GREEN MUNICIPAL FUND
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GHG Reduction Pathway Feasibility Study

Guidance Document

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A program of FCM

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Introduction

Program definition

FCM's Community Buildings Retrofit (CBR) and Sustainable Municipal Buildings initiatives provide funding to optimize the energy performance and reduce the greenhouse gas (GHG) emissions of existing municipal and community buildings. Both offers are administered through FCM's Green Municipal Fund (GMF).

Grants for GHG reduction pathway feasibility studies help municipalities to integrate reductions in emissions and energy use into longer-term plans for managing municipal buildings. These studies enable municipalities to identify a sequence of GHG reduction measures—the "GHG reduction pathway"— to reduce GHG emissions from municipal buildings by:

- Reducing GHG emissions by at least 50% within 10 years, AND
- A 20-year plan that meets either of the following requirements:
  - Thermal energy demand intensity (TEDI) for the appropriate climate zone for the project AND meeting the energy use intensity (EUI) for the appropriate building type as per the CaGBC Zero Carbon Building Standard v3, OR
  - 25% better than NECB 2020 for building areas with unique heating/cooling demand AND the TEDI and EUI targets for the remainder of the building

For a full list of eligibility requirements for GHG reduction pathway feasibility studies, see GMF's application guide.

Completing a GHG reduction pathway feasibility study (or an equivalent study) is a **prerequisite** for applying for capital project funding. Equivalent studies must meet the minimum energy performance requirements laid out in this document (although they do not need to have been funded by GMF). If you have conducted a feasibility study and are uncertain if it meets the minimum requirements, please contact us for guidance.

For additional information, please see our webpage for the Community Buildings Retrofit Offer. Find information on Sustainable Municipal Buildings here.

About this document

This document provides guidance on the preparation of a GHG reduction pathway feasibility study for GMF's Sustainable Municipal Buildings and Community Buildings Retrofit initiatives. The guide is intended to be read by energy modelling professionals who will communicate necessary requirements to their clients.

The document is organized in two important ways:

Purpose, process, details: Part 1 summarizes the overall purpose of the GHG reduction pathway feasibility study. Part 2 discusses process and delivery details and quality of work. Part 3 includes a glossary of important terms and technical references.

Requirements versus recommendations: In Parts 1 and 2, each section includes GMF's requirements for the study as well as recommendations and/or best practices. Typically, there are fewer requirements than recommendations/best practices, and the requirements are often qualitative in nature. The recommendations or best practices go into more detail on industry norms for similar work and offer useful starting points for analysis.

Part 1: Study purpose and outcomes

The purpose of the GHG reduction pathway feasibility study ("study") is to support municipal and not-for-profit decision-makers in making early, informed decisions on capital planning for their assets that align with their GHG-reduction goals and other organizational goals (e.g., financial, sustainability, operational, etc.). The study should enable these project proponents[1] to explore GHG reduction measures and capital investment timing to meet their goals.

Studies should consider the following:

- The status of the site that is to be developed or redeveloped (e.g., the selected site may involve infill redevelopment, brownfield remediation, etc.)
- The uniqueness of the site and any organizational and jurisdictional constraints and/or opportunities the project proponent faces
- A wide variety of GHG reduction measures that might be suitable
- The systemic nature of deep carbon retrofit projects (i.e., looking beyond isolated retrofits of single systems and considering interactions and interrelations of building systems as a whole)
- The projected lifecycle cost implications, considering upfront capital requirements, facility operations and equipment maintenance
- How critical the facility is to the project proponent's operations (i.e., operational constraints for implementation of each measure)

Given the complexities of deep retrofits—especially their implementation in existing, operating facilities with fixed capital and maintenance budgets—the study should also look at capital planning.

Required outcome of the study

The study must articulate at least one GHG reduction pathway selected through a comparison of at least two GHG reduction pathway scenarios.

A GHG reduction pathway describes a set of GHG reduction measures ("package") to reduce GHG emissions by at least 50% within 10 years and achieve the specified CaGBC Zero Carbon Building Standard energy targets within 20 years (compared to baseline performance).[2]

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[1] "Project proponent" refers to the entity that is undertaking the study (e.g., municipal or not-for-profit facility owners).

[2] The Zero Carbon Building Standard.

The study must also identify opportunities for potable water consumption reduction. All plumbing fixtures in the building must meet the flow rates for fixtures and fittings outlined by the USGBC LEED v4 BD+C New Construction Indoor Water Use Reduction credit.[3]

A note on climate zones

To select your EUI/TEDI targets, you will need to determine your climate zone. The National Building Code of Canada defines six climate zones[4] based on the number of heating degree days experienced in a calendar year (see Table 1).

Table 1: Climate zones in Canada

Climate zone	Heating degree-days of building location (Celsius degree-days)
4	<3,000
5	3,000–3,999
6	4,000–4,999
7A	5,000–5,999
7B	6,000–6,999
8	7,000+

GHG reduction pathway scenarios

The project proponent may choose the outcome of the study to be *two or more* GHG reduction pathways articulated for key decision-makers. Alternatively, the project proponent may choose to incorporate the selection of *one* GHG reduction pathway to be studied. Regardless of whether the study presents one or more GHG reduction pathways, the study *must* include the development of at least two GHG reduction pathway scenarios as indicated below.

The study **must** include the following GHG reduction pathway scenario:

- Phasing out all fossil fuel energy sources except those used for back-up energy sources.
- A "minimum performance" scenario with the following components:
    - A 10-year plan that achieves a minimum 50% reduction in on-site GHG emissions versus current performance.
- A 20-year plan that meets either of the following requirements:
    - Thermal energy demand intensity (TEDI) for the appropriate climate zone for the project AND meeting the energy use intensity (EUI) for the appropriate building type as per the CaGBC Zero Carbon Building Standard v3, OR

[3] United States Green Building Council LEED v4 Indoor Water Use Reduction Credit: Indoor water use reduction | U.S. Green Building Council (usgbc.org).

[4] National Energy Code for buildings. 2020. Produced by the National Research Council of Canada. National Energy Code of Canada for Buildings 2020 - National Research Council Canada.

- 25% better than NECB 2020 for building areas with unique heating/cooling demand AND the TEDI and EUI targets for the remainder of the building.

Employing the flexible approach: NECB 2020 versus TEDI/EUI

The CaGBC Zero Carbon Building Standard offers a flexible approach for non-office buildings to meet their energy targets by using a 25% improvement over the federal government's NECB 2020 standard.

For buildings or building areas that have unique heating and ventilation loads, the reference building model should meet the prescriptive requirements of NECB 2020 in place of the TEDI (thermal energy demand intensity) target. This includes the heating of a swimming pool, refrigeration of ice rinks or materials, garage/service bay areas, laboratories, or any other activity not meant for general heating and cooling of building occupants.

The modelling output will provide an area weighted TEDI value, including areas of unique heating and ventilation. See the ZCB performance energy modelling guide v3[6] for guidance on this calculation.

The study must also include at least one of the following GHG reduction pathway scenarios:

- A "short-term deep retrofit" scenario: This includes the same GHG reduction measures as the "minimum performance" scenario but with all measures being implemented in the first five years (possibly through inclusion of additional funding and financing options).

OR

- An "aggressive decarbonization" scenario: This delivers a similar lifecycle cost result over the study period as the "minimum performance" scenario while maximizing cumulative GHG reductions over the same period.[1]

Although it is not required, the project proponent may also consider including a "like-for-similar" scenario for comparison purposes.[7] This is a business-as-usual (BAU) scenario based on planned or required maintenance and equipment replacement (determined from a site assessment) in combination with traditional energy audit recommendations from previous studies of the facility.

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[6] See the CaGBC ZCB Energy Modelling Guidelines v3 reference document.
[1] Also known as accumulated emissions, this is the sum of GHG emissions over a particular time period.
[7] Because a "like-for-similar" or "business-as-usual" scenario is unlikely to meet the required GHG reduction targets, it does not count towards the minimum two GHG reduction pathway scenarios required for inclusion in the study.

Other considerations

The following additional items may be considered as part of the study.

Alignment with funding opportunities

It is recommended that the final study document identify prospective national and regional incentives and funding programs for capital projects, including GMF's CBR and Sustainable Municipal Buildings retrofit capital projects. Funding opportunities can inform capital planning for the GHG reduction pathway, so any requirements or prerequisites for these incentives and programs that could be integrated into the study's scope of work are worth considering.

Future work preparation

The study could include additional activities that would accelerate the next phase of work. Examples include the preparation of a measurement and verification (M&V) plan for the recommended design, an electrical capacity assessment, individual equipment and site testing (e.g., thermal conductivity testing), and/or more detailed schematic design work.

Broader sustainability and resilience analysis

It is understood that GHG reduction pathway scenarios will have other qualitative benefits (e.g., occupant comfort) or non-energy/GHG benefits (e.g., water savings) that may be important to the project proponent and other key stakeholders. Study teams are encouraged to integrate these considerations into a broader decision-making process.

The project proponent should also consider aligning the study's outcomes with climate resilience planning (e.g., by applying a Climate lens[8]). This could include examining future weather and climate impacts (e.g., rising temperatures or flood risks) and assigning qualitative or quantitative values to measures that improve resilience.

Education and collaboration

Given the highly integrated nature of decarbonization planning, many stakeholders are often involved in the study process. This creates a great opportunity to educate stakeholders about the process of decarbonization in general and the unique challenges and opportunities that buildings present. Likewise, there may be the opportunities to collaborate or partner with other organizations (equipment manufacturers, non-government organizations, other municipalities, etc.), particularly where innovative technologies or processes being explored are outside normal operating expectations.

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[8] The Climate Lens is an assessment framework developed by Canada's federal government intended to assess infrastructure projects with a focus on GHG mitigation and climate change resilience. For more information, please review the Government of Canada's Investing in Canada Infrastructure Program Climate Lens – General Guidance.

Embodied carbon assessment

Embodied carbon associated from building construction currently accounts for approximately 10% of Canada's carbon emissions. With the building sector moving towards zero-carbon operations, and with projected growth in building floor areas, embodied carbon represents an increasing proportion of overall emissions.

Given the growing importance of embodied carbon, it is recommended that project proponents recommend conducting a whole-building, cradle-to-grave lifecycle carbon assessment (LCCA) as part of the study. The goals of this assessment are to encourage project teams to consider materiality and reduce potential embodied carbon throughout the design process. Enhanced reporting on embodied carbon intensities also allows for a more holistic approach to decarbonization over the building's life and will facilitate benchmarking of future construction projects.

Potable water conservation

Building retrofits can offer an opportunity to simultaneously complete improvements on systems and fixtures that consume potable water. Replacing existing plumbing fixtures with low-flow models and introducing high-efficiency appliances and other water-saving strategies can reduce operating water requirements. This will reduce utility costs while helping to protect natural water bodies. Reduced demand for water can also yield energy savings from reduced requirements for domestic hot water heating.

Future change considerations

Given the long timeframe considered in the study, the project proponent should considering future events that would trigger a need to revisit results and calculations in the future. Potential triggers that may impact the study results and motivate an update in the future include:

- New technologies or significant improvements in existing technologies
- Significant changes to emission factors (especially for electricity grids) and the cost of carbon
- New/additional incentives or funding opportunities
- Changes in the cost of capital to procure materials for the retrofit
- Facility use changes or major renovations

Therefore, it is recommended that the project proponent ensure the required analysis and study components be provided in a form that can be updated relatively easily when required. For example, service providers can provide electronic versions of calibrated energy models and use energy analysis software that is not expected to be obsolete in the short or medium term.

Part 2: Study process and requirements

Figure 1 shows the steps involved in completing the study. Part 2 provides expected deliverables and other requirements for each step, along with best practice recommendations. References to other standards or guidelines have been highlighted where appropriate and links to those references are included in Part 3.

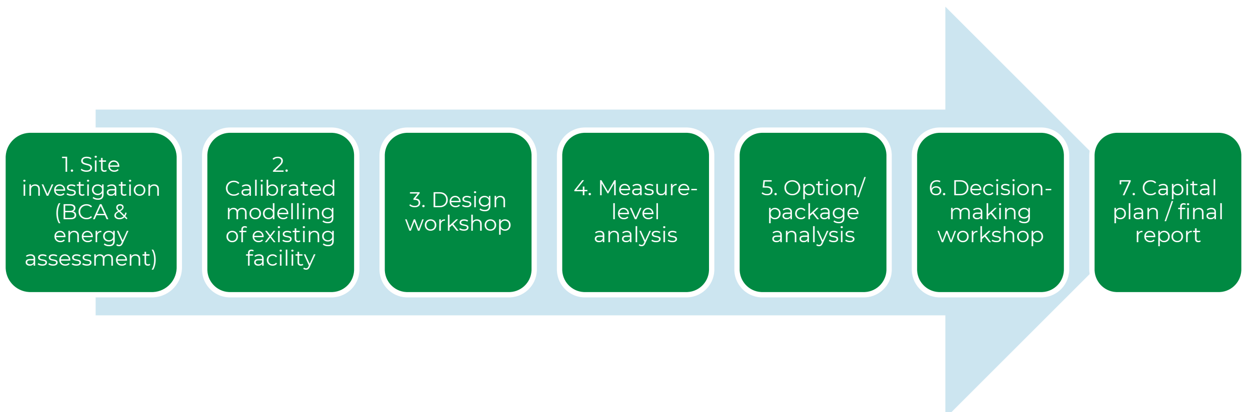

Figure 1: Study workflow

Step 1: Site investigation

To begin the study, the "study team"[9] conducts a review of all available documentation (e.g., previous studies completed, existing drawings, etc.), followed by a site walkthrough and operator interviews to gain an understanding of the existing facility and its operations.

Additional site investigation work may also be required to finalize measures and (occasionally) to collect metering data that is needed to better understand and calibrate the facility's energy model.

Operator interview is an important part of the site investigation. Operators have the greatest insight into the current state of repair and operating conditions of the energy-using equipment in the facility, and they often have significant insight into how to improve these systems and address deficiencies.

Minimum requirements

The study team should use the site investigation to gather data consistent with, at a minimum, the requirements defined for an ASHRAE Level 2 energy and water audit—but with enough detail to support a robust data-driven financial analysis and accurate estimates of energy consumption, costs and savings, as well as GHG

[9] "Study team" refers to the service providers engaged by the project proponent to deliver the pathway study (e.g., engineers, architects, energy modellers, building scientists, cost consultants, etc.).

emissions and emission reductions. The study team does not have to meet all of the ASHRAE requirements and the ASHRAE 211 standard should be used as a guideline only.[2]

The energy assessment portion of the feasibility study must be completed by a qualified professional, i.e., someone with a P.Eng, CEM or CEA designation.

The site investigation is required to have, at minimum, the following components:

- A review of available documents, such as drawings, O&M records and manuals, equipment specifications/cutsheets, previous relevant audits/reports/condition assessments, etc.
- Analysis of utility bills or past energy and water usage going back a minimum of 12 months (but preferably 36 months), plus performance benchmarking
- A facility site survey reviewing key building systems, which should fill in any knowledge gaps identified during the documentation review and include interviews with operations and/or property management staff.
- An interview (or other form of engagement) with operational staff, capturing operational implications and opening a meaningful dialogue with these critical team members.

Best practices/recommendations

A robust site investigation will help the study team identify site-specific opportunities, constraints and barriers in relation to potential measures to be considered in the study.

If a building condition assessment (BCA) has not been conducted in the past three years, if significant changes have occurred since the last BCA, or if the study team feels that a recent BCA does not provide adequate information to inform a 20-year capital plan for the current facility's energy systems, we recommend that the study team conduct a BCA or property condition assessment (PCA) in accordance with ASTM E2018-15, *Standard Guide for Property Condition Assessments: Baseline Property Condition Assessment Process*. [3]

For the energy systems investigation, it is recommended that the study team generally follow ASHRAE Level 3. Since the project is considered capital-intensive, and both detailed energy modelling and robust data-driven financial analysis are expected, the level of site investigation at a systems level will fall somewhere between a Level 2 and Level 3 audit, depending on the depth of system change and the importance of a given measure to the overall decarbonization plan.

Although a formal Level 3 audit would include a higher degree of data collection than is required for this study, it would improve the overall results because higher-

[2] Standards 180 and 211. ASHRAE. N.d https://www.ashrae.org/technical-resources/bookstore/standards-180-and-211
[3] "Standard Guide for Property Condition Assessments: Baseline Property Condition Assessment Process" 2024. ASTM. Retrieved from: https://www.astm.org/e2018-15.html

quality data would be collected. But note that a Level 3 audit may add to potential study costs.

We generally recommend that studies rely on existing documentation and visual reviews. However, destructive investigation of enclosures, and occasionally HVAC systems, may be valuable where there are gaps in information that could significantly impact the results of the study (e.g., uncertainty surrounding the existing construction and condition of the enclosure or structure). Whether destructive investigation is warranted should be weighed carefully—it may help to identify possible measures, performance impacts and associated costs.

Step 2: Calibrated modelling of the existing facility

Following the completion of the site investigation, a calibrated energy model of the existing building should be prepared. This energy model will be used to determine measure-level and facility-level energy and GHG results, and will inform analyses of lifecycle costs (e.g., energy cost savings).

Acceptable software for calibrated energy modelling includes IES VE, eQuest/CanQuest and EnergyPlus, among others.

Minimum requirements

To ensure best results for what are likely to be more systemic (i.e., complex and interrelated) facility-level GHG reduction measure packages, the model should be calibrated in accordance with the requirements established in the current revision of ASHRAE Guideline 14, and a calibration report should be provided. The energy model calibration portion of the study must be completed by a qualified professional, i.e., either P.Eng or BEMP designation.

All facility energy use should be included in the model, including process loads, even when the building studied have significant process loads or include system types not typically handled natively by the hourly modelling tool chosen by the team. Where a process load (or any system) has not been modelled natively in the hourly analysis software, additional documentation and calculations should be provided and the results of external calculations should be combined with natively modelled results. Include any other documentation of overall results.

Accounting for significant baseline variation

Sometimes facilities are anticipated to undergo changes in independent operating parameters, such as peak occupancy, schedule of use, temperature set-points or user-driven equipment usage. In cases where such variation is expected to be significant, the calibrated model should be adjusted to account for these factors before measure-level and facility-level analysis begins.

Where there is substantial variation (e.g., when the facility has an entirely new functional program), a case can be made to ignore the need for a calibrated model of the existing facility and to use the results of a model that better reflects the new facility usage as the baseline. In such a case, however, more work may be required later to understand how to properly capture the GHG savings of implemented measures. These implications should be carefully considered in the study.

Best practices/recommendations

Total envelope performance: A best practice for modelling building enclosures—consistent with the most recent version of the National Energy Code for Buildings (NECB)—includes the holistic analysis of thermal bridging, including point and linear heat loss. This analysis can provide insight into potential existing enclosure issues, especially at system intersections (e.g., wall and window, parapet, etc.) and can more accurately reflect the benefit of best practice approaches for enclosure improvements. This work will typically require more detailed site investigation as well as the input of a facade expert. BC Hydro and the City of Toronto have published guidance and spreadsheet tools to support the work and quantify whole facility and system-specific heat loss. Links to these and other resources are included in Part 3.

Electricity demand impact modelling: It is recommended that, in cases where fuel-switching to electricity (e.g., air-source heat pumps) is expected to be a critical component of the final decarbonization solution, enough detail be included in the analysis to reflect the impact on the site's electricity demand. Such demand-modelling requires an accurate understanding of : (i) building schedules of use and (ii) the combined part-load and temperature-sensitive performance curves for major equipment. This additional information can take more time to collect during site investigation and measure analysis, but can yield important (critical) insights where there are project feasibility concerns related to electrical service.

Embodied impact analysis: Embodied emissions are those generated at points in the building's lifecycle other than during operation, such as from the material supply chain (i.e., raw material extraction, materials processing, transportation or manufacturing), from construction, and at a building's end of life (i.e., demolition and disposal). Careful selection of materials/products for potential upgrades may help to significantly reduce lifecycle emissions, or even offer carbon-storing opportunities (e.g., bio-based enclosure materials have a carbon storage benefit). The Canada Green Building Council's *Zero Carbon Building Performance Standard* has requirements for embodied carbon, including an embodied carbon reporting template.

Future weather: Accounting for changes in weather caused by climate change is considered a best practice for long-term studies. Typically, study teams can rely on local conservation authorities and other provincial government sources of climate projections for estimates of weather changes over 25- and 50-year time horizons.[4] Note that, while future weather impacts should be considered, the typical best practice is to treat the impacts to equipment size pessimistic manner (e.g., ignoring potential benefits to heating equipment sizing, but including increased cooling equipment requirements).

[4] For more information on future weather trends, see Climate Data, Climate Atlas of Canada.

Step 3: Design workshop

The purpose of holding a design workshop is to confirm the overall direction of the study, identify key study team members, and identify and screen measures for further analysis, both from the site assessment and calibrated energy modelling.

Discussions should address site-specific opportunities, constraints and barriers to the implementation of potential measures, and alignment of measures with the goals of the facility and any broader goals that the project proponent might have.

Minimum requirements

Conduct and document a workshop with the study team and key project stakeholders.

Best practices/recommendations

Important steps in the design workshop include:

- Confirmation of the project proponent’s goals for the building, including GHG reduction, TEDI and TEUI targets, sustainability outcomes, operational goals, financial assessments, etc., and specific goals for the study (e.g., how the study will be used to inform council decision-making)
- Discussion of available funding, financing and capital-planning constraints.
- Discussion of scheduling, key milestones, potential conflicts/concerns, etc.
- Review of the study process, including roles and responsibilities for the study team and project proponent representatives (i.e., key stakeholders and decision-makers, such as asset managers or capital planners, user groups, operations and maintenance staff, and energy management staff).
- Basic facility decarbonization education, including an explanation of how GHG emissions, TEUI and TEDI are calculated and why results are expected to vary over time as a function of various regulatory factors and grid emission factors
- Review of the building maintenance and equipment replacement requirements uncovered during the site investigation and a discussion of the existing capital plan for the building and/or planned maintenance, repairs, replacements and upgrades
- Brainstorming, describing and qualitatively screening of GHG and energy reduction measures for further analysis
- Identification of non-energy or qualitative benefits (e.g., improved thermal comfort improvements, future-proofing, showcase/educational opportunities, etc.) that should support decision making.
- Promotion of preferred measures and ruling out undesired measures from consideration based on feasibility and compatibility with the site and proponent needs

Although it can be useful for some measure-level analysis to have been completed prior to the first study workshop, it is not required.

Step 4: Measure-level analysis

The study team will need to determine the GHG and energy reduction potential of each measure identified in the design workshop (or elsewhere) along with its capital cost. This should be done using appropriate energy analysis techniques and quantity surveying procedures. For more on this, refer to Part 3, which provides a list of potential information sources.

Other (qualitative/non-energy) benefits identified in the workshop should also be documented for each measure and used to support decision-making.

Minimum requirements

At a minimum, the following measures must be analyzed:

- Full facility fuel-switching from fossil fuels (including process loads)
- On-site renewable electricity generation (e.g., geothermal, photovoltaic panels[10])
- For any facility components requiring replacement during the study period (identified during the site investigation or in the building condition assessment), at least one improved alternate must be studied, where feasible (e.g., if windows will need to be replaced within the study period, at least one window improvement measure must be explored)

The description and documentation of each measure explored should discuss the following:

- Scope/high-level design of the measure, including major equipment required and sufficient detail to understand systemic complexity (e.g., schematics or equipment selections)
- Identification of measures or systems that are interrelated or dependent on each other for successful operation
- Assumptions used to analyze the measure
- Annual GHG reduction potential of the measure
- TEDI, EUI and/or savings over baseline

[10] For renewable energy systems where excess energy is generated relative to energy used (on an hourly basis) and exported to the grid, the avoided emissions may be calculated using a marginal electricity grid emission factor instead of an average grid emission factor. Refer to the Canada Green Building Council's ZCB-Design v2 Workbook for current regional marginal emission.
Additional information on marginal emission factors can be found in The Atmospheric Fund's *A Clearer View on Ontario's Emissions*.

- Capital cost to implement the measure in year zero of the study (adjusted for inflation)[11,12]
- Implementation strategy (including limitations, if any) for the measure
- Potential commissioning, measurement and verification, plus any other relevant implementation considerations

Strategies for potable water conservation should also be identified and quantified.

The accuracy (and associated design detail prepared) of the capital costing in the measure-level analysis should generally be in the range of +/- 20–25%, resulting in a CIQS Class C level capital estimate.

Analysis techniques for measures often require additional tools beyond what is available in hourly analysis software programs. For example, closed-loop geo-exchange systems are not easily analyzed in the most-used modelling tools (e.g., eQUEST, IES, Energy Plus), often necessitating analysis in other tools (e.g., GLD or TRNSYS). Where separate software or analysis tools are determined to be required to achieve the level of accuracy desired from the study, they should be used and appropriately documented.

Best practices/recommendations

Studied measures

Table 2 lists the measures that are likely to be explored as part of a robust decarbonization analysis. Note that **this is not an exhaustive list,** and the study team may identify measures beyond those listed in the table.

Table 2: List of potential measures to be studied

Building system	Potential measures to be explored
User-driven loads (e.g., lighting)	• LED technology: interior and exterior • Daylighting and dimming control • Task lighting and/or addressable lighting for occupant-customized lighting needs • Energy Star® appliances and computer system equipment • Enhanced server room design (e.g., hot aisle/cold aisle)

11 For measures that are expected to require a construction period greater than one year, the study team may use an average yearly cost (i.e., the total cost divided by the number of years in the construction period) as opposed to an exact cost for each year of the construction period, for simplicity of determining the year zero cost.

12 The accuracy (and associated design detail prepared) of the capital costing in the measure-level analysis should generally be in the range of +/- 20–25%, resulting in a CIQS Class C level capital estimate.

Building system	Potential measures to be explored
Envelope/enclosure	• Recladding or overcladding walls (increasing effective insulation level) • Roof insulation upgrades, including options modifying roof/wall intersections (e.g., parapets) so additional insulation can be installed • High-performance glazing and framing systems for doors, windows and skylights, particularly windows with low-emissivity coatings, triple-glazing, noble gas fills, and framing systems with enhanced thermal breaks or that use non-metallic materials (e.g., fibreglass) • Air sealing at both the interior and exterior of facades • Below-grade foundation wall insulation upgrades (especially where adjacent landscape will be disturbed anyway)
HVAC (delivery)	• Revised building zoning: space planning, fundamental changes to the HVAC strategy • Natural ventilation, operable windows, atrium/stack effect • Labyrinth or earth tube to pre-condition ventilation make-up air • Demand control ventilation (e.g., CO_2 sensors) • Underfloor/displacement delivery of ventilation • Dedicated outdoor air systems with variable-air volume • Energy recovery using multiple technologies, including heat/enthalpy wheels, reverse-flow systems, energy recovery chillers, waste heat from electrical vault, heat pump energy redistribution, etc. • Near-temperature and low-power heating/cooling delivery approaches (e.g., chilled beams, VRF, "oversized" ECM fan-coils) • Solar thermal pre-heat of ventilation systems (e.g., transpired solar collectors) and thermal system (e.g., solar hot water)
HVAC (plant)	• Advanced air-source heat pumps (e.g., those suitable for cold climate) • Geo-exchange heat pumps (e.g., closed- and open-loop, where applicable) • Electric supplementary boilers
On-site renewable energy systems	• Solar power (i.e., photovoltaic panels) in roof-mounted, parking-awning and building-integrated arrangements • Hydrogen/fuel cell (in traditional or Combined heat-and-power configurations) • Battery energy storage systems (BESS) to take advantage of variation in grid emissions • Wind power and micro-hydro, where appropriate

Building system	Potential measures to be explored
Process loads[13]	• Ice plant improvements and heat recovery (for rinks) • Customized process heat recovery (for pools) • Drain-water heat recovery (for large, collected domestic hot water loads) • Variable-speed fans and ecology unit heat recovery units (for kitchens)
Carbon storage/ sequestration[5]	• Bio-based/carbon-storing insulation materials (e.g., cellulose) • FSC-certified wood structural materials and finishes • Large-scale carbon sequestration equipment (e.g., POND technologies)

A strong study also considers a range of alternatives *within* each measure (e.g., more than just one approach for low-power HVAC delivery) and increasing levels of performance for the same general measure (e.g., a dedicated outdoor air system with two or three approaches to heat/energy recovery, yielding increasing effectiveness).

Measure analysis

The best practice for measure analysis is to employ a broadly experienced study team that can inform the proper financial and energy analysis of the identified measure. The team should include experts who understand design constraints and opportunities as well as building science concerns, and can offer appropriate assumptions for modelling and costing work sufficient to achieve the level of accuracy expected for the study.

Energy/GHG metrics studied at the measure level should include:

- Total and percentage emissions reduction compared to baseline year[6] (tCO_2e or %)
- Greenhouse gas intensity (GHGI) (tCO_2e/m^2)
- Energy use intensity (EUI) (kWh/m^2)
- Thermal energy demand intensity (TEDI) (kWh/m^2)

Water conservation metrics should include the following:

- Baseline water consumption of fixtures and fittings (litres per flush or litres per minute)
- Total and percentage water consumption reduction compared to baseline year (m^3 or %)

[13] See links for modelling guidance resources for ice plant and pool process loads.
[5] This is not required for the energy model.
[6]" Baseline year" is defined as a year with the most recent 12 months of consecutive and reliable data that represents a typical year of facility operations without any significant changes. The first month of the baseline year must be no more than five years prior to the project proponent's submission date of their full application.

Financial metrics at this stage to be used as part of measure analysis should include:

- Capital cost (both absolute and incremental capital cost)
- Operating savings (energy/carbon savings, maintenance savings)
- Simple payback and net present value (NPV), where relevant to the project proponent
- Alternative funding sources for specific measures

Computer-aided optimization and results visualization techniques (e.g., a parallel coordinates plot) are often used to explore and summarize the results of many or all combinations of measures as an interim step toward making full facility-level recommendations. These techniques can be very useful to help study teams identify key parameters and measures required to achieve energy- and GHG-reduction targets. Such techniques, where employed, should be explained clearly to the project proponent, and there should be discussion of their value to the overall process.

Step 5: GHG reduction pathway scenarios and package analysis

In this phase, the study team will assemble measures into packages for each GHG reduction pathway scenario and then conduct a technical and financial analysis to determine the effectiveness of each package. The team's analysis should include an incremental capital and lifecycle cost comparison for alternative packages to the "minimum performance" GHG reduction pathway scenario (see Part 1).

Minimum requirements

At a minimum, the scenario and package analysis documentation should include:

- The full list of the measures that make up the packages(s) and the reasoning for including them in the package (include descriptions of measures or systems that are interrelated or dependent on each other for successful operation)
- A comparison and discussion of critical GHG reduction and financial metrics (see metrics below)
- A summary of the non-energy or qualitative benefits of the package, building on the measure-level analysis
- Results from an analysis of the sensitivity of the scenarios(s) explored to the following factors:
    - **Price of carbon**: The study team should clearly state and justify future carbon pricing assumptions used in the sensitivity analysis. The current information on the projected price of carbon is different in each province. See Part 3, Carbon Pricing to 2030 for useful references.
    - **Projected grid emission factors**: The sensitivity analysis to grid emission factors should look at the target years and assess the impact of grid emissions on achieving the targets.

Given the long timeframe of the study, changes in the provincial electricity grids may have a material impact on prospective emission reductions. It is expected that the study team use projected grid emission factors (at least at a provincial/territory/regional level). The study team should clearly document and provide assumptions for the basis of the projected grid emission factors. See Part 3 for potential sources of information on projected grid emission factors.

In analyzing the performance of different packages that achieve the GHG and energy thresholds outlined above, the study team is required to document the following energy and GHG metrics using an energy model:

- Total and percentage reduction in operational GHG emissions[7] versus baseline year[8] (including from on-site energy generation)

[7] Emission factors should be appropriately referenced (including any assumptions relating to grid emission projections).
[8] This should be the same baseline year used in the measure-level analysis.

- Greenhouse gas intensity (GHGI) (tCO_2e/m^2)
- Thermal energy demand intensity (TEDI) (kWh/m^2)
- Energy use intensity (EUI) (kWh/m^2)

The study team is required to document the following financial metrics for each package:

- Absolute and incremental capital cost comparisons of the "minimum performance" package with any other recommended packages over a straight 20-year capital planning horizon (with all dollar amounts adjusted back to the baseline year)
- Operating costs (including maintenance, energy and carbon costs)
- Incremental lifecycle cost (ILCC) versus a "minimum performance" package (in dollars) over at least 20 years
- Cost per tonne of carbon abated over the study period ($\$ILCC/tCO_2e$)

Lifecycle cost analysis process

The purpose of a lifecycle cost analysis (LCCA) is to determine the cost-effectiveness of the packages presented in the study. As such, the following should be completed when conducting an LCCA for each option:

- The LCCA should start at the anticipated year of completion of the first major project and extend at least 20 years beyond that point
- Lifecycle costing should consider:
    - capital costs—including hard and soft costs (i.e., design, engineering and construction costs)
    - operation and maintenance costs (including anticipated repairs and replacement of equipment)
    - anticipated cost of energy and carbon
    - available external funding (incentives, grants, etc.)[9]
    - residual value at the last year of the study period using (at least) a straight-line depreciation
    - time value-of-money assumptions (e.g., interest, inflation, discount rate), which the project proponent should have reviewed and approved for the purpose of the study
- The sources and calculation rationale for energy conversions, utility rates, LCCA rates and carbon pricing assumptions should be clearly documented and aligned with industry best practices (see Part 3 for further guidance)

Best practices/recommendations

The following is a list of additional energy/GHG metrics that can be used to inform decision-making:

- On-site annual zero carbon balance

[9] Confirmed external funding should be separately listed if the project proponent deems it necessary. If desired, prospective funding can be included within a sensitivity analysis.

- Change in peak electricity demand for the facility (kW-peak, summer and winter)
- Embodied carbon impacts of deep retrofit activities (tCO_2e)
- Upstream GHG impacts of fossil fuel usage (tCO_2e)

Additionally, the project proponent may benefit from sensitivity analyses of package performance in relation to other factors such as:

- Capital cost
- Cost of energy
- Construction/utility escalation rates
- Variation in time value of money assumptions (e.g., inflation, discount rate)
- 20-year global warming potential (GWP) emission factors

Multi-parameter financial sensitivity methods can be a suitable means of testing the sensitivity of measure packages to variations in financial parameters. The study team should fully explain the conclusions and benefits of such an analysis to the project proponent.

Though unlikely, if there are no recommendable options that achieve a 50% reduction over the baseline within the study period of 10 years, an additional narrative can be included in the study report explaining why and outlining the key factors preventing achievement of the minimum target.

Step 6: Decision-making workshop

The purpose of the decision-making workshop is to review the measure- and facility-level analysis results and reach a consensus on the GHG reduction pathways to be included in the final report.

Once the GHG reduction pathway, or pathways, is/are agreed upon, the participants in the workshop can discuss how to roll out the package(s) in the short, medium and long term to balance capital considerations with goals for GHG reduction and long-term financial performance.

Minimum requirements

Conduct and document a decision-making workshop with the study team and key project stakeholders.

Best practices/recommendations

Important steps in the workshop include:

- Present GHG and financial analyses for each scenario package along with preliminary options and analyses for bundling measures within each package
- Review non-energy and qualitative benefits of each scenario
- Ensure agreement with the project proponent and study team agree on key assumptions and decision-making metrics
- Reach consensus on the analysis and agree on the GHG reduction pathways to be fully articulated in the final report
- Review potential roll-out scenarios for the package(s) associated with the selected GHG reduction pathway scenarios and discuss feasibility issues and financial constraints that impact timelines for GHG reduction measure implementation

Step 7: Capital plan or final report

The output of this study should be in the form of a final report. The report should outline the GHG reduction pathway scenarios that allow the facility to achieve the necessary reduction targets within the required timeframe. It should also discuss how alternative measures and facility-level options were explored and discussed with the broader stakeholders as part of the process that led to the identification of the preferred pathway(s).

Minimum requirements

At a minimum, the study team should prepare a decarbonized capital plan and comparison matrix made up of a table of cash flows and capital investments and aligned with the study period (e.g., 20-year, 40-year, etc.) and granularity (e.g., annual, five-year, 10-year) desired by the project proponent for each GHG reduction pathway.

As well, the study team should prepare a final summary of each of the study steps above, including design, energy modelling, capital planning and costing results. The report should be organized in a logical manner that addresses each of the requirements listed within the anticipated workflow presented in this document. The final report should include all assumptions and limitations associated with each stage of work and contain an appendix with the following information:

- Site assessment reports (building condition assessment and energy systems investigation)
- Model calibration summary report
- Measure descriptions, including any basis of design information (quantity take-offs, equipment selection information, system diagrams, etc.)
- Energy, GHG and cost analyses at the measure and/or facility scale not suitable for inclusion in the main report body
- Capital cost estimate (cost consultant report)
- Other reference material

Best practices/recommendations

Part 3 of this guide includes an example table of contents (outline) for a final summary report.

The project proponent should consider using the report as a deliverable for other potential funding streams (i.e. the final report should align with other incentive, grant or other funding programs, such that the project proponent can directly use the study to meet the requirements of those programs).

A final presentation of the results to the broader stakeholders is recommended to brings closure to the process while transitioning to the next phase of work (e.g., funding/financing applications, schematic design, etc.).

Part 3: Definitions and references

Key terms and definitions

Term	Definition	Link/reference
Cumulative GHG reductions	Also known as accumulated emissions, this is the sum of GHG emissions over a particular time period. Cumulative emissions are an important concept, as two reduction scenarios with the same reduction (e.g. an 80% reduction within 20 years) can have different cumulative emissions depending on the implementation time frame for specific measures.	
ASHRAE 211	The *Standard for Commercial Building Energy Audits* addresses Standard 211, which establishes consistent practices for conducting and reporting energy audits for commercial buildings.	https://www.ashrae.org/technical-resources/bookstore/standards-180-and-211
ASTM E2018–15	The *Standard Guide for Property Condition Assessments: Baseline Property Condition Assessment Process* is intended for use on a voluntary basis by parties who want to establish baseline property condition assessment of commercial real estate.	https://www.astm.org/e2018-15.html
ASHRAE Guideline 14	The *Measurement of Energy, Demand, and Water Savings* guideline establishes energy model calibration requirements.	https://www.techstreet.com/ashrae/standards/guideline-14-2014-measurement-of-energy-demand-and-water-savings?product_id=1888937

Term	Definition	Link/reference
National energy code for buildings (NECB)	The Government of Canada's *National Energy Code for Buildings* sets out technical requirements for the energy-efficient design and construction of new buildings and additions.	National Energy Code of Canada for Buildings 2020 See also: The energy code in your province or territory (nrcan.gc.ca)
BC Hydro	BC Hydro offers guidance and tools on building envelope thermal bridging.	Commercial new construction (bchydro.com)
City of Toronto	Toronto Green Standard Energy Modelling Guidelines also offers building envelope guidance and tools.	Energy Modelling Guidelines Version 4—City of Toronto
Ice plant improvements	Facilities with ice plants must consider this critical process load. To ensure accurate results, the ice plant and associate improvements should be modelled. See references for guidance on modelling and ice plants.	Guide: Taking your indoor ice rink to net zero This International Building Performance Simulation Association (IBPSA) case study on modelling a community centre, including a pool and ice rink, covers all major loads to consider:
Customized process heat recovery	Like ice plants, swimming pools must also be considered when modelling process loads. See the reference for guidance on modelling pools.	Modelling indoor swimming pools, NECB. 5.2.10.2

Term	Definition	Link/reference
Greenhouse Gas Intensity (GHGI)	The total greenhouse gas emissions associated with energy use on the building site. It is reported in kilograms of CO_2-equivalent per square metre ($kgCO_2e/m_2$) and includes onsite emissions sources as well as those associated with provincial electricity generation.	Defined as per the Canada Green Building Council's *Making the Case for Building to Zero Carbon*
Energy use intensity (EUI)	The sum of all site energy (not source energy) consumed on site (e.g. electricity, natural gas, district heat) including all process loads, divided by the floor area of the building.	Defined per the Canada Green Building Council's *Zero Carbon Building Performance Standard*
Thermal energy demand intensity (TEDI)	The annual heat loss from a building's envelope and ventilation after accounting for all passive heat gains and losses, per unit of modelled floor area	Defined per the Canada Green Building Council's *Zero Carbon Building Performance Standard*
Absolute capital cost	The baseline cost plus the incremental cost of achieving the energy benefit of the measure or package. The baseline cost should be informed by the building condition assessment (BCA).	
Incremental capital cost	The increase or decrease in the cost of construction, relative to the baseline costs outline by the facility BCA.	
Operational carbon	The emissions associated with the energy used to operate the building.	Defined per the Canada Green Building Council's *Zero Carbon Building Design Standard v3*

Term	Definition	Link/reference
Incremental lifecycle cost (ILCC)	The net present value (NPV) of the increase or decrease in total costs per square metre for construction, operation and maintenance over the study period, relative to the "minimum performance" package (or other reference package).	Definition adapted from the Canada Green Building Council's *Making the Case for Building to Zero Carbon*
Cost per tonne of carbon abated ($ILCC/t$CO_2$e)	The net present value (NPV) of the increase or decrease in total costs per tonne of CO_2-equivalent saved, relative to the "minimum performance" package.	Definition adapted from the Canada Green Building Council's *Making the Case for Building to Zero Carbon*
On-site annual zero carbon balance	This balance represents the net emissions of the sum of embodied carbon, operational carbon and avoided emissions.	Defined per the Canada Green Building Council's *Zero Carbon Building Design Standard v3*
Embodied carbon	These are carbon emissions associated with materials and construction processes throughout the whole lifecycle of a building. They are additional to operational carbon emissions.	Defined per the Canada Green Building Council's *Zero Carbon Building Design Standard v3*
Residual value	The residual value of a system (or component) is its remaining value at the end of the study period, or at the time it is replaced during the study period.	See the section entitled "Residual Values" in this guide on lifecycle cost analysis from Whole Building Design Guide: https://www.wbdg.org/resources/life-cycle-cost-analysis-lcca

Term	Definition	Link/reference
Upstream GHG impacts	An additional consideration can be made for natural gas consumption in relation to methane leakage from the extraction, processing and distribution of natural gas. Methane, while short-lived, has a higher global warming potential than carbon dioxide. Therefore, the potential impact to upstream GHG emissions could be an important consideration for a holistic analysis (i.e., when calculating lifecycle emissions).	A recent study further outlined potential life cycle emission factors that include consideration for life cycle electricity grid emission factors and upstream natural gas emissions: "Lifecycle greenhouse gas emissions from electricity in the province of Ontario at different temporal resolutions," L. Pereira and D. Posen, *Journal of Cleaner Production*, October 2020, https://doi.org/10.1016/j.jclepro.2020.122514

Factors and assumptions

Energy and GHG factors	Possible sources/guidelines
Energy conversion factors	Canada Energy Regulator conversion tables https://apps.cer-rec.gc.ca/Conversion/conversion-tables.aspx The Canada Energy Regulator provides a comprehensive list of conversion factors.
GHG emission factors	The Canada Green Building Council's Zero Carbon Building Workbook (ZCB-Design v3 Workbook) is available here: https://www.cagbc.org/wp-content/uploads/2022/06/ZCB-Design_v3_Workbook.xlsx The Canada Green Building Council has released an Excel workbook that summarizes current emission factors for provincial grids (including average and marginal factors) as well as common fossil fuels. The calculator primarily draws factors from two sources: Canada's National Inventory Report (2018) available here: http://www.publications.gc.ca/site/eng/9.506002/publication.html *Energy Star Portfolio Manager Technical Reference: Greenhouse Gas Emissions*, available here: https://www.energystar.gov/buildings/tools-and-resources/portfolio-manager-technical-reference-greenhouse-gas-emissions
Future grid emissions	Canada Energy Regulator, *Canada's Energy Future 2016: Energy Supply and Demand Projections to 2040*, data appendices, available here: https://apps.rec-cer.gc.ca/ftrppndc/dflt.aspx The Canada Energy Regulator annually publishes projections for future grid mix nationally and by provincial/territory year over year.

Energy and GHG factors	Possible sources/guidelines
Marginal emission factors	The Canada Green Building Council's Zero Carbon Building Workbook (ZCB-Design v3 Workbook) is available here: https://www.cagbc.org/wp-content/uploads/2022/06/ZCB-Design_v3_Workbook.xlsx The workbook summarizes current emission factors for provincial grids (including average and marginal factors) as well as common fossil fuels.
Time value of carbon	*The Time Value of Carbon: Smart Strategies to Accelerate Emission Reductions* https://www.cpacanada.ca/en/business-and-accounting-resources/financial-and-non-financial-reporting/sustainability-environmental-and-social-reporting/publications/time-value-of-carbon-smart-strategies Produced by CPA (Chartered Professional Accountants) Canada, this publication examines how to accelerate GHG reductions by addressing near-term climate forcers (NTCFs), the short-lived GHGs that significantly contribute to climate change.

Utility and carbon pricing

Utility and carbon pricing	Possible sources/guidelines
Electricity—consumption	Utility provider or energy authority
Electricity—demand	If provided as separate rate schedule
Natural gas	Utility provider or energy authority
Water	Utility provider or energy authority
Propane	Utility provider or energy authority
Diesel	Utility provider or energy authority
Carbon shadow pricing	It is recommended that studies align with Canada's "greening government" carbon shadow pricing, available here: https://www.canada.ca/en/treasury-board-secretariat/services/innovation/greening-government/strategy.html
Carbon pricing (to 2030)	Studies should factor in the federal government's anticipated increase to the carbon price of $15 per tonne starting in 2023, rising to $170 per tonne by 2030. The details are available here: https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/climate-plan-overview/healthy-environment-healthy-economy.html
Carbon pricing (after 2030)	Currently, the federal government has not provided guidance on potential carbon tax escalation after 2030. The project proponent should make reasonable assumptions as to any carbon pricing after 2030 and clearly document any assumptions. It is required to conduct a carbon pricing sensitivity analysis, so different scenarios for carbon pricing after 2030 should be considered. Examples of different carbon pricing schemes that could be considered: • Flat carbon pricing after 2030 (i.e. no increases) • Continued $15/tonne increases every year to the end of the study period

Lifecycle costing

Lifecycle costing	Possible sources/guidelines
LCCA methodology	*2019 ASHRAE Handbook—HVAC Applications*, Chapter 38, available here: https://www.ashrae.org/technical-resources/ashrae-handbook National Institute of Standards and Technology, NIST Handbook 135, *Life Cycle Costing Manual for the Federal Energy Management Program*, 2020 edition, available here: https://doi.org/10.6028/NIST.HB.135-2020 Whole Building Design Guide "Life-Cycle Cost Analysis (LCCA)" available here: https://www.wbdg.org/resources/life-cycle-cost-analysis-lcca
Escalation rate—capital	Consistent with project proponent's portfolio rates for capital projects or federal government life cycle cost analyses (Scope of Work for Carbon Neutral Study Services—Life Cycle Costing Analysis)
Escalation rate—utilities	Consistent with project proponent's portfolio rates for capital projects or federal government life cycle cost analyses (Scope of Work for Carbon Neutral Study Services—Life Cycle Costing Analysis)
Inflation/price escalation	Consistent with project proponent's portfolio rates for capital projects or the Canadian Consumer Price Index, available here: https://www.statcan.gc.ca/eng/subjects-start/prices_and_price_indexes/consumer_price_indexes

Lifecycle costing	Possible sources/guidelines
Discount rate	Consistent with project proponent’s portfolio rates for capital projects or federal government life cycle cost analyses. It is expected that GHG reduction pathways in applications for GHG reduction pathway capital projects will use a discount rate of their preference— but this discount rate should be no greater than 5% (5% is aligned with the federal government’s discount rate outlined in its Greening Government Strategy: Real Property Guidance document). Proponents wishing to use a discount rate higher than 5% should contact FCM. Treasury Board of Canada Secretariat’s (TBS’s) *Canadian Cost-Benefit Analysis Guide* also provides a discount rate for the opportunity cost of capital for the federal government. For additional information on the TBS *Canadian Cost-Benefit Analysis Guide*, visit: https://www.tbs-sct.gc.ca/rtrap-parfa/analys/analys-eng.pdf

Cost estimates

Cost estimate	Possible sources/guidelines
Capital estimates	*Elemental Cost Analysis, Format, Method of Measurement, Pricing: Measurement of Buildings by Area and Volume*, available here
Maintenance	Supplied by operator "Maintenance Costs," *2019 ASHRAE Handbook—HVAC Applications*, Chapter 38, available here: https://www.ashrae.org/technical-resources/ashrae-handbook Building Owners and Managers Association International, *Preventative Maintenance Guidebook: Best Practices to Maintain Efficient and Sustainable Buildings*, available here: https://www.boma.org/BOMA/BOMA/Research-Resources/Publication_Pages/Preventive%20Maintenance%20Guidebook.aspx
Residual	Straight line depreciation Canada Revenue Agency, Depreciable Properties and Their Rates, available here

Appendix A: Sample report outline

This sample report outline is adapted from ASHRAE Standard 211-2018:

Executive summary

a. Overall assessment of energy benchmarking and performance

b. Aggregated savings and costs of recommended measures

c. Table of recommended measures and options, with savings and costs

d. Lifecycle cost analysis

Introduction

a. Study scope

Facility description

a. Building information

b. Building envelope

c. HVAC

d. Service hot water/domestic hot water

e. Lighting

f. Process and plug loads

Historical utility data

a. Data summary

b. Utility rate structures

c. Benchmarking

d. Target and savings estimate

e. End-use breakdown

Measures and options analysis

a. Energy modelling approach

b. Measure interactions

c. Measurement and analysis

d. Lifecycle cost analysis

e. Schematic diagrams (as applicable)

g. Workshop summary

h. Measures considered but not recommended

GHG reduction pathway capital plan

a. GHG reduction pathway(s) summary and capital plan(s)

b. Comparison matrix

Appendices

Appendix B: Example GHG reduction pathway scenarios

Figure shows essential quantitative features of the “minimum performance,” “aggressive decarbonization” and “like-for-similar” GHG reduction pathway scenarios for a community building in Ontario.

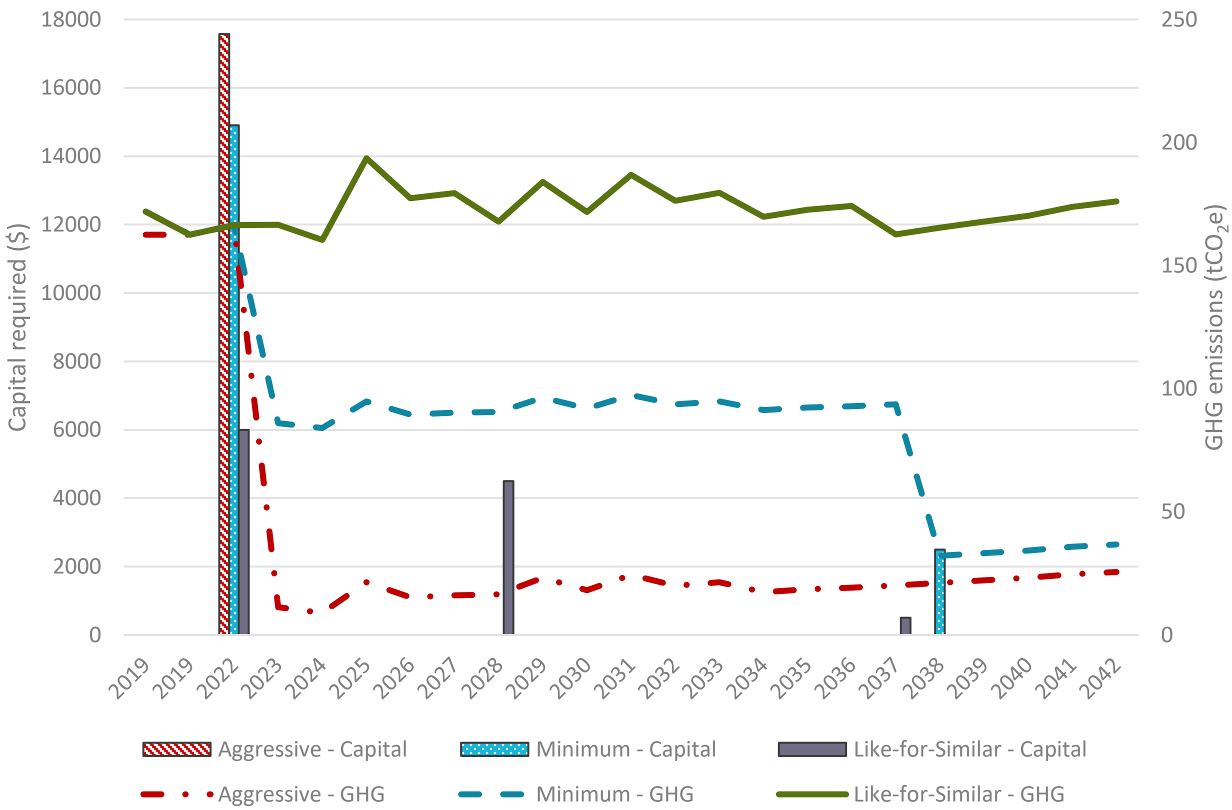

Figure 2: Example of capital investment and annual GHG emissions—minimum performance compared to like-for-similar over a 20-year period

In this example, the GHG emissions for the baseline year are calculated as an average of the building’s GHG emissions in 2018 and 2019. The “like for similar” scenario is based on three pre-planned capital projects to address critical maintenance and to replace the HVAC system at end of life. GHG emissions in the “like for similar” scenario are not expected to decrease due to current projections that the grid emission factor in Ontario will increase. The sensitivity of the GHG reductions to the grid emission factor projection is explored as part of the study (but not shown here).

In the “minimum performance” scenario, the first large project includes work originally planned for 2028 in the “like-for-similar” scenario to minimize disruption and facility downtime while ensuring that load reduction efforts are not done after

HVAC upgrades (thus keeping overall capital costs down). The situation could also have been reversed—where the optimal and least disruptive roll-out of the "minimum performance" scenario was to split the work between 2022 and 2028 in a similar manner to the "like-for-similar" scenario. The remainder of the "minimum performance plan" work is completed in 2038 (when rooftop units will be fuel-switched to air-source heat pumps).

In the "aggressive decarbonization" scenario, all work is completed in a single project.