MAYORS' MEGAWATT CHALLENGE
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Roadmap to Net Zero Ice Rinks Pilot Study Completion Report

September 30, 2021

GMF No. 16858

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Acknowledgments

We would like to take this opportunity to thank our sponsors – Cimco Refrigeration and Enbridge Gas – who have been critical to helping us, and our participating municipalities, achieve our objectives.

We would also like to thank members of our Technical Committee for their invaluable support. From start to finish, this has been a group effort. We are fortunate to have a technical committee made up some of the leading lights in technology in ice rinks that have generously volunteered hours of their time and lending their expertise to help shape the pilot and develop the measures. They have worked with us to develop the high impact conservation measures for the archetypal rink and actively participated in the preparation integrated design meetings for each individual rink.

The Technical Committee participants are as follows:

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AMP Solar

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Zamboni

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This project was carried out with assistance from the Green Municipal Fund, a Fund financed by the Government of Canada and administered by the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.

1 Introduction

The Roadmap to Net Zero Ice Rinks pilot study was conducted by the Mayors' Megawatt Challenge program and supported by the Federation of Canadian Municipalities. The study took a cohort approach to developing individual roadmap studies for nine municipal ice rinks from seven municipalities to get their building operations to net zero carbon emissions over time. The nine rinks comprise 705,874 ft2 of building area and 241,191 ft2 of rink area.

The participating municipalities and rinks are as follows:

City of Barrie	Sadlon Arena
City of Brampton	Terry Miller Recreation Centre
Town of Caledon	Caledon East Community Complex
Town of Halton Hills	Acton Arena
	Mold Masters Sportsplex
Township of King	Trisan Centre
City of Markham	Crosby Arena
	Mount Joy Community Centre
City of Toronto	Downsview Arena

Technical Advisory Committee members are listed in the acknowledgements. They provided invaluable technical advice, direction and support. Technical leadership and services were provided by Enerlife Consulting.

The results of the pilot are conclusive and transformational. Net zero carbon emissions is achievable and financially feasible in municipal ice rinks. It requires an all-encompassing evaluation and plan of measures, employing life cycle costing to account for operations and maintenance costs, and aligns the timing of measures with capital renewal or planned capital investments over time.

Although much of the pilot unfolded as planned, there were a few unexpected developments. COVID 19 had a substantial impact on implementation timelines as site visits were delayed when buildings were closed, building performance data was more difficult to collect and meetings with municipal and building staff more difficult to schedule. During the pilot, funding opportunities from Infrastructure Canada (Green and Inclusive Community Buildings), the Federation of Canadian Municipalities (FCM) and others became available, which added urgency and a different focus to the pilot, particularly around implementation. For example, some municipalities requested additional details on the measures and costing (beyond the original scope) to support the application requirements. See Appendix A (Measure cost details) of the individual reports for details.

Responding to participant demand, the pilot team incorporated more immediate municipal staff engagement and coaching through the process. Rather than using tools, templates, and case studies, municipalities preferred the coaching as it allowed them to learn as they go, to build ownership, and to be able to replicate the process. This coaching model greatly accelerated acceptance and adoption within the participating facilities and municipalities.

2 Feasibility Studies

2.1 Process

Each of the participating municipalities is a member of the Mayors' Megawatt Challenge, a program working with municipalities since 2003 to reduce energy use and emissions in their own facilities. The idea of the pilot project began at the 2019 Mayors' Megawatt Challenge Forum, which explored the practical ways that municipalities could go from vision to action for net zero carbon. A panel of expert speakers, including Matt Jungclaus from Rocky Mountain Institute, Dharmin Dhalia from the Town of Halton Hills and Professor Alexander Hay from Southern Harbour, spoke to zero-over-time for existing buildings, integrating climate goals with asset management, and climate resiliency respectively. Following this, the MMC team led a facilitated working session with member municipalities on organizational readiness for net zero carbon, identifying municipal priorities. The Roadmap to Net Zero Ice Rink cohort pilot project was developed based on these priorities.

Ice rinks were chosen as the pilot building type, as they are often the largest greenhouse gas emitters and typically account for 20-30% of the energy usage in municipal building portfolios. Seven member municipalities in Southern Ontario submitted nine rinks to the pilot project. These municipalities worked together with the pilot team and with leading industry experts to identify how to get existing ice rink facilities to net zero emissions. The pilot used a cohort approach so municipalities could learn from each other and reduce their individual risk. The pilot was designed to incorporate net zero readiness best practices not yet adopted by many of the municipalities. These best practices included early identification of prioritized projects, low carbon design brief, integrated design teams, life cycle costing, capital planning aligned with asset management, and zero-over-time planning.

A feasibility study was developed for each participating rink providing a high-level technical solution to reduce greenhouse gas emissions, including an outline of potential measures and lifecycle financial analysis for each measure in an incremental, over time approach. Solutions were aligned with individual municipal timelines – targets and urgency in getting to net zero, capital renewal timelines and asset management plans. A standard model was developed, based on collective learning from all participating ice rinks, plus generic considerations, to be applied to other ice rinks. Best practices and lessons learned will be shared through the Mayors' Megawatt Challenge program and will inform the 2021 Forum.

The individual studies for each participating rink are the culmination of three phases of work. During the first phase, the pilot team reviewed energy and building data, key drawings (mechanical and refrigeration), trend logs (as available), previous energy audits and building condition assessments, as well as the building's capital plan. Site visits were conducted to confirm data and information already received, collect additional information, and interview the building operator and facility manager to identify operational conditions and potential issues. An initial archetypal building model for arenas was developed in eQUEST software and referenced for measures in each specific participating rink. Measures were reviewed with facility staff to confirm details.

Following the site visit and measure reviews, Integrated Design Workshops were conducted bringing together building management, operators, energy managers, technical experts, and asset management to determine the best possible solution and plan for the rink. Participants reviewed the current performance of the rink and potential carbon reductions, low/no carbon measures that best fit municipal greenhouse gas emissions reduction goals for the facility, and measure implementation timelines. The workshops brought together technical and operational expertise, ensured operations and asset renewal were considered and that everyone had input at an early stage. This helped with buy-in and avoided costly

omissions. Participants discussed how implementation and funding need to be done differently and what additional help would be required. Measures and associated costs were reviewed with the municipal finance group (including capital and procurement groups) either in the Integrated Design Workshops or in subsequent Capital Review Workshops, depending on staff availability.

The nine Roadmap to Net Zero feasibility reports map the retrofit and operational changes required to get each rink close to net zero emissions. They summarize the current energy and greenhouse gas performance, explore three potential target scenarios, and include each municipality's preferred measures, implementation timelines, and target greenhouse gas emissions. Findings and feedback from all municipal stakeholders have been incorporated in each final report.

2.2 Objectives

The objectives of the Roadmap to Net Zero Ice Rinks pilot study were as follows:

- Aid municipalities in setting achievable carbon reduction targets for ice rink facilities and determine a roadmap to achieving them.
- Test the four-phase measure prioritization and zero-over-time approach to identifying, budgeting and planning low carbon measures. Focus initially on operational savings and high impact carbon measures to get early returns.
- Build the case for low carbon measures by comparing the upfront project costs and net present value of a "business as usual" like-for-like replacement of equipment with the project costs and net present value of the best possible low carbon measures.
- Introduce the Integrated Design process into measure development, bringing together facility staff and technical experts with capital and finance.
- Compare ice rink performance metrics to evaluate how ice rink building systems perform and whether there are opportunities for operational improvements or better efficiency when replacing the equipment.
- Assist municipalities in planning equipment renewal in advance to allow for low carbon options to be considered and costs budgeted.

2.3 Methodology

2.3.1 Participating ice rinks

Various types of municipal ice rinks were included in the pilot project, from single pad to double and quadruple pad rinks, with some having significant other recreational space in addition to the rink. The study focused on facilities that do not have a pool. Two facilities already had heat recovery integrated in the refrigeration plant, although one of those facilities only has it on the newer of the refrigeration plants. One of the facilities is an Ontario Hockey League facility with the attendant facility requirements. Most of the rinks did not have facility-wide building automation systems.

Ice rink facility details can be found in Appendix A Participating rink details.

2.3.2 Phases of measure identification and prioritization

Measures were identified and prioritized using a four-phase approach, incorporating a zero-over-time alignment of major capital upgrades at equipment end of life:

i) Maximizing the energy efficiency of the existing systems is the first priority. Ensuring the rinks are running efficiently and taking advantage of opportunities for operational energy efficiency reduces the energy load and provides early wins.

ii) Recovering waste heat in ice rinks is key to reducing heating requirements and offsetting high emissions gas consumption. Early implementation of heat recovery, after thoughtful design, is emphasized because of its holistic positive impact on all measures which leads to a more financially attractive low carbon path in aggregate with a larger net present value (NPV) when compared to the business-as-usual path. Recovering heat from the refrigeration plant is the most significant measure for reducing carbon in rinks. A number of subsequent measures are dependent on heat recovery proceeding.

iii) As building equipment reaches end of life, extending the life of the equipment if possible, and replacing equipment with the best lower carbon option, is key.

iv) On-site renewable energy generation was examined for technical and financial suitability for reducing carbon emissions. Solar photovoltaics (PV) are generally the most attractive on-site renewable for this type of facility.

If the facility's net zero carbon goal is not reached after the last phase, any remaining emissions can be offset by purchasing renewables credits.

2.3.3 Lifecycle costing: Net Present Value (NPV) and comparative costs and NPV by system

Net present value (NPV) is pivotal in determining the lifecycle costing and evaluating which measures are viable. It lays out the total cost savings over 30-year period, as compared to current operations, using 2019 calendar year as the baseline.

Life cycle costing considers initial costs, annual utility costs, carbon pricing, any change in annual operation and maintenance costs and any significant replacement costs during the life expectancy of the replaced equipment. When a measure has a positive NPV, it was recommended. With a negative NPV, the decision is less straightforward and should be based on trade-offs between emission savings and creation of financial value. Measures recommended in each of the individual rink reports have either a positive NPV, positive emission savings or both. If a measure has a negative NPV, an increase in emissions and is not needed to support other low carbon measures, then it was not recommended.

This approach follows FCM's life cycle costing requirements for a GHG reduction pathway study, which is required before applying for a GHG reduction pathway retrofit or a GHG impact retrofit.

2.3.4 Measure scenarios, timing and assumptions

Each rink report provides three different scenarios of measures, timing, and actions with initial outlay of costs, emission savings, total net annual savings, simple payback, and net present value (NPV). Each of these scenarios considers a 30-year implementation timeline taking each facility to the end date for most municipal greenhouse gas reduction goals.

The scenarios are as follows:

i) Business-as-usual measures. This outlines the replacement of equipment as needed with equivalent, standard replacements, no optimization of existing systems, no heat recovery, nor any consideration for renewables.

ii) Low Carbon approach without funding. This scenario incorporates all reviewed low carbon measures based on maximizing energy efficiency, utilizing heat recovery and replacement of equipment at end of life. It includes implementing operational measures first, along with measures that make technical and financial sense to be implemented immediately.

iii) Low Carbon with funding. This envisions the implementation of low carbon measures using Green and Inclusive Community Building (GICB) funding from Infrastructure Canada, according to the implementation timelines. Low carbon measures implementation timelines may have been accelerated to meet the GICB requirement of completion on or before March 2026.

Low Carbon with funding scenario is similar to the Low Carbon approach without funding scenario, except measures are scheduled to be implemented sooner to take advantage of GICB funding that requires completion on or before March 2026. Some measures include two capital outlays for replacement, as equipment would need to be replaced twice within the 30-year timeline, based on recommended lifespan. If the second equipment replacement was due on or before 2051, the cost was included, and amortization period extended beyond the timelines of the feasibility study to include the savings associated with the last equipment change for the full life of the equipment. Note that the initial funding covers the first replacement only.

2.3.5 Costing and Assumptions

Analysis includes both upfront costs (initial outlay of costs) and life cycle cost analysis. Costing assumptions for measures were provided in the appendices of each report. They were based on costs from suppliers, rules of thumb and previous experience.

Life cycle costing calculations include the total cost of the measure including initial, operational and carbon costs, incorporating inflation and other considerations. Net present value model assumptions and sources are listed in Appendix B Life cycle cost assumptions.

2.4 Consultations

No public consultations were conducted as part of this study. Significant effort was made to engage all internal stakeholders in the development process to facilitate implementation. Depending on staff availability, three to four separate engagements took place, after the initial measures and implementation plan had been drafted. The first was a review with facility staff, including operators where possible, to get feedback and input to the measures. The second was an Integrated Design workshop to review the proposed measures, costing, implementation plan and emission savings. The attendees also provided feedback on implementation assistance. The third was a Capital Review workshop with representatives from finance and procurement to review the measures, costing and implementation plan. One of the biggest benefits of this was the introduction and review of the life cycle costing methodology and net present value. None of the participating municipalities were actively evaluating projects using net present value, although some were planning to adopt it.

The project team also consulted a team of technical experts who made up the Technical Committee. They provided initial feedback on the foundations of the pilot study at the Co-creation workshop on August 16, 2020 and brought ideas from other projects in rinks. They brought in-depth subject matter expertise in ice rink operations, technologies, energy efficiency, sustainability and planning carbon reduction

measures. These experts provided input to the original concept, initial measures and site-by-site technical knowledge for each rink.

3 Findings and recommendations

3.1 Energy performance findings

3.1.1 Total and target energy use intensity (EUI)

As can be seen in Figure 1 below, the planned measures outlined in the individual rink studies will significantly reduce the energy intensity of the rinks. It shows the 2019 total energy use intensity (EUI) and the target energy use intensity, broken down by electricity and gas, for each participating rink. The participating rinks have wide range of current EUIs with Ice Rink 3 the highest total EUI of the group at 40.2 ekWh/ft2 and Ice Rink 6 with the lowest at 26.5 ekWh/ft2. The average total EUI for the group of nine rinks is 34.1 ekWh/ft2.

The target EUI for each rink is energy intensity of the rink after all the planned measures are completed. Ice Rink 9 has the highest target EUI of the group at 24.3 ekWh/ft2 and is the only rink with natural gas use remaining as, at the request of the municipality, only operational and low-cost measures were considered due to planned major renovations. As such, it has an EUI percentage reduction of 32.5%, the lowest in the group. Ice Rink 7 has the lowest target EUI of the group at 0 ekWh/ft2 with a corresponding EUI percentage reduction of 100%. This municipality wished to understand what it would take to avoid the purchase of carbon credits.

Target EUIs for the other seven rinks range from 3.9 ekWh/ft2 to 14.1 ekWh/ft2. The average target EUI for the group of nine rinks is 9.6 ekWh/ft2.

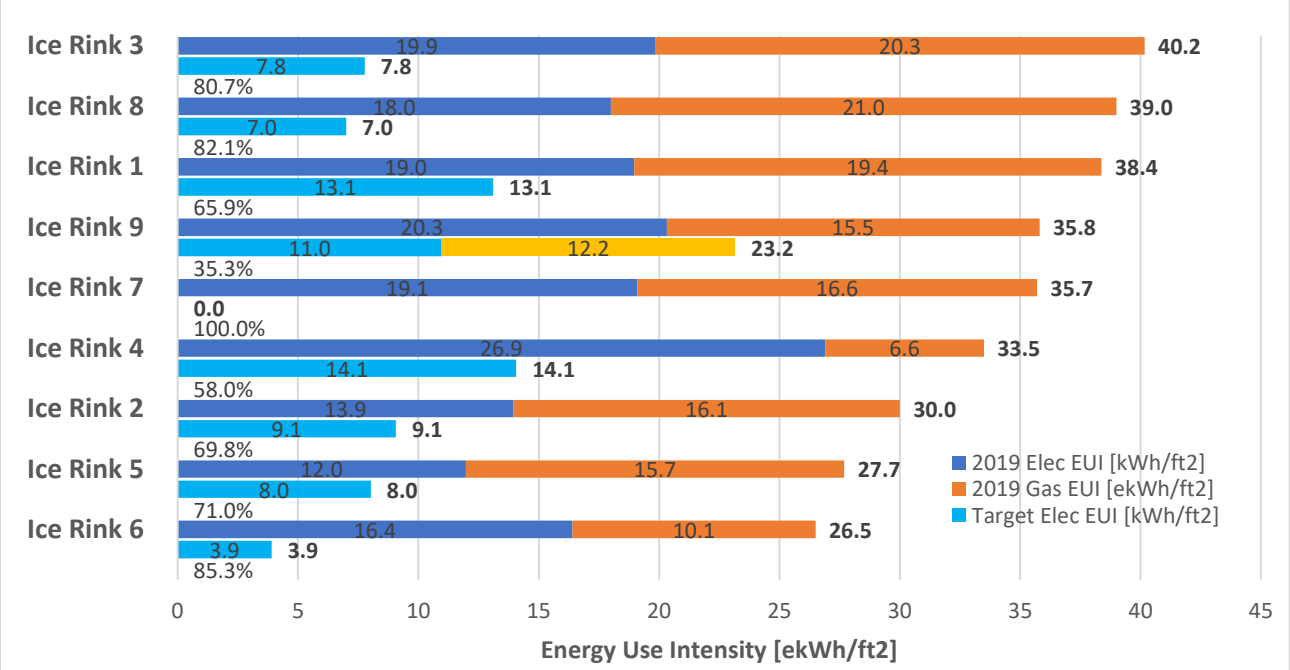

Figure 1 2019 Energy Use Intensity (EUI) and Target Energy Use Intensity (EUI) for participating rinks

3.2 Greenhouse gas emission findings

Figure 2 below shows the range of 2019 total emissions and target emissions for all participating rinks, in tonnes of carbon dioxide equivalent (CO2e). Ice Rink 1 has the highest 2019 total emissions at 628 tonnes CO2e and Ice Rink 9 has the lowest at 119 tonnes CO2e. For all nine rinks combined, the total emissions are 2,441 tonnes CO2e, with an average of 271 tonnes CO2e.

Emissions reductions range from 99% for almost complete elimination of carbon emissions to 26% which are operational measures, with an average of 85%.

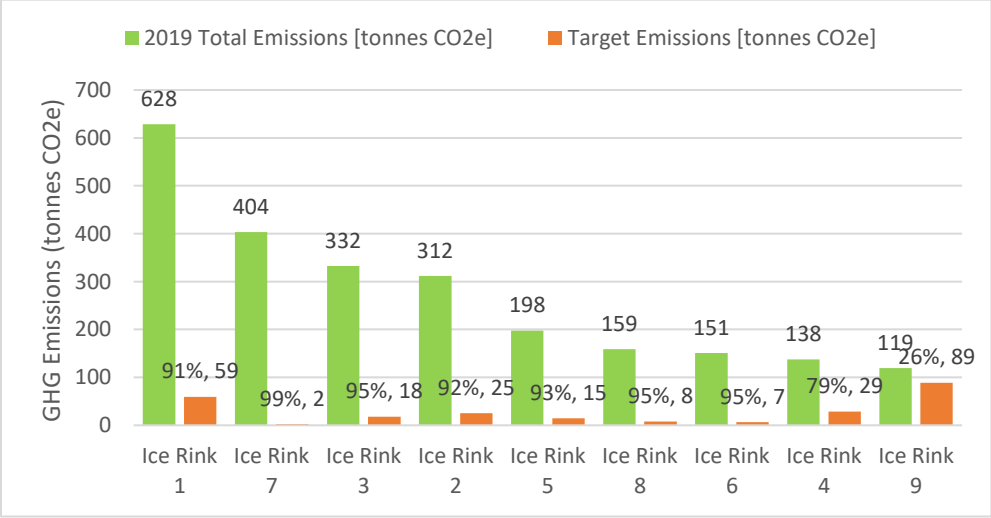

Figure 2 2019 total emissions and target emissions for participating rinks

Emission reductions for each participating rink, broken down by system, are shown in Figure 3. Collectively, by following the roadmaps, the nine rinks can reduce GHG emissions by 2,189 tonnes of CO2e by 2050. Individually, the rinks can save between 30 tonnes and 569 tonnes of CO2e. The average emission reductions for the nine rinks 243.3 tonnes CO2e. The total emissions reduction by system and by rink can be found in Appendix C.

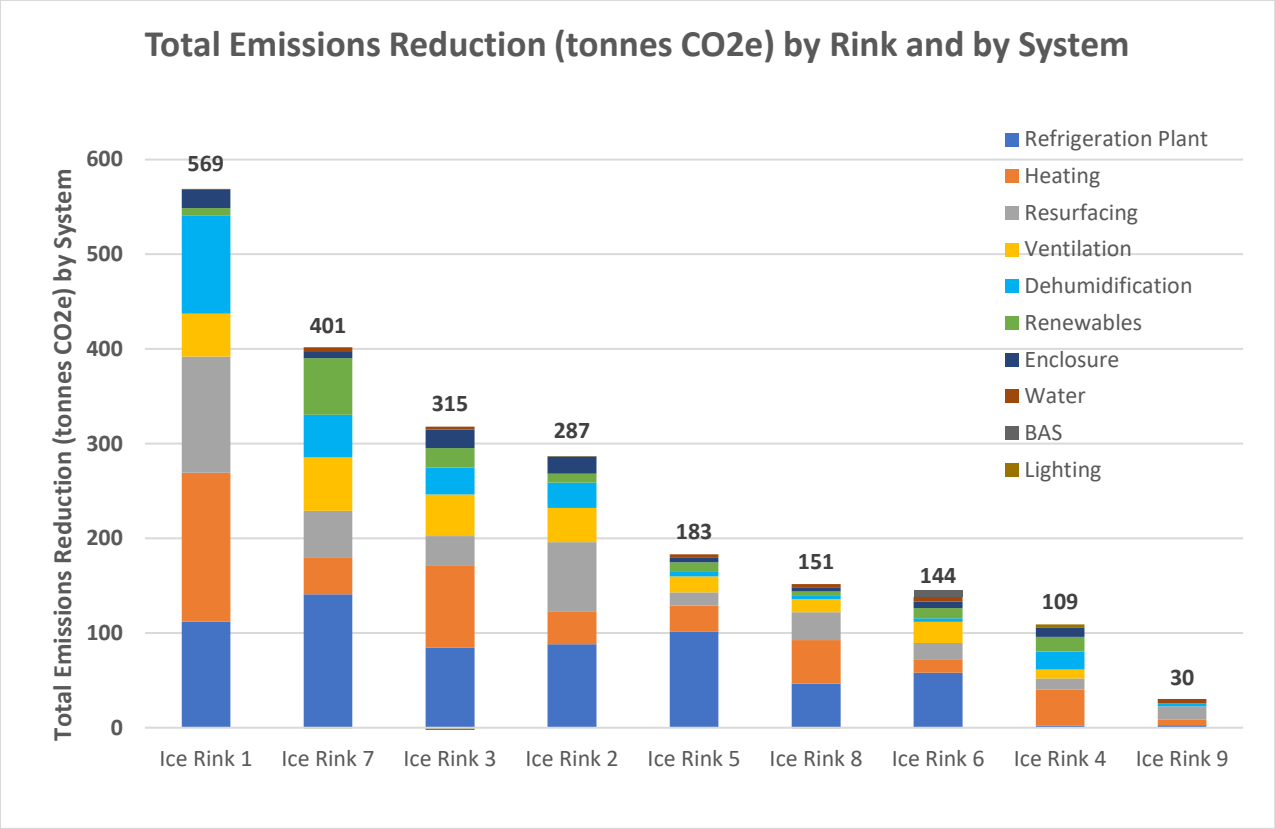

Figure 3 Emission reductions by system (tonnes CO2e) for participating rinks

The breakdown of the total greenhouse gas emissions reductions by building system improvement measures is shown below in Figure 4. Not surprisingly, the largest greenhouse gas emissions savings come from improvements to the refrigeration plant which include heat recovery. Refrigeration measures account for 29% of the emissions savings. Heating measures account for a significant part of the recommended measures with 21% of the emission savings. In most facilities, resurfacing measures, such as cold water resurfacing technology, would have a significant impact on GHG reductions. Enclosure measures, such as insulation and window replacements, did not make as much financial sense as originally anticipated. These measures could be implemented for improving comfort but were not the best choice financially. Heat recovery and other measures were better investments for emissions reductions and energy savings. Further details on recommended measures can be found in the individual reports. Anonymous versions of the individual reports are provided in Appendix D.

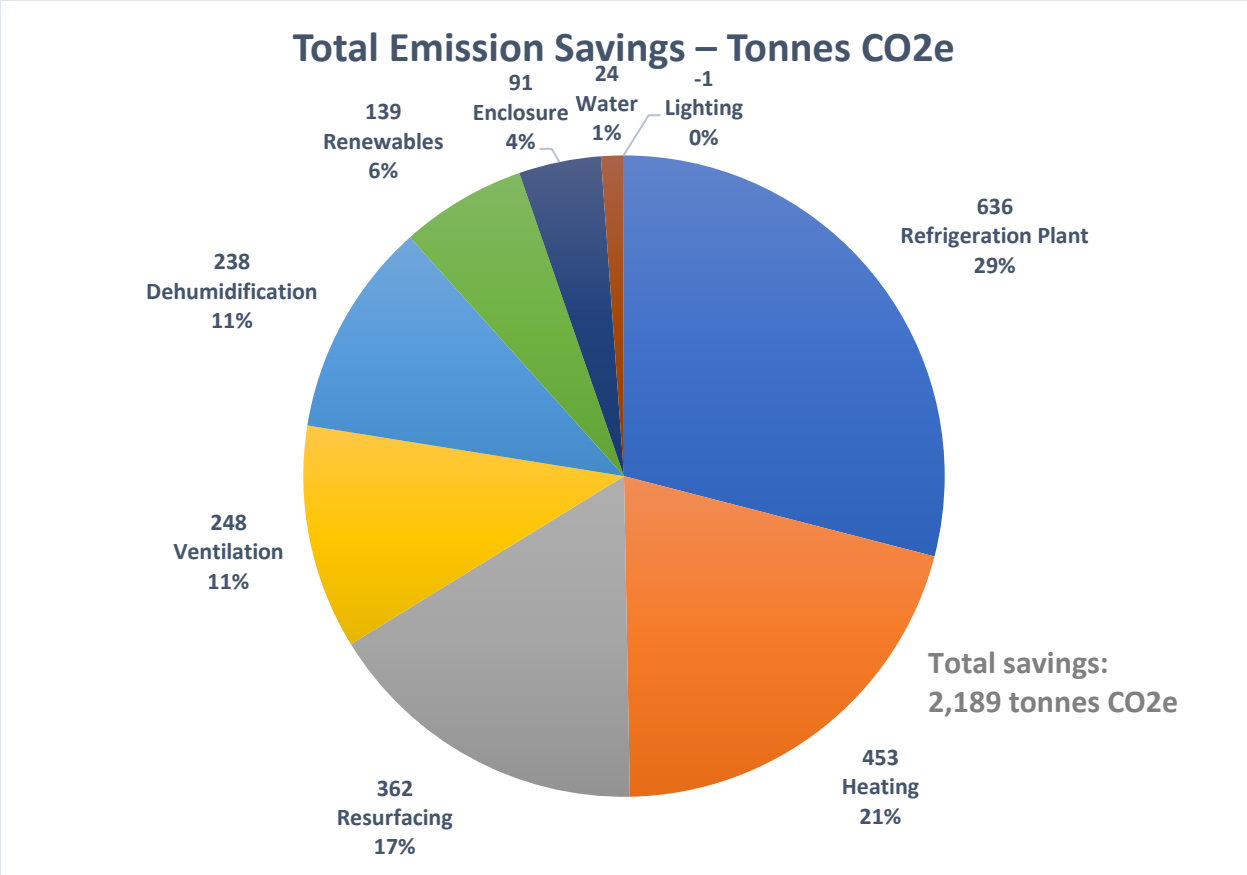

Figure 4 Breakdown of total emission savings (tonnes CO2e) by system

3.3 Summary of financial findings

As indicated in Section 2.3.3, the feasibility studies provide three financial scenarios. The Business-as-usual scenario assumes a like-for-like replacement of existing equipment with no improvements, including no operational changes. The Low Carbon approach without funding looks at the operational improvements and equipment upgrades that provide the best emission reductions, immediate energy savings and are timed for end-of-life equipment replacement. The Low Carbon approach with funding is the Low Carbon approach but timed and funded in alignment with the GICB funding.

Table 1 below shows the net present value (NPV) financial evaluation which indicates that, despite higher initial costs and without additional outside funding, the low carbon measures are much better investments than like-for-like replacement of equipment without operational changes. The financial picture is further improved if available grant funding can be used to finance the improvements.

System	Business As Usual		Low Carbon approach without funding		Low Carbon approach with funding	
	Total Project Costs ($)	NPV ($)	Total Project Costs ($)	NPV ($)	Total Project Costs ($)	NPV ($)
Refrigeration Plant	$5,298,000	($5,084,023)	$11,185,875	$4,626,367	$4,555,575	$14,793,199
Heating	$2,516,854	($2,244,546)	$2,226,205	($214,450)	$805,241	$1,154,239
Resurfacing	$945,000	($1,284,733)	$1,720,000	$11,575,659	$1,272,000	$9,373,519
Ventilation	$1,616,376	($2,315,698)	$2,703,048	$999,902	$1,067,810	$2,775,088
Dehumidification	$1,733,200	($2,673,514)	$2,754,793	$3,880,101	$667,759	$5,442,670
Renewables	$0	$0	$8,102,376	$13,696,313	$4,080,137	$17,564,057
Enclosure	$0	$0	$3,242,148	($228,394)	$786,670	$2,239,359
Water	$0	$0	$7,000	$941,918	$1,400	$947,115
Lighting	$5,592	$242,811	$279,221	$1,286,403	$55,844	$1,525,427
Grand Total	**$12,115,022**	**($13,359,703)**	**$32,220,667**	**$36,563,819**	**$13,292,435**	**$55,814,674**

Table 1 Total comparison of financial scenarios

Without funding, the low carbon measure costs were about $46/ft2 on average, with many of the measures focused on the ice rink. With funding, the average projects costs were just slightly higher than like-for-like replacement at $19/ft2.

3.4 Recommendations

The Roadmap to Net Zero Ice Rinks pilot study confirmed the validity of the four-step process to identify and prioritize the measures. It also confirmed the value of having a plan that will be implemented over time and aligned with asset management, equipment replacement timelines and emissions reduction goals.

In creating roadmaps to net zero carbon, it is important to consider the integration between the low carbon measures. Heat recovery is pivotal to the plans to significantly reduce carbon emissions in these rinks and will need to be more widely used and understood in the coming years as municipalities work to reduce emissions in their facilities. Many other measures depend on the implementation of heat recovery. For example, replacing natural gas boilers with electric boilers was recommended after heat recovery is installed since heating a facility electrically is costly. As well, many of the ventilation measures and boiler plant measures use heat from the heat recovery system.

Operational improvements can provide significant energy savings early on. These include adjusting temperature and humidity set points, scheduling building systems to run smoothly and only when needed, lighting controls, and adjusting ice thickness and water per flood. Successful implementation of these measures requires greater control of building operations. Few of the arenas in the study had comprehensive BAS systems, yet they are crucial tools for operating ice rinks optimally and finding energy and emission savings. All rinks considering greenhouse gas emissions reduction plans should install or expand their BAS and/or reprogram it. With operational measures, operator training is also critical and was identified by most municipalities as an area where additional support would be needed. By focusing

on implementing operational improvements and leveraging high emissions reductions measures early, municipalities can achieve early returns and improve the net present value of the investment in measures.

Switching to cold water ice resurfacing, after testing as appropriate, can provide significant savings and emissions reduction. To adopt this measure widely, more opportunities are needed for conversation and consultation with operators in buildings where this has been implemented successfully. MMC conducted a webinar on this subject, making connections within the pilot. The webinar recording is available on the program website. Addressing barriers like this is fundamental to getting high impact measures implemented that require operator buy-in and operational change.

4 Next Steps

The overall aim of the pilot project was to accelerate action on reducing emissions in municipal buildings. MMC will be building on the feasibility studies from this pilot to help municipalities implement the recommended measures and extend this approach to other ice rinks and building types.

4.1 Funding Opportunities

As the pilot developed, a number of funding opportunities became available that were not in place in early 2020 when the pilot was initiated. This added to the urgency in completing the studies and accelerated engagement. The roadmaps for the participating rinks evolved to support applications for the following funding opportunities:

Infrastructure Canada Green and Inclusive Community Buildings (GICB) Program funding

(https://www.infrastructure.gc.ca/gicb-bcvi/index-eng.html). Funding is provided for 80% of eligible project costs for retrofits up to $9,999,999 (and 60% for retrofits of $10 million+). All retrofit projects must be planned to be completed between April 1, 2021 and March 31, 2026. Applications are accepted on an ongoing basis for projects under $3 million. Additional support may be needed for the funding application. The

4.1.1 Canada Community Revitalization Fund (CCRF)

(https://www.wd-deo.gc.ca/eng/20176.asp). Funding is provided for up to $750,000 but projects must be completed on or before March 31, 2023.

4.1.2 Federation of Canadian Municipalities Community Buildings Retrofit (CBR) funding

Funding is provided for a range of projects, including GHG Impact Retrofits (Capital Projects). The project must have a minimum of 30% reduction in GHG emissions. Financing (loan and grant) is provided up to $5 million dollars. To apply, visit the CBR webpage (https://fcm.ca/en/programs/green-municipal-fund/community-buildings-retrofit-initiative) and review the application guide (https://data.fcm.ca/documents/programs/GMF/cbr/cbr-application-guide-gmf.pdf).

4.2 Ongoing support through the Mayors' Megawatt Challenge (MMC) program

The feasibility studies were conducted through an ongoing program, which provided a network of support and continuous sharing of experiences, best practices and lessons learned. In consultation with participating municipalities and experts, the MMC program will continue to develop and evaluate implementation support, such as identifying what outside help might be needed, sample business cases, funding options and Request for Proposal/Quote language.

The MMC program, in parallel with and in support of the pilot project, has been conducting informative webinars on topics that support energy and greenhouse gas reduction in all municipal facilities. They have included an in-depth exploration of heat recovery, cold water resurfacing for building operators, and financial and technical viability of geothermal in existing municipal buildings. Upcoming program events include a webinar on using interval metering for operational savings and the annual Forum which will present the pilot project results.

5 Lessons Learned

5.1 Recommendations to municipalities doing a similar study

5.1.1 Gather building data and documentation early

Building data and documentation gathering is critical to understanding how the building is designed and how it functions now. This stage took far longer than expected, exacerbated by COVID closures. Given how pivotal this is, we recommend that municipalities initiate this process early. Getting organized to provide this data in the future will accelerate the initial stage and ensure that current design, operations and performance are well understood.

Key information for municipalities to prepare ahead of a net zero feasibility study:

- Critical drawings - mechanical, refrigeration, electrical (lighting), architectural, schematics
- Previous energy audits and a summary of recent measures completed
- Current operating conditions and occupancy schedules
- Building condition assessments
- Asset management plan/capital plan
- Building performance data
    - Monthly (2 years)
    - Interval, if available (2 years)
    - Submetering or datalogging high energy using equipment and systems

Refrigerant use and embodied carbon impact carbon emissions of the building but were not included in the scope of this study.

5.1.2 Trends and Building Automation System (BAS)

Eight of nine arenas in the pilot study did not have BAS systems that covered the whole building. Most arenas, however, had the capability of capturing trends in their refrigeration systems. Accessing these trends was difficult and most buildings were not reviewing them on a regular basis. Reviewing the trend logs allowed the project team to identify immediate operational savings opportunities that helped improve the financial forecast. Planning to implement a whole building BAS early in the low carbon plan will help better control building systems, develop and consistently apply best operational practices, and provide a view into how the building is operating.

Recommendations for BAS procurement:

- Ensure the system is compatible with existing controllers and systems.

- Consider an open-source system, BACnet, which allows for modifications and does not restrict service options.
- Consider servicing capability and including outcomes-based maintenance requirements in service contracts.

Recommendations for all arenas, not just those looking at deep retrofits to net zero:

- Set up trend logs and archive them for a minimum of 2 of the most recent years.
- If equipment is not connected to the BAS, use temporary or permanent data loggers to collect operational and energy data.
- Document and update the sequence of operations/controls sequences.

5.1.3 Integrated Design – Working together

This pilot was structured on the premise that working collectively gets better results, which was demonstrated throughout. We used a cohort approach so that municipalities could learn from each other throughout the process and to reduce risk. Both were identified by municipalities as barriers to developing carbon reduction plans. This also allowed us to compare performance metrics of different rinks.

We used an integrated approach to developing the plan for the archetypal rink and each individual rink, which we would recommend to any municipality undertaking this type of study. Stakeholders for each municipality had an opportunity to participate in the development of measures, review them and ask questions. Initially, the facility staff and the pilot team outlined the measures and plan at a preliminary design meeting. Each rink had an Integrated Design workshop bringing together building management, operators, energy managers, our technical advisory group, technical experts, the modelling engineers, and asset management to review the building characteristics, layout and performance to determine a solution and plan for the rink. This leveraged technical and operational expertise, ensuring operations and asset renewal were factored in and that everyone had input at an early stage. If finance and/or procurement staff were unable to attend the integrated design workshop, an additional Capital Review workshop was held to review the planned measures, capital investment phases and life cycle costing. This helped with buy-in and avoided costly omissions. Integrated design is used frequently in new building design, but it is key in existing buildings as well.

5.1.4 Timing of measures and alignment with asset management and capital planning

Planning out measures over time was a successful feature of the pilot and is highly recommended to any municipality undertaking a low carbon feasibility study. Benefits of this approach include achieving early energy savings from operational measures which are planned first, aligning investment in lower carbon options with planned equipment replacement, and being able to plan ahead for capital expenditures. The approach included installing BAS early on, as monitoring and fine-tuning building performance is fundamental from the beginning.

5.1.5 Lifecycle costing and Net Present Value

Lifecycle costing using net present value, as outlined by FCM, allowed the pilot and municipal teams to evaluate the viability of the measures over the equipment life. This longer-term view revealed surprising outcomes where some measures made more sense than others and demonstrated that low carbon measures made better financial sense than continuing with business-as-usual. It illustrated the value of investing in higher efficiency and lower carbon measures in the long term over a shorter-term view using simple payback to evaluate financial feasibility of measures.

None of the municipalities participating in the pilot study currently use net present value or lifecycle costing to evaluate the financial feasibility of projects. Some of them plan to start implementing the plan in the near future.

We recommend that all municipalities undertaking a similar study use this approach, already identified as valuable by FCM. The methodology is outlined in the Community Buildings Retrofit Application guide: https://data.fcm.ca/documents/programs/GMF/cbr/cbr-application-guide-gmf.pdf

5.2 Barriers and/or challenges

The primary challenge for this pilot was the timing and the impact on implementation timelines. The pilot started just as the COVID-19 pandemic began and municipal buildings were closed to the public for much of that time. It significantly delayed data gathering and site visits, as neither visitors nor staff could go to the buildings. A baseline of 2019 was chosen for the studies as the last year of regular operation of ice rinks. To better understand equipment and building operations, technical contractors planned to submeter key equipment which was not possible. Even obtaining trend logs was significantly more difficult, as this often required a visit to the rink with a technician. Overall, the site visit and data gathering took much longer than expected and delayed the project.

Collecting building and trend data for the rinks took longer and was more difficult than anticipated for other reasons as well. Drawings of older buildings were hard or impossible to find. Many of the rinks do not have building-wide BAS so the only trend logs available were from the systems controlling the refrigeration plants. These systems were not easily accessed and often did not have trend archiving capabilities.

Lastly, due to COVID-19 restrictions, it was challenging to bring together municipal teams for site visits consultations, interviews, Integrated Design workshops and Capital Review workshops.

6 Knowledge sharing

Initial findings and plans for the Roadmap pilot study were presented at FCM's Sustainable Communities conference in 2020. The link to highlights and the agenda of the conference can be found here: https://fcm.ca/en/events-training/conferences/past-conferences/sustainable-communities-conference-2020.

The MMC program will work to support municipalities with their implementation of these and other plans. All of the key findings from the Roadmap to Net Zero Ice Rinks pilot study and participant case studies will be covered in depth at our Annual Forum in November 2021. It and other information supporting greenhouse gas reduction in municipal facilities are posted on the Mayors' Megawatt Challenge website at https://mayorsmegawattchallenge.com/.

Recordings of webinars that cover topics germane to reducing greenhouse gas emissions in arenas and in other municipal facilities can also be found here at https://mayorsmegawattchallenge.com/events/.

7 Appendix A Participating rink details

Arena	Ice pad [ft2]	Rink less ice pad [ft2]	Building other [ft2]	Gross Floor Area [ft2]	# Ice pads	Months of ice in	# Of refrigeration plants	Heat recovery	Desuperheater
Ice Rink 1	65,450	8,187	77,363	151,000	4	9	2	1 plant only	YES
Ice Rink 2	37,556	13,166	41,278	92,000	3	8	2	NO	YES
Ice Rink 3	28,595	9,637	54,236	92,468	2	1 pad - 12 months 1 pad - 9 months	1	NO	YES
Ice Rink 4	25,381	13,895	28,720	67,996	2	1 pad - 12 months 1 pad - 8 months	1	YES	YES
Ice Rink 5	17,484	6,849	36,164	60,497	1	8	1	NO	NO
Ice Rink 6	17,000	4,705	39,339	61,044	1	10.5	1	NO	Decommissioned
Ice Rink 7	17,000	28,713	64,287	110,000	1	9	1	NO	Decommissioned
Ice Rink 8	15,725	4,925	15,926	36,576	1	8	1	NO	Bypassed
Ice Rink 9	17,000	1,100	16,193	34,293	1	10	1	NO	YES

8 Appendix B Life cycle cost assumptions

The assumptions incorporated in life cycle costing are outlined below. The primary sources for the tables are the Community Buildings Retrofit Initiative Green Municipal Fund, Federation of Canadian Municipalities, the Pricing Carbon Pollution announced by Canada.ca, and the National Inventory Report for emission factors. Escalation rates may change in the future, however, varying the escalation rates does not change the overall impact.

Pricing Carbon Pollution, A Healthy Environment and A Healthy Economy. - www.canada.ca/content/dam/eccc/documents/pdf/climate-change/climate-plan/annex_pricing_carbon_pollution.pdf

Assumptions	
Inflation (current consumer price index)	2.20%
Escalation rate - Utilities - Elec	5.00%
Escalation rate - Utilities - Gas	10.00%
Escalation rate - Utilities - Water	4.50%
Escalation rate - Labor and maintenance	5.00%
Discount Rate	2.20%
Amortization Period (yrs)	30

Carbon pricing assumptions	
Year	**$/tonne**
2021	$40.00
2022	$50.00
2023	$65.00
2024	$80.00
2025	$95.00
2026	$110.00
2027	$125.00
2028	$140.00
2029	$155.00
2030	$170.00
2031 - 2039	+ $15.00/year up to 300$/tonne max
2040 - 2051	$305.00

Emissions table CO2e				
Province	**Electricity**	**Gas**	**Water**	**Propane**
	tonnes/kWh	**tonnes/m3**	**tonnes/m3**	**tonnes/m3**
Ontario	0.000030	0.001915	0.00013	1.51513

Source: National Inventory Report published April 2021

Utility Rates 2021 Pricing Assumptions	
Electricity	0.17 $/kWh
Gas	0.33 $/$m^3$
Water	4.00 $/$m^3$

9 Appendix C Total Emissions Reduction (tonnes CO2e) by rink and by system

System	Arena									
	Ice Rink 1	Ice Rink 7	Ice Rink 3	Ice Rink 2	Ice Rink 5	Ice Rink 8	Ice Rink 6	Ice Rink 4	Ice Rink 9	Total
Refrigeration Plant	112.1	140.8	84.4	88.1	101.8	46.6	58.0	1.9	2.5	636.3
Heating	157.3	39.2	87.4	34.9	27.2	45.8	13.6	38.4	6.1	449.7
Resurfacing	122.5	49.2	30.6	72.8	13.8	29.5	18.0	11.6	13.9	362.0
Ventilation	45.3	56.3	44.0	36.4	17.0	13.8	22.2	9.7	0.0	244.8
Dehumidification	103.4	45.0	28.5	26.5	4.8	3.6	3.6	18.8	3.0	237.2
Renewables	8.0	59.9	20.5	9.4	10.3	4.5	10.8	15.4	0.0	138.9
Enclosure	20.0	7.2	19.5	18.5	4.7	4.3	6.8	9.8	0.0	90.8
Water	0.0	4.1	3.2	0.0	3.5	3.5	5.0	0.0	4.9	24.2
BAS	0.0	0.0	0.0	0.0	0.0	0.0	6.5	0.0	0.0	6.5
Lighting	0.4	-0.6	-3.4	0.0	0.0	-0.6	-0.3	3.5	0.0	-1.0
TOTAL	**569**	**401**	**315**	**287**	**183**	**151**	**144**	**109**	**30**	**2189**