lighting conversion with occupancy sensors</li><li>• <b>Heating System:</b><br/>Heat Pump RTU and backup electric heater with SCR<br/>Condensing boiler upgrade for perimeter and terminal heating<br/>Maximize use of temperature setbacks</li><li>• <b>Ventilation:</b><br/>VAV conversion<br/>Ventilation fan speed control with VFD</li><li>• <b>Pumps:</b><br/>Pumps equipped with VFD and</li></ul>                                                                        | 14                            | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Lighting</td><td>31%</td></tr><tr><td>Space Heating</td><td>25%</td></tr><tr><td>Water Heating</td><td>10%</td></tr><tr><td>Space Cooling</td><td>11%</td></tr><tr><td>Auxiliary Motors</td><td>23%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Lighting | 31% | Space Heating | 25% | Water Heating | 10% | Space Cooling | 11% | Auxiliary Motors | 23% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Lighting                                                   | 31%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Space Heating                                              | 25%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Water Heating                                              | 10%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Space Cooling                                              | 11%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Auxiliary Motors                                           | 23%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |          |     |               |     |               |     |               |     |                  |     |                     |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|------------------|-----|----------|-----|---------------|-----|---------------|-----|---------------------|----|
|                                                            | <p>eliminate three-way valves<br/>Use of DP control<br/>Install variable speed DCW pumps</p> <ul style="list-style-type: none"><li>• <b>Domestic Hot Water:</b><br/>No additional upgrade</li><li>• <b>Other:</b><br/>Maximize use of night time setbacks (occupancy sensors day / night linked to BAS)</li></ul> <p><u>Summary</u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>298,000 or 41% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$21,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$384,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$287,000</p> |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Upgrade Package 3: target 70% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+100% R-Value from BAU) and triple glazed windows</li><li>• <b>Lighting:</b><br/>Incorporate daylight harvesting</li><li>• <b>Heating System:</b><br/>Geo-exchange system<br/>AHUs with WSHP ducted coil equipped with backup electric heater with SCR WSHP system for perimeter and terminal heating with electric boiler backup<br/>Maximize use of temperature setbacks<br/>ERV for washroom heat recovery</li></ul>                                                                      | 28                            |  <table><caption>Distribution of Energy Savings by End-Use</caption><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>27%</td></tr><tr><td>Auxiliary Motors</td><td>22%</td></tr><tr><td>Lighting</td><td>21%</td></tr><tr><td>Space Cooling</td><td>17%</td></tr><tr><td>Water Heating</td><td>13%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 27% | Auxiliary Motors | 22% | Lighting | 21% | Space Cooling | 17% | Water Heating | 13% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Space Heating                                              | 27%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Auxiliary Motors                                           | 22%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Lighting                                                   | 21%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Space Cooling                                              | 17%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Water Heating                                              | 13%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |         |            |               |     |                  |     |          |     |               |     |               |     |                     |    |

| Upgrade Scenarios   | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|----------|-----|------------------|-----|---------------|-----|---------------------|----|---------------|----|
|                     | <p>linked to AHU supply</p> <ul style="list-style-type: none"><li>• <b>Ventilation:</b><br/>Maximize use of Demand Control Ventilation with CO2 sensor<br/>Ventilation fans equipped with VFDs</li><li>• <b>Pumps:</b><br/>Electronically Commutated Motor driven pumps with DP control (no sensor)</li><li>• <b>Domestic Hot Water:</b><br/>ASHP HW heaters (highest efficiency option available)</li><li>• <b>Other:</b><br/>No additional upgrade</li></ul> <p><u><b>Summary</b></u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>473,000 or 66% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$31,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$583,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$872,000</p> |                               |  <table><caption>Distribution of Energy Savings by End-Use</caption><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>33%</td></tr><tr><td>Lighting</td><td>28%</td></tr><tr><td>Auxiliary Motors</td><td>20%</td></tr><tr><td>Water Heating</td><td>19%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr><tr><td>Space Cooling</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 33% | Lighting | 28% | Auxiliary Motors | 20% | Water Heating | 19% | Auxiliary Equipment | 0% | Space Cooling | 0% |
| End-Use             | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Space Heating       | 33%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Lighting            | 28%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Auxiliary Motors    | 20%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Water Heating       | 19%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Auxiliary Equipment | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Space Cooling       | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |

#### Archetype 5

The following figure is the result of energy modeling for Archetype 5, large-format schools (K12).

| Upgrade Scenarios             | ECM Upgrade Packages                                                                                              | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU) |
|-------------------------------|-------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------|
| Upgrade Package 1: target 30% | <ul style="list-style-type: none"> <li>• <b>Insulation:</b><br/>No upgrade</li> <li>• <b>Lighting:</b></li> </ul> | 5                             |                                                                  |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                              |         |            |          |     |               |     |               |     |                  |     |                     |    |               |    |
|------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|----------|-----|---------------|-----|---------------|-----|------------------|-----|---------------------|----|---------------|----|
| energy savings from baseline                               | <p>LED Lighting</p> <ul style="list-style-type: none"><li>• Heating System:<br/>Condensing boilers for AHUs and terminal and perimeter reheat<br/>Night time temperature setbacks</li><li>• Ventilation:<br/>Reduce runtime hours to match building occupancy</li><li>• Pumps:<br/>VFD on DHW pumps with minimum setback<br/>Delta temperature control</li><li>• Domestic Hot Water:<br/>Install low flow fixtures<br/>Condensing boiler</li><li>• Other:<br/>Schedule DHW recirculatory pump to shut off overnight<br/>Maximize use of night time setbacks (programmable thermostats)<br/>Reduce HVAC fan runtimes</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>1,051,000 or 31% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$87,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$1,637,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$475,000</p> |                               | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Lighting</td><td>43%</td></tr><tr><td>Space Heating</td><td>27%</td></tr><tr><td>Water Heating</td><td>15%</td></tr><tr><td>Auxiliary Motors</td><td>15%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr><tr><td>Space Cooling</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Lighting | 43% | Space Heating | 27% | Water Heating | 15% | Auxiliary Motors | 15% | Auxiliary Equipment | 0% | Space Cooling | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |                     |    |               |    |
| Lighting                                                   | 43%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |                     |    |               |    |
| Space Heating                                              | 27%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |                     |    |               |    |
| Water Heating                                              | 15%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |                     |    |               |    |
| Auxiliary Motors                                           | 15%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |                     |    |               |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |                     |    |               |    |
| Space Cooling                                              | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |                     |    |               |    |
| Upgrade Package 2: target 50% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>No upgrade</li><li>• <b>Lighting:</b><br/>LED Lighting conversion with occupancy sensors</li><li>• <b>Heating System:</b><br/>AHU with ducted VRF heat pump coil and</li></ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | 13                            |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |               |     |                  |     |                     |    |               |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU) |
|------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------|
|                                                            | <p>backup electric heater with SCR<br/>Air to water heat pump with backup electric<br/>Low temperature heating terminal units</p> <ul style="list-style-type: none"> <li>• <b>Ventilation:</b><br/>VAV conversion<br/>Ventilation fan speed control with VFD</li> <li>• <b>Pumps:</b><br/>Pumps equipped with VFD and eliminate three-way valves<br/>Use of DP control</li> <li>• <b>Domestic Hot Water:</b><br/>ASHP hot water heaters (highest efficiency available)</li> <li>• <b>Other:</b><br/>Maximize use of night time setbacks (occupancy sensors day / night linked to BAS)<br/>Reduce HVAC fan runtimes on off-peak periods (holidays, professional development days and summer hours)</li> </ul> <p><b><u>Summary</u></b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>2,093,000 or 61% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$116,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$2,111,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$1,540,000</p> |                               |                                                                  |
| Upgrade Package 3: target 70% energy savings from baseline | <ul style="list-style-type: none"> <li>• <b>Insulation:</b><br/>Additional roof-insulation (+100% R-Value from BAU) and triple glazed windows</li> <li>• <b>Lighting:</b><br/>Incorporate daylight harvesting</li> <li>• <b>Heating System:</b></li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | 26                            |                                                                  |

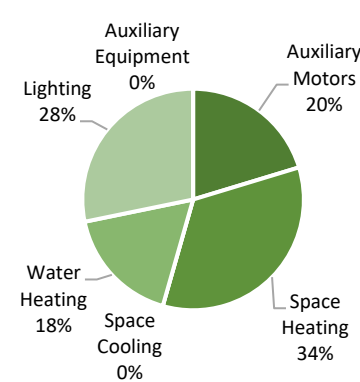
| Upgrade Scenarios   | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
|---------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|----------|-----|------------------|-----|---------------|-----|---------------------|----|---------------|----|
|                     | <p>CCHP (highest efficiency available)</p> <ul style="list-style-type: none"><li>• <b>Ventilation:</b><br/>Maximize use of Demand Control Ventilation with CO2 sensor<br/>Ventilation fans equipped with VFDs<br/>Kitchen DCV for exhaust hood sensors</li><li>• <b>Pumps:</b><br/>Electronically Commutated Motor driven pumps with DP control (no sensor)</li><li>• <b>Domestic Hot Water:</b><br/>No additional upgrade</li><li>• <b>Other:</b><br/>No additional upgrade</li></ul> <p><u>Summary</u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>2,200,000 or 64% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$130,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$2,368,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$3,361,000</p> |                               | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>34%</td></tr><tr><td>Lighting</td><td>28%</td></tr><tr><td>Auxiliary Motors</td><td>20%</td></tr><tr><td>Water Heating</td><td>18%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr><tr><td>Space Cooling</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 34% | Lighting | 28% | Auxiliary Motors | 20% | Water Heating | 18% | Auxiliary Equipment | 0% | Space Cooling | 0% |
| End-Use             | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Space Heating       | 34%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Lighting            | 28%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Auxiliary Motors    | 20%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Water Heating       | 18%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Auxiliary Equipment | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Space Cooling       | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |

### Archetype 6

The following figure is the result of energy modeling for Archetype 6, small-format schools (K12).

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                              |         |            |          |     |               |     |                  |     |               |     |                     |    |               |    |
|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|----------|-----|---------------|-----|------------------|-----|---------------|-----|---------------------|----|---------------|----|
| Upgrade Package 1: target 30% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>No upgrade</li><li>• <b>Lighting:</b><br/>LED Lighting</li><li>• <b>Heating System:</b><br/>Condensing boilers for AHUs and terminal and perimeter reheat<br/>Night time temperature setbacks</li><li>• <b>Ventilation:</b><br/>Reduce runtime hours to match building occupancy</li><li>• <b>Pumps:</b><br/>VFD on DHW pumps with minimum setback<br/>Delta temperature control</li><li>• <b>Domestic Hot Water:</b><br/>Install low flow fixtures<br/>Condensing boiler</li><li>• <b>Other:</b><br/>Schedule DHW recirculatory pump to shut off overnight<br/>Maximize use of night time setbacks (programmable thermostats)<br/>Reduce HVAC fan runtimes</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>190,000 or 31% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$15,000</p> | 6                             | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Lighting</td><td>41%</td></tr><tr><td>Space Heating</td><td>26%</td></tr><tr><td>Auxiliary Motors</td><td>18%</td></tr><tr><td>Water Heating</td><td>15%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr><tr><td>Space Cooling</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Lighting | 41% | Space Heating | 26% | Auxiliary Motors | 18% | Water Heating | 15% | Auxiliary Equipment | 0% | Space Cooling | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |                  |     |               |     |                     |    |               |    |
| Lighting                                                   | 41%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |                  |     |               |     |                     |    |               |    |
| Space Heating                                              | 26%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |                  |     |               |     |                     |    |               |    |
| Auxiliary Motors                                           | 18%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |                  |     |               |     |                     |    |               |    |
| Water Heating                                              | 15%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |                  |     |               |     |                     |    |               |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |                  |     |               |     |                     |    |               |    |
| Space Cooling                                              | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |          |     |               |     |                  |     |               |     |                     |    |               |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|----------|-----|------------------|-----|---------------|-----|---------------------|----|---------------|----|
|                                                            | <b>Lifetime Bill Savings (\$)</b><br>\$280,000<br><br><b>Upgrade Package Cost (\$)</b><br>\$86,000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Upgrade Package 2: target 50% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>No upgrade</li><li>• <b>Lighting:</b><br/>LED Lighting conversion with occupancy sensors</li><li>• <b>Heating System:</b><br/>AHU with ducted VRF heat pump coil and backup electric heater with SCR<br/>Air to water heat pump with backup electric<br/>Low temperature heating terminal units</li><li>• <b>Ventilation:</b><br/>VAV conversion<br/>Ventilation fan speed control with VFD</li><li>• <b>Pumps:</b><br/>Pumps equipped with VFD and eliminate three-way valves<br/>Use of DP control</li><li>• <b>Domestic Hot Water:</b><br/>ASHP hot water heaters (highest efficiency available)</li><li>• <b>Other:</b><br/>Maximize use of night time setbacks (occupancy sensors day / night linked to BAS)<br/>Reduce HVAC fan runtimes on off-peak periods (holidays, professional development days and summer hours)</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>366,000 or 60% reduction to BAU</p> | 14                            | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>32%</td></tr><tr><td>Lighting</td><td>29%</td></tr><tr><td>Auxiliary Motors</td><td>21%</td></tr><tr><td>Water Heating</td><td>18%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr><tr><td>Space Cooling</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 32% | Lighting | 29% | Auxiliary Motors | 21% | Water Heating | 18% | Auxiliary Equipment | 0% | Space Cooling | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Space Heating                                              | 32%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Lighting                                                   | 29%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Auxiliary Motors                                           | 21%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Water Heating                                              | 18%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Space Cooling                                              | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
|------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|----------|-----|------------------|-----|---------------|-----|---------------------|----|---------------|----|
|                                                            | <p><b>Annual Bill Savings (\$)</b><br/>\$19,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$364,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$264,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Upgrade Package 3: target 70% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+100% R-Value from BAU) and triple glazed windows</li><li>• <b>Lighting:</b><br/>Incorporate daylight harvesting</li><li>• <b>Heating System:</b><br/>CCHP (highest efficiency available)</li><li>• <b>Ventilation:</b><br/>Maximize use of Demand Control Ventilation with CO2 sensor<br/>Ventilation fans equipped with VFDs<br/>Kitchen DCV for exhaust hood sensors</li><li>• <b>Pumps:</b><br/>Electronically Commutated Motor driven pumps with DP control (no sensor)</li><li>• <b>Domestic Hot Water:</b><br/>No additional upgrade</li><li>• <b>Other:</b><br/>No additional upgrade</li></ul> <p><u><b>Summary</b></u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>390,000 or 64% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$23,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$422,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$530,000</p> | 23                            |  <table><caption>Distribution of Energy Savings by End-Use</caption><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>34%</td></tr><tr><td>Lighting</td><td>28%</td></tr><tr><td>Auxiliary Motors</td><td>20%</td></tr><tr><td>Water Heating</td><td>18%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr><tr><td>Space Cooling</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 34% | Lighting | 28% | Auxiliary Motors | 20% | Water Heating | 18% | Auxiliary Equipment | 0% | Space Cooling | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Space Heating                                              | 34%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Lighting                                                   | 28%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Auxiliary Motors                                           | 20%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Water Heating                                              | 18%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |
| Space Cooling                                              | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |         |            |               |     |          |     |                  |     |               |     |                     |    |               |    |

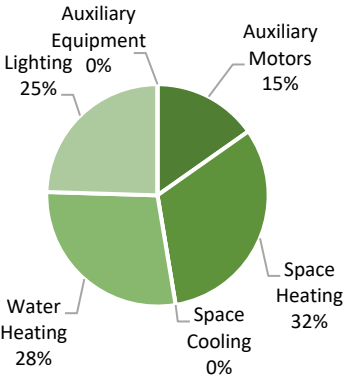
| Upgrade Scenarios | ECM Upgrade Packages | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU) |
|-------------------|----------------------|-------------------------------|------------------------------------------------------------------|
|                   |                      |                               |                                                                  |

### Archetype 7

The following figure is the result of energy modeling for Archetype 7, long-term-care buildings.

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                             |         |            |          |     |               |     |               |     |                  |    |                     |    |               |    |
|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|----------|-----|---------------|-----|---------------|-----|------------------|----|---------------------|----|---------------|----|
| Upgrade Package 1: target 30% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>No upgrade</li><li>• <b>Lighting:</b><br/>LED Lighting</li><li>• <b>Heating System:</b><br/>Condensing boilers for AHU coils<br/>Improve heat recovery effectiveness of units (heat wheel, heat pipes or other with 60% heat recovery effectiveness)<br/>Night time temperature setbacks</li><li>• <b>Ventilation:</b><br/>No upgrade</li><li>• <b>Pumps:</b><br/>VFD on DHW pumps with minimum setback<br/>Delta temperature control</li><li>• <b>Domestic Hot Water:</b><br/>Install low flow fixtures<br/>Condensing boiler</li><li>• <b>Other:</b><br/>Schedule DHW recirculatory pump to shut off overnight<br/>Maximize use of night time setbacks (programmable thermostats)</li></ul> <p><u><b>Summary</b></u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>493,000 or 32% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b></p> | 8                             | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Lighting</td><td>40%</td></tr><tr><td>Water Heating</td><td>31%</td></tr><tr><td>Space Heating</td><td>26%</td></tr><tr><td>Auxiliary Motors</td><td>3%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr><tr><td>Space Cooling</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Lighting | 40% | Water Heating | 31% | Space Heating | 26% | Auxiliary Motors | 3% | Auxiliary Equipment | 0% | Space Cooling | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |          |     |               |     |               |     |                  |    |                     |    |               |    |
| Lighting                                                   | 40%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |          |     |               |     |               |     |                  |    |                     |    |               |    |
| Water Heating                                              | 31%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |          |     |               |     |               |     |                  |    |                     |    |               |    |
| Space Heating                                              | 26%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |          |     |               |     |               |     |                  |    |                     |    |               |    |
| Auxiliary Motors                                           | 3%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |          |     |               |     |               |     |                  |    |                     |    |               |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |          |     |               |     |               |     |                  |    |                     |    |               |    |
| Space Cooling                                              | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |          |     |               |     |               |     |                  |    |                     |    |               |    |

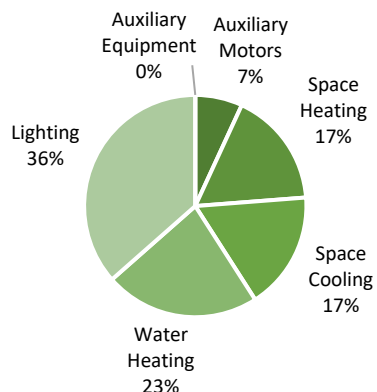
| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |          |     |               |     |                  |     |                     |    |               |    |
|------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|----------|-----|---------------|-----|------------------|-----|---------------------|----|---------------|----|
|                                                            | <p>\$37,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$568,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$284,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |               |     |                  |     |                     |    |               |    |
| Upgrade Package 2: target 50% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+30% R-Value from BAU)</li><li>• <b>Lighting:</b><br/>LED Lighting conversion with occupancy sensors</li><li>• <b>Heating System:</b><br/>Two-stage ducted heat pump for primary AHUs and Kitchen units with backup electric<br/>MSHP/VRF for terminal reheat in patient rooms<br/>Improve heat recovery effectiveness of units (heat wheel or other with +65% heat recovery effectiveness)</li><li>• <b>Ventilation:</b><br/>No upgrade</li><li>• <b>Pumps:</b><br/>Pumps equipped with VFD and eliminate three-way valves<br/>Use of DP control</li><li>• <b>Domestic Hot Water:</b><br/>ASHP hot water heaters (highest efficiency available)</li><li>• <b>Other:</b><br/>Maximize use of night time setbacks (occupancy sensors day / night linked to BAS)</li></ul> <p><u><b>Summary</b></u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>932,000 or 61% reduction to BAU</p> | 14                            | <table border="1"><caption>Energy Savings by End-Use</caption><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>37%</td></tr><tr><td>Lighting</td><td>29%</td></tr><tr><td>Water Heating</td><td>19%</td></tr><tr><td>Auxiliary Motors</td><td>15%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr><tr><td>Space Cooling</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 37% | Lighting | 29% | Water Heating | 19% | Auxiliary Motors | 15% | Auxiliary Equipment | 0% | Space Cooling | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |               |     |                  |     |                     |    |               |    |
| Space Heating                                              | 37%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |               |     |                  |     |                     |    |               |    |
| Lighting                                                   | 29%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |               |     |                  |     |                     |    |               |    |
| Water Heating                                              | 19%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |               |     |                  |     |                     |    |               |    |
| Auxiliary Motors                                           | 15%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                               |                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |               |     |                  |     |                     |    |               |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |               |     |                  |     |                     |    |               |    |
| Space Cooling                                              | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |               |     |                  |     |                     |    |               |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                                                                                                                    |         |            |               |     |               |     |          |     |                  |     |                     |    |               |    |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|---------------|-----|----------|-----|------------------|-----|---------------------|----|---------------|----|
|                                                            | <p><b>Annual Bill Savings (\$)</b><br/>\$47,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$852,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$644,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |               |     |          |     |                  |     |                     |    |               |    |
| Upgrade Package 3: target 70% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+100% R-Value from BAU) and triple glazed windows</li><li>• <b>Lighting:</b><br/>Incorporate daylight harvesting</li><li>• <b>Heating System:</b><br/>Heat recovery for bathrooms<br/>Install DCV system for commercial kitchen</li><li>• <b>Ventilation:</b><br/>VAV conversion<br/>Ventilation fans equipped with VFDs for main and kitchen zones</li><li>• <b>Pumps:</b><br/>Electronically Commutated Motor driven pumps with DP control (no sensor)</li><li>• <b>Domestic Hot Water:</b><br/>no additional upgrade</li><li>• <b>Other:</b><br/>No additional upgrade</li></ul> <p><u><b>Summary</b></u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>1,036,000 or 68% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$60,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$1,089,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$1,233,000</p> | 20                            |  <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>32%</td></tr><tr><td>Water Heating</td><td>28%</td></tr><tr><td>Lighting</td><td>25%</td></tr><tr><td>Auxiliary Motors</td><td>15%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr><tr><td>Space Cooling</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 32% | Water Heating | 28% | Lighting | 25% | Auxiliary Motors | 15% | Auxiliary Equipment | 0% | Space Cooling | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |               |     |          |     |                  |     |                     |    |               |    |
| Space Heating                                              | 32%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |               |     |          |     |                  |     |                     |    |               |    |
| Water Heating                                              | 28%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |               |     |          |     |                  |     |                     |    |               |    |
| Lighting                                                   | 25%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |               |     |          |     |                  |     |                     |    |               |    |
| Auxiliary Motors                                           | 15%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |               |     |          |     |                  |     |                     |    |               |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |               |     |          |     |                  |     |                     |    |               |    |
| Space Cooling                                              | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |               |     |          |     |                  |     |                     |    |               |    |

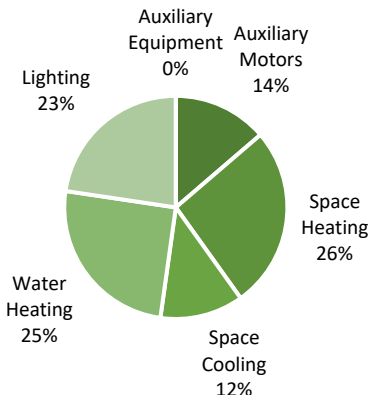
| Upgrade Scenarios | ECM Upgrade Packages | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU) |
|-------------------|----------------------|-------------------------------|------------------------------------------------------------------|
|                   |                      |                               |                                                                  |

### Archetype 8

The following figure is the result of energy modeling for Archetype 8, multi-storey hotels with a restaurant. A key feature of this building archetype is the use of centralized natural gas heating systems.

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                                                                                                                                                  |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
|------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|----------|-----|---------------|-----|---------------|-----|---------------|-----|------------------|----|---------------------|----|
| Upgrade Package 1: target 30% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>No upgrade</li><li>• <b>Lighting:</b><br/>LED Lighting</li><li>• <b>Heating System:</b><br/>Natural gas condensing boilers</li><li>• <b>Ventilation:</b><br/>Scheduling setbacks on AHUs for meeting rooms, administration offices and other zones with varied occupancy)</li><li>• <b>Pumps:</b><br/>VFD on DHW pumps with minimum setback<br/>Delta temperature control</li><li>• <b>Domestic Hot Water:</b><br/>Install low flow fixtures<br/>Condensing boiler</li><li>• <b>Other:</b><br/>Schedule DHW recirculatory pump to shut off overnight<br/>Maximize use of night time setbacks (programmable thermostats)<br/>Reduce HVAC fan run times</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>2,669,000 or 27% reduction to BAU</p> | 3                             |  <table><caption>Distribution of Energy Savings by End-Use</caption><tr><th>End-Use</th><th>Percentage</th></tr><tr><td>Lighting</td><td>36%</td></tr><tr><td>Water Heating</td><td>23%</td></tr><tr><td>Space Cooling</td><td>17%</td></tr><tr><td>Space Heating</td><td>17%</td></tr><tr><td>Auxiliary Motors</td><td>7%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></table> | End-Use | Percentage | Lighting | 36% | Water Heating | 23% | Space Cooling | 17% | Space Heating | 17% | Auxiliary Motors | 7% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Lighting                                                   | 36%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Water Heating                                              | 23%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Space Cooling                                              | 17%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Space Heating                                              | 17%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Auxiliary Motors                                           | 7%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |

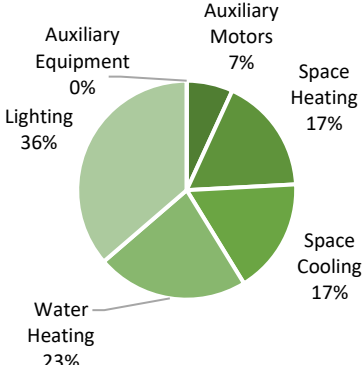
| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                               |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|----------|-----|------------------|-----|---------------|-----|---------------|-----|---------------------|----|
|                                                            | <p><b>Annual Bill Savings (\$)</b><br/>\$230,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$4,239,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$774,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Upgrade Package 2: target 50% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+20% R-Value from BAU)</li><li>• <b>Lighting:</b><br/>LED Lighting conversion with occupancy sensors</li><li>• <b>Heating System:</b><br/>Natural gas condensing boilers</li><li>• <b>Ventilation:</b><br/>VAV conversion<br/>Maximize use of DCV with CO2 control<br/>Ventilation fans with VFDs<br/>Scheduling setbacks on AHUs for meeting rooms, administration offices and other zones with varied occupancy)</li><li>• <b>Pumps:</b><br/>Pumps equipped with VFD and eliminate three-way valves<br/>Use of DP control</li><li>• <b>Domestic Hot Water:</b><br/>ASHP hot water heaters (highest efficiency available)</li><li>• <b>Other:</b><br/>Maximize use of night time setbacks (occupancy sensors day / night linked to BAS)</li></ul> <p><u><b>Summary</b></u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>3,737,000 or 38% reduction to BAU</p> | 6                             | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Water Heating</td><td>30%</td></tr><tr><td>Lighting</td><td>27%</td></tr><tr><td>Auxiliary Motors</td><td>16%</td></tr><tr><td>Space Heating</td><td>14%</td></tr><tr><td>Space Cooling</td><td>13%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Water Heating | 30% | Lighting | 27% | Auxiliary Motors | 16% | Space Heating | 14% | Space Cooling | 13% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Water Heating                                              | 30%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Lighting                                                   | 27%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Auxiliary Motors                                           | 16%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Space Heating                                              | 14%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Space Cooling                                              | 13%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |               |     |          |     |                  |     |               |     |                     |    |
|------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|---------------|-----|----------|-----|------------------|-----|---------------|-----|---------------------|----|
|                                                            | <p><b>Annual Bill Savings (\$)</b><br/>\$300,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$4,667,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$1,785,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |                  |     |               |     |                     |    |
| Upgrade Package 3: target 70% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+100% R-Value from BAU) and triple glazed windows</li><li>• <b>Lighting:</b><br/>Incorporate daylight harvesting</li><li>• <b>Heating System:</b><br/>Facility wide VRF with DOAS units for ventilation and terminal and perimeter heating loads<br/>Improve heat recovery effectiveness (example: heat wheel)<br/>Install DCV system for commercial kitchen<br/>Heat recovery from bathrooms</li><li>• <b>Ventilation:</b><br/>No additional upgrade</li><li>• <b>Pumps:</b><br/>Electronically Commutated Motor driven pumps with DP control (no sensor)</li><li>• <b>Domestic Hot Water:</b><br/>no additional upgrade</li><li>• <b>Other:</b><br/>Reduce HVAC fan run times</li></ul> <p><u><b>Summary</b></u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>5,691,000 or 58% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$335,000</p> | 15                            |  <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>26%</td></tr><tr><td>Water Heating</td><td>25%</td></tr><tr><td>Lighting</td><td>23%</td></tr><tr><td>Auxiliary Motors</td><td>14%</td></tr><tr><td>Space Cooling</td><td>12%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 26% | Water Heating | 25% | Lighting | 23% | Auxiliary Motors | 14% | Space Cooling | 12% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |                  |     |               |     |                     |    |
| Space Heating                                              | 26%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |                  |     |               |     |                     |    |
| Water Heating                                              | 25%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |                  |     |               |     |                     |    |
| Lighting                                                   | 23%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |                  |     |               |     |                     |    |
| Auxiliary Motors                                           | 14%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |                  |     |               |     |                     |    |
| Space Cooling                                              | 12%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |                  |     |               |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |                  |     |               |     |                     |    |

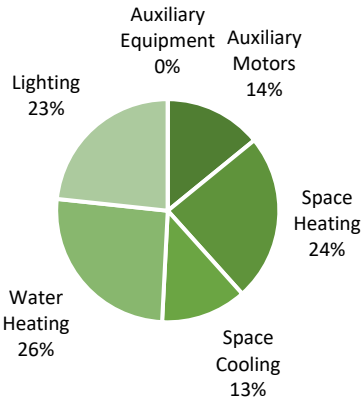
| Upgrade Scenarios | ECM Upgrade Packages                                                                                    | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU) |
|-------------------|---------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------|
|                   | <b>Lifetime Bill Savings (\$)</b><br>\$5,045,000<br><br><b>Upgrade Package Cost (\$)</b><br>\$5,107,000 |                               |                                                                  |

### Archetype 9

The following figure is the result of energy modeling for Archetype 9, which is the same as Archetype 8 but based on an electric-heating archetype with units conditioned via packaged terminal air-conditioning units (PTAC).

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                                                                                                                    |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|----------|-----|---------------|-----|---------------|-----|---------------|-----|------------------|----|---------------------|----|
| Upgrade Package 1: target 30% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>No upgrade</li><li>• <b>Lighting:</b><br/>LED Lighting</li><li>• <b>Heating System:</b><br/>High efficiency PTAC Units<br/>Condensing boiler for perimeter/ventilation</li><li>• <b>Ventilation:</b><br/>Scheduling setbacks on AHUs for meeting rooms, administration offices and other zones with varied occupancy)</li><li>• <b>Pumps:</b><br/>VFD on DHW pumps with minimum setback<br/>Delta temperature control</li><li>• <b>Domestic Hot Water:</b><br/>Install low flow fixtures<br/>Condensing boiler</li></ul> | 6                             |  <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Lighting</td><td>36%</td></tr><tr><td>Water Heating</td><td>23%</td></tr><tr><td>Space Cooling</td><td>17%</td></tr><tr><td>Space Heating</td><td>17%</td></tr><tr><td>Auxiliary Motors</td><td>7%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Lighting | 36% | Water Heating | 23% | Space Cooling | 17% | Space Heating | 17% | Auxiliary Motors | 7% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Lighting                                                   | 36%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Water Heating                                              | 23%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Space Cooling                                              | 17%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Space Heating                                              | 17%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Auxiliary Motors                                           | 7%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                     |         |            |          |     |               |     |               |     |               |     |                  |    |                     |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|----------|-----|------------------|-----|---------------|-----|---------------|-----|---------------------|----|
|                                                            | <ul style="list-style-type: none"><li>• <b>Other:</b><br/>Schedule DHW recirculatory pump to shut off overnight<br/>Maximize use of night time setbacks (programmable thermostats)<br/>Reduce HVAC fan run times</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>2,390,000 or 28% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$227,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$3,907,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$1,321,000</p>                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                       |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Upgrade Package 2: target 50% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+20% R-Value from BAU)</li><li>• <b>Lighting:</b><br/>LED Lighting conversion with occupancy sensors</li><li>• <b>Heating System:</b><br/>Natural gas condensing boilers</li><li>• <b>Ventilation:</b><br/>VAV conversion<br/>Maximize use of DCV with C02 control<br/>Ventilation fans with VFDs<br/>Scheduling setbacks on AHUs for meeting rooms, administration offices and other zones with varied occupancy)</li><li>• <b>Pumps:</b><br/>Pumps equipped with VFD and eliminate three-way valves<br/>Use of DP control</li></ul> | 9                             | <table border="1"><caption>Distribution of Energy Savings by End-Use</caption><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Water Heating</td><td>29%</td></tr><tr><td>Lighting</td><td>26%</td></tr><tr><td>Auxiliary Motors</td><td>16%</td></tr><tr><td>Space Heating</td><td>16%</td></tr><tr><td>Space Cooling</td><td>13%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Water Heating | 29% | Lighting | 26% | Auxiliary Motors | 16% | Space Heating | 16% | Space Cooling | 13% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                       |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Water Heating                                              | 29%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                       |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Lighting                                                   | 26%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                       |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Auxiliary Motors                                           | 16%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                       |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Space Heating                                              | 16%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                       |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Space Cooling                                              | 13%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                       |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                       |         |            |               |     |          |     |                  |     |               |     |               |     |                     |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                                                                                                                     |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
|------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|---------------|-----|----------|-----|---------------|-----|------------------|-----|---------------------|----|
|                                                            | <ul style="list-style-type: none"><li>• <b>Domestic Hot Water:</b><br/>ASHP hot water heaters (highest efficiency available)</li><li>• <b>Other:</b><br/>Maximize use of night time setbacks (occupancy sensors day / night linked to BAS)</li></ul> <p><u><b>Summary</b></u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>3,429,000 or 40% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$303,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$5,423,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$2,772,000</p>                                                                                      |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Upgrade Package 3: target 70% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+100% R-Value from BAU) and triple glazed windows</li><li>• <b>Lighting:</b><br/>Incorporate daylight harvesting</li><li>• <b>Heating System:</b><br/>Facility wide VRF with DOAS units for ventilation and terminal and perimeter heating loads<br/>Improve heat recovery effectiveness (example: heat wheel)<br/>Install DCV system for commercial kitchen<br/>Heat recovery from bathrooms</li><li>• <b>Ventilation:</b><br/>No additional upgrade</li><li>• <b>Pumps:</b><br/>Electronically Commutated Motor driven</li></ul> | 15                            |  <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Water Heating</td><td>26%</td></tr><tr><td>Space Heating</td><td>24%</td></tr><tr><td>Lighting</td><td>23%</td></tr><tr><td>Space Cooling</td><td>13%</td></tr><tr><td>Auxiliary Motors</td><td>14%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Water Heating | 26% | Space Heating | 24% | Lighting | 23% | Space Cooling | 13% | Auxiliary Motors | 14% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Water Heating                                              | 26%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Space Heating                                              | 24%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Lighting                                                   | 23%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Space Cooling                                              | 13%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Auxiliary Motors                                           | 14%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                      |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |

| Upgrade Scenarios | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU) |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------|
|                   | <p>pumps with DP control (no sensor)</p> <ul style="list-style-type: none"> <li>• <b>Domestic Hot Water:</b><br/>no additional upgrade</li> <li>• <b>Other:</b><br/>Reduce HVAC fan run times</li> </ul> <p><b><u>Summary</u></b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>4,517,000 or 53% reduction to BAU</p> <p><b>Annual Bill Savings (\$)</b><br/>\$328,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$5,994,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$5,103,000</p> |                               |                                                                  |

## Archetype 10

The following figure is the result of energy modeling for Archetype 10, stand-alone restaurant buildings.

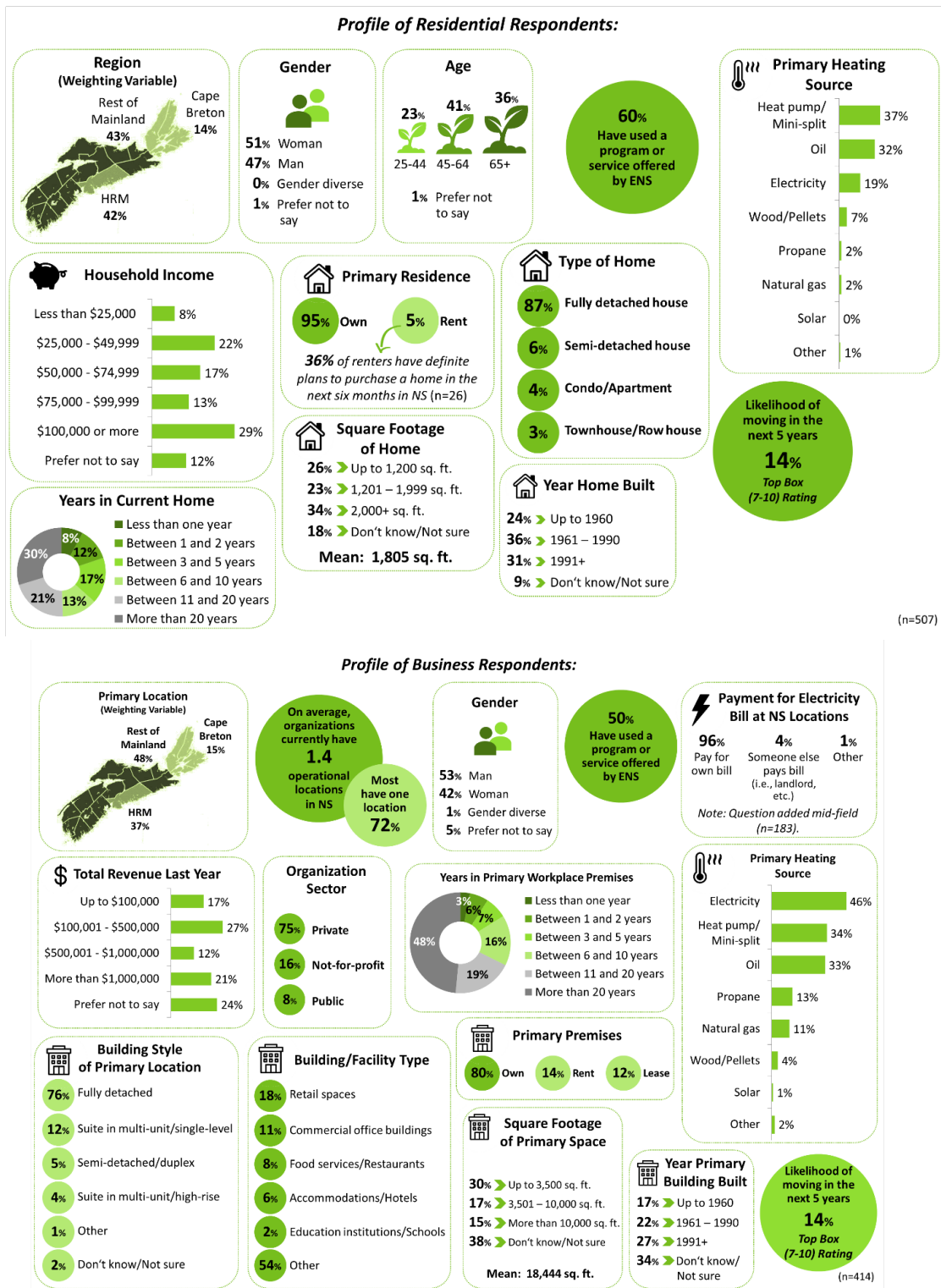
| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                             |         |            |               |     |          |     |               |     |                  |    |               |    |                     |    |
|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|----------|-----|---------------|-----|------------------|----|---------------|----|---------------------|----|
| Upgrade Package 1: target 30% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>No upgrade</li><li>• <b>Lighting:</b><br/>LED Lighting</li><li>• <b>Heating System:</b><br/>ASHP RTU with backup electric</li><li>• <b>Ventilation:</b><br/>Scheduling setbacks for facility ventilation systems</li><li>• <b>Pumps:</b><br/>VFD on DHW pumps with minimum setback<br/>Delta temperature control</li><li>• <b>Domestic Hot Water:</b><br/>Install low flow fixtures</li><li>• <b>Other:</b><br/>Schedule DHW recirculatory pump to shut off overnight<br/>Maximize use of nighttime setbacks (programmable thermostats)<br/>Reduce HVAC fan run times</li></ul> <p><b>Summary</b></p> <p><b>Annual Energy Savings (ekWh)</b><br/>119,000 or 32% reduction to BAU</p> | 13                            | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>42%</td></tr><tr><td>Lighting</td><td>33%</td></tr><tr><td>Space Cooling</td><td>12%</td></tr><tr><td>Auxiliary Motors</td><td>7%</td></tr><tr><td>Water Heating</td><td>6%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 42% | Lighting | 33% | Space Cooling | 12% | Auxiliary Motors | 7% | Water Heating | 6% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |                  |    |               |    |                     |    |
| Space Heating                                              | 42%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |                  |    |               |    |                     |    |
| Lighting                                                   | 33%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |                  |    |               |    |                     |    |
| Space Cooling                                              | 12%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |                  |    |               |    |                     |    |
| Auxiliary Motors                                           | 7%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |                  |    |               |    |                     |    |
| Water Heating                                              | 6%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |                  |    |               |    |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                              |         |            |               |     |          |     |               |     |                  |    |               |    |                     |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                              |         |            |               |     |               |     |          |     |                  |     |               |    |                     |    |
|------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|---------------|-----|----------|-----|------------------|-----|---------------|----|---------------------|----|
|                                                            | <p><b>Annual Bill Savings (\$)</b><br/>\$5,100</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$87,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$69,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |               |     |          |     |                  |     |               |    |                     |    |
| Upgrade Package 2: target 50% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+20% R-Value from BAU)</li><li>• <b>Lighting:</b><br/>LED Lighting conversion with occupancy sensors in washrooms</li><li>• <b>Heating System:</b><br/>No additional upgrade</li><li>• <b>Ventilation:</b><br/>VAV conversion<br/>Ventilation fans with VFDs</li><li>• <b>Pumps:</b><br/>Pumps equipped with VFD and eliminate three-way valves<br/>Use of DP control</li><li>• <b>Domestic Hot Water:</b><br/>ASHP hot water heaters (highest efficiency available)</li><li>• <b>Other:</b><br/>Maximize use of night time setbacks (occupancy sensors day / night linked to BAS)</li></ul> <p><u><b>Summary</b></u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>141,000 or 38% reduction to BAU</p> | 19                            | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>29%</td></tr><tr><td>Water Heating</td><td>28%</td></tr><tr><td>Lighting</td><td>24%</td></tr><tr><td>Auxiliary Motors</td><td>10%</td></tr><tr><td>Space Cooling</td><td>9%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 29% | Water Heating | 28% | Lighting | 24% | Auxiliary Motors | 10% | Space Cooling | 9% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |               |     |          |     |                  |     |               |    |                     |    |
| Space Heating                                              | 29%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |               |     |          |     |                  |     |               |    |                     |    |
| Water Heating                                              | 28%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |               |     |          |     |                  |     |               |    |                     |    |
| Lighting                                                   | 24%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |               |     |          |     |                  |     |               |    |                     |    |
| Auxiliary Motors                                           | 10%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |               |     |          |     |                  |     |               |    |                     |    |
| Space Cooling                                              | 9%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |               |     |          |     |                  |     |               |    |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                               |                                                                                                                                                                                                                                                                                                                                                               |         |            |               |     |               |     |          |     |                  |     |               |    |                     |    |

| Upgrade Scenarios                                          | ECM Upgrade Packages                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU)                                                                                                                                                                                                                                                                                               |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
|------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|------------|---------------|-----|---------------|-----|----------|-----|---------------|-----|------------------|-----|---------------------|----|
|                                                            | <p><b>Annual Bill Savings (\$)</b><br/>\$6,000</p> <p><b>Lifetime Bill Savings (\$)</b><br/>\$105,000</p> <p><b>Upgrade Package Cost (\$)</b><br/>\$117,000</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Upgrade Package 3: target 70% energy savings from baseline | <ul style="list-style-type: none"><li>• <b>Insulation:</b><br/>Additional roof-insulation (+100% R-Value from BAU) and triple glazed windows</li><li>• <b>Lighting:</b><br/>Incorporate daylight harvesting for dining area</li><li>• <b>Heating System:</b><br/>CCHP RTU with backup electric<br/>Install heat recovery<br/>Install DCV system for commercial kitchen<br/>Heat recovery from bathrooms</li><li>• <b>Ventilation:</b><br/>Maximize use of DCV with CO2 control</li><li>• <b>Pumps:</b><br/>Electronically Commutated Motor driven pumps with DP control (no sensor)</li><li>• <b>Domestic Hot Water:</b><br/>no additional upgrade</li><li>• <b>Other:</b><br/>No additional upgrade</li></ul> <p><u><b>Summary</b></u></p> <p><b>Annual Energy Savings (ekWh)</b><br/>165,000 or 44% reduction to BAU</p> | 22                            | <table><thead><tr><th>End-Use</th><th>Percentage</th></tr></thead><tbody><tr><td>Space Heating</td><td>29%</td></tr><tr><td>Water Heating</td><td>24%</td></tr><tr><td>Lighting</td><td>21%</td></tr><tr><td>Space Cooling</td><td>11%</td></tr><tr><td>Auxiliary Motors</td><td>15%</td></tr><tr><td>Auxiliary Equipment</td><td>0%</td></tr></tbody></table> | End-Use | Percentage | Space Heating | 29% | Water Heating | 24% | Lighting | 21% | Space Cooling | 11% | Auxiliary Motors | 15% | Auxiliary Equipment | 0% |
| End-Use                                                    | Percentage                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Space Heating                                              | 29%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Water Heating                                              | 24%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Lighting                                                   | 21%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Space Cooling                                              | 11%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Auxiliary Motors                                           | 15%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |
| Auxiliary Equipment                                        | 0%                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                               |                                                                                                                                                                                                                                                                                                                                                                |         |            |               |     |               |     |          |     |               |     |                  |     |                     |    |

| Upgrade Scenarios | ECM Upgrade Packages                                                                                                                                  | Simple Payback Period (Years) | Distribution of Energy Savings by End-Use (in comparison to BAU) |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|------------------------------------------------------------------|
|                   | <b>Annual Bill Savings (\$)</b><br>\$9,000<br><br><b>Lifetime Bill Savings (\$)</b><br>\$156,000<br><br><b>Upgrade Package Cost (\$)</b><br>\$203,000 |                               |                                                                  |

## Appendix C: Market Research Respondents Profiles



## Appendix D: Recommendations

| <i>Key Challenges:</i>                                                                                                                             | <i>Recommendations:</i>                                                                                                                                                                                                                                                                                                                                                                                |
|----------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| High cost of deep energy retrofit projects                                                                                                         | <b>R1.1</b> Substantially increase incentives to help alleviate the costs of deep energy retrofits for Nova Scotia building owners.                                                                                                                                                                                                                                                                    |
| Lack of economic incentives                                                                                                                        | <b>R1.2</b> Investigate tax strategies to drive the needed pace of deep energy retrofits, such as tax-based drivers could be an effective form of incentive along with program rebates.                                                                                                                                                                                                                |
| Lack of existing economical upgrade packages for exterior facade retrofits                                                                         | <b>R1.3</b> Provide support for exterior-facade retrofits (financial, marketing, education, training) and incentivize large-scale community retrofits to minimize per-project costs.                                                                                                                                                                                                                   |
| Availability of costing information                                                                                                                | <b>R1.4</b> Conduct additional research to quantify and refine updated ECM costs by building type and other enabling project costs when deep energy retrofit programs are being developed. This information will help refine estimates for the levels of incentives needed to increase program uptake and build a database of knowledge to be shared with contractors                                  |
| Detailed non-electrical energy consumption data for C&I buildings in Nova Scotia would be helpful in the design of a deep energy retrofit program. | <b>R1.5</b> Absent a requirement for mandatory reporting or building performance labeling conduct research to gather this information by archetype, for all non-electric energy consumption.                                                                                                                                                                                                           |
| Lack of financing options                                                                                                                          | <b>R1.6</b> Offer innovative financing options for deep energy retrofit costs at attractive interest rates that have repayment terms of more than 15 years. One option could be to share risk with project owners by creating a loan-loss recovery fund.                                                                                                                                               |
| Limited awareness and understanding of deep energy retrofits among consumers                                                                       | <b>R1.7</b> Invest in education and awareness programs and services that advance consumer knowledge of the economic benefits, energy benefits, emission reductions, and non-energy benefits (NEBs) associated with deep energy retrofits.                                                                                                                                                              |
| Limited incentives for saving non-electrical energy in commercial, industrial, and institutional buildings.                                        | <b>R1.8</b> Future programs for these sectors should provide incentives for deep energy retrofits that save non-electrical energy.                                                                                                                                                                                                                                                                     |
| Limited project management capacity, equipment, and trade experience                                                                               | <b>R2.1</b> Build capacity by investing in specialized project management and trades programs as well as the tools and equipment needed to complete these projects. Future programs and policies should create a stable, predictable investment climate that encourages private industry to grow capacity and increase the number of qualified professionals willing to deliver deep energy retrofits. |
| Building codes must continue to drive improvements in construction practices                                                                       | <b>R2.2</b> Adoption of tiered building codes and a future retrofit code as early as possible will heighten industry focus on developing the needed skills and building designs to implement deep energy retrofits.                                                                                                                                                                                    |

| Key Challenges:                                                                                     | Recommendations:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                     | All municipalities in Nova Scotia should use the same codes (i.e., NBC, NECB, and any future retrofit code) to ensure continuity in the market, but provincial government should set an energy performance tier floor and afford municipalities the discretion to require higher tiers within those codes if desired.                                                                                                                                                                                                                                                                                                                                                                   |
| Deep energy retrofits are rare, custom, one-off projects that are not appealing to many contractors | <b>R2.3</b> Reducing costs via incentives and economies of scale by incentivizing large-scale, community retrofits that would enable bulk pricing for that community and create a compelling business case for contractors.                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| Technical solutions are well-known, but new delivery models are needed to succeed                   | <p><b>R2.4</b> Exterior facade retrofits are extremely costly. If the cladding on a building is being replaced, the incremental cost of adding insulation and replacing windows is the lowest it will ever be. Programs which provide incentives to encourage comprehensive exterior facade retrofits whenever cladding or window replacement projects occur will leverage this advantage and maximize savings potential of otherwise costly upgrades.</p> <p>Combining such programs with investments in scalable, repeatable solutions such as the Energiesprong-inspired ReCover initiative could simplify and make facade retrofits more economical through economies of scale.</p> |
| Limited scope of cost-effectiveness testing for electricity ratepayer-funded programs               | <b>R3.1</b> Expand the scope of the current cost-effectiveness test used for DSM programs. Focus should be placed on added non-energy benefits, such as improved health and safety, reduced operating and maintenance costs, auxiliary costs, increased comfort, and reduced carrying cost to the utility system. Without considering these benefits, it may limit the ability to design and deliver innovative pilot programs that could reduce the barriers to deep energy retrofits.                                                                                                                                                                                                 |
| Deep energy retrofit projects incur enabling costs which are not considered in current programs     | <b>R3.2</b> Programs should not exclude the cost of enabling activities such as service upgrades, structural issues and/or the abatement of harmful substances.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| Limited education and awareness on how to undertake deep energy retrofits in homes and businesses   | <p><b>R4.1</b> Launch a program dedicated to deep energy retrofit education and awareness. The program should facilitate the following:</p> <ul style="list-style-type: none"> <li>• Guidance on ECM upgrade packages for different building and home archetypes.</li> <li>• Guidance on available incentives and financing options for ECM upgrade packages.</li> </ul>                                                                                                                                                                                                                                                                                                                |
| Limited understanding of the true measure life of various deep energy retrofits                     | <b>R4.2</b> Commission further analysis to determine the measure life of various deep energy retrofit scenarios for each representative building                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

| <i><b>Key Challenges:</b></i>                         | <i><b>Recommendations:</b></i>                                                                                                                                                                                                                                                                                                                                                                                   |
|-------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                       | archetype to better quantify financial return on investment and risk assessments to instill confidence in home and business owners.                                                                                                                                                                                                                                                                              |
| Procurement strategies must include energy efficiency | <b>R5.1</b> When procuring engineering design services, place increased focus on the need to include energy efficiency measures and take advantage of incentive programs.                                                                                                                                                                                                                                        |
| Operational staff training for ESCO projects.         | <b>R5.2</b> Buildings entering or undergoing an energy performance contract should place increased emphasis on staff training to sustain the project's energy savings and enhance the long-term cost savings of the project.                                                                                                                                                                                     |
| Planning for the long term                            | <b>R5.3</b> Building owners should consider the need for deep energy retrofits when planning major renovations and other activities intended to increase the building's Facility Condition Index. This should also include structural or other changes needed to make the building ready for solar PV and including upgrades such as window replacements and exterior wall insulation during cladding retrofits. |