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MEADOW PARK SPORTS CENTRE – CLEAN COMMUNITIES FUND

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Clean Communities Fund Feasibility Study

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PREPARED FOR:
Resort Municipality of Whistler
4325 Blackcomb Way
Whistler, BC V8E 0X5
T (604)-932-5535

ATTN:
Andy Chalk
Capital Projects Supervisor, Resort Operations
E achalk@whistler.ca

PREPARED BY:
Ryan Antonsen, EIT
Building Performance Specialist
E ryanantonsen@amegroup.ca

REVIEWED BY:
Mike Kasuya, AScT, PTech, CPHD, LEED AP BD+C
Principal
E mikekasuya@amegroup.ca

Scott Stewart, P.Eng., CPHD, LEED AP
Associate
E scottstewart@amegroup.ca

200-638 Smithe Street, Vancouver BC V6B1E3
T 604-684-5995

Permit to Practice No: 1000236
PROFESSIONAL
PROVINCE OF
S. K. STEWART
#30441
BRITISH COLUMBIA
ENGINEER
2022-05-20

PROFESSIONAL'S SEAL & SIGNATURE

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1. EXECUTIVE SUMMARY

The AME Group was retained by the Resort Municipality of Whistler (RMOW) to carry out a feasibility study investigating decarbonization measures at the Meadow Park Sports Centre (MPSC); this study was carried out in pursuit of an application to CleanBC's Clean Communities Fund (CCF). This report investigates a series of different options to upgrade MPSC's mechanical systems and envelope including installing heat recovery to the arena-side ventilation systems from the refrigeration plant's desuperheater, installing cross-connections between the arena-side heat recovery system and the pool's heating systems, upgrading the envelope of the building to address known air leakage issues, and the addition of an electric boiler to the pool's heating systems.

It is recommended that BDL-2 is considered for implementation, which includes implementing heat recovery capacity in the arena, interconnecting said heat recovery system with the pool's heating system, upgrading the envelope, and adding an electric boiler as an intermediate source of heat to the pool heating system. This measure achieves significant emission and utility cost savings and addresses a number of known operational issues in the building.

The expected savings results of the measures investigated are summarized in the table below.

Table 1: Summary of System Energy Consumption Under Different Upgrade Options

ECM No.	Description	Annual Gas Consumption (GJ/y)	Annual Incremental Electricity Consumption (kWh/y)	Annual System Emissions (tCO_2e/y)	Annual Utility Costs ($/y)	2030 Annual Carbon Tax ($/y)	Incremental Capital Costs ($)
EXIST	Existing Building	5,676	2,173,026	304.1	$212,160	$41,059	N/A
ECM-1	Arena-Side Heat Recovery	2,882	2,212,700	165.2	$197,454	$22,302	$1,472,800
ECM-2	Interconnection Between Arena and Pool	649	2,498,652	56.6	$200,675	$7,644	$1,684,200
ECM-3	Envelope Upgrade	3,683	2,009,943	203.2	$186,199	$27,428	$9,034,200
ECM-4	Electric Boiler	4,440	2,499,167	245.7	$231,807	$33,165	$301,075
BDL-1	Bundle 1: Interconnection + Envelope	157	2,252,737	29.7	$179,443	$4,010	$10,718,400

ECM No.	Description	Annual Gas Consumption (GJ/y)	Annual Incremental Electricity Consumption (kWh/y)	Annual System Emissions (tCO_2e/y)	Annual Utility Costs ($/y)	2030 Annual Carbon Tax ($/y)	Incremental Capital Costs ($)
BDL-2	Bundle 2: Interconnection, Envelope, and Electric Boiler	87	2,271,425	26.4	$182,558	$3,557	$11,019,475
BDL-3	Bundle 3: Interconnection, Envelope, and RNG	157	2,252,737	21.9	$181,220	$2,950	$11,019,475

Table 2: Summary of System Energy Savings Under Different Upgrade Options

ECM No.	Description	Annual Gas Savings (GJ/y)	Annual Incremental Electricity Savings (kWh/y)	Annual Emission Savings (tCO_2e/y)	Annual Utility Cost Savings ($/y)	2030 Annual Carbon Tax Savings ($/y)	Incremental Capital Costs ($)
ECM-1	Arena-Side Heat Recovery	2,794	(39,674)	139	14,706	18,757	$1,472,800
ECM-2	Interconnection Between Arena and Pool	5,027	(325,626)	248	11,485	33,415	$1,684,200
ECM-3	Envelope Upgrade	1,993	163,083	101	25,961	13,631	$9,034,200
ECM-4	Electric Boiler	1,236	(326,141)	58	(19,647)	7,894	$301,075
BDL-1	Bundle 1: Interconnection + Envelope	5,519	(79,711)	274	32,717	37,049	$10,718,400
BDL-2	Bundle 2: Interconnection, Envelope, and Electric Boiler	5,589	(98,399)	278	29,602	37,502	$11,019,475
BDL-3	Bundle 3: Interconnection, Envelope, and RNG	5,519	(79,711)	282	30,940	38,109	$11,019,475

2. ABBREVIATIONS

AHU	Air Handling Unit
BAS	Building Automation System
CHWS	Chilled Water Supply
COP	Coefficient of Performance
DDC	Direct Digital Control
DHW	Domestic Hot Water
ECM	Energy Conservation Measure
GHGI	Green House Gas Intensity
GJ	Gigajoule
GSHP	Geo-Source Heat Pump
GWP	Global Warming Potential
HRC	Heat Recovery Chiller
HWST	Heating Water Supply Temperature
HX	Heat Exchanger
kWh	Kilowatt Hour
MBH	Thousand British Thermal Units per Hour
MUA	Make Up Air
MWh	Megawatt Hour
OAT	Outdoor Air Temperature
O&M	Operation and Maintenance
tCO2e	Tonnes of Carbon Dioxide Equivalent
SAT	Supply Air Temperature
TEDI	Thermal Energy Demand Intensity
VFD	Variable Frequency Drive
EUI	Energy Use Intensity

3. INTRODUCTION

The AME Consulting Group was retained by the Resort Municipality of Whistler (RMOW) to carry out a feasibility study investigating decarbonization measures at Meadow Park Sports Centre (MPSC) in Whistler, BC; this study was completed in pursuit of CleanBC's Clean Communities Fund (CCF). As outlined in the CCF program guide, decarbonization measures applied under the program are primarily intended to conserve greenhouse gas (GHG) emissions but are also expected to improve public infrastructure and improve the climate resiliency of public property.

Four different energy conservation measures (ECMs) are included in this study, including the following:

1. Incorporating mechanical equipment to MPSC's arena that will allow for improved heat recovery between occupied spaces and the refrigeration plant
2. Investigating the net benefit of connecting the same heat recovery system to the building's pool heating system
3. Investigating an envelope upgrade as described by RJC under separate cover
4. Investigating the benefits of installing an electric boiler to the pool's heating system.

These measures are combined to three different ECM 'bundles', to highlight their performance when implemented simultaneously.

3.1 Background Information

AME and RJC have assisted the RMOW in installing different mechanical upgrades and adjustments to MPSC over the last decade, with decarbonization efforts focused primarily on the building's pool heating systems. With air handling units (AHUs) serving the arena-side planned for end-of-service-life replacement, and with a recent air tightness test revealing a high volume of air leakage from the building's envelope, the opportunity exists to upgrade the building more holistically to allow for heat recovery and heat retention throughout as many occupied spaces as possible, including both the arena and pool areas. These upgrades align with the goals of the CCF program, making MPSC a prime applicant for incentives.

3.2 Report Purpose

This report is intended to describe the proposed scope of work to upgrade MPSC, to show the amount of expected energy savings, emission savings, and impact on utility costs from the implementation of deep-retrofit decarbonization measures. This report includes a description of the concept design carried out by AME regarding these upgrades, including sketches and written descriptions of how different components of the new systems would be expected to perform and how different measures may interact. To ensure that the analysis of these measures is as transparent as possible, key input quantities and assumptions regarding the operation of the building are described in this report; a separate file showing calculations will also be made available to the CCF evaluation team. Costing for investigated measures was carried out by BTY Quantity Surveyors, see costing report submitted under separate cover.

This report also describes other required information for program evaluation purposes, including exclusions from the analysis and known risks to the implementation of the decarbonization measures proposed.

3.3 Rationale for Greenhouse Gas Emission Savings

Under the CCF program, different proposed measures are meant to fall under one of four different types of decarbonization measures – all the measures investigated in this report fall under the CCF's Option 3 decarbonization measure type, meaning that they all seek to "increase energy efficiency of buildings". This informs the process undertaken to analyze the impact of investigated measures, including the fact that the analysis of system operation is limited to within the existing building and its existing infrastructure and services.

Moreover, all of the measures investigated in this report are either predicated on retaining heat within the envelope as much as possible or directly 'fuel-switching' the heating load where it would otherwise be expected to be met with the burning of fossil fuels.

4. BUILDING CONDITIONS

This section describes the existing building condition; this provides context for the current operation and energy efficiency of the building.

4.1 Building Description

MPSC is situated along BC's highway 99 and serves as the community's main hub for ice skating and swimming activities.

.1 Building Divided Into Two Sections

MPSC is divided into two primary areas, including the pool (south) and the arena (north); these two spaces are connected by a common lobby, administrative space, corridors, and a fitness studio. These two areas are currently mechanically separate from one another, with the pool's heating systems dedicated to the heating of the pool and reheating of ventilation air on the pool side. The air handling units on the arena-side have gas-fed heating capacity; domestic hot water heating capacity and storage are also divided between the pool and arena.

.2 Pool Heating System

The pool's heating systems have been upgraded with several different electrified sources of heat, including a geo-field heat pump plant, solar collectors, and an air-source heat pump; the pool's heating is topped-up with heat from condensing boilers. The pool's heating system is split into a medium-temperature header and a high-temperature header. The medium-temperature header is heated by the building's electrified heat sources, and the high-temperature header is heated by the boiler plant. The medium-temperature header and high-temperature header are connected via a heat exchanger to allow heat from the high-temperature header to be transferred to the medium-temperature header when required.

A photo of the heat pump plant in the pool-side mechanical room is shown below.

Figure 1: Pool-Side Heat Pump Plant

The pool's heating system is also interconnected with its dehumidification system – the pool's dehumidifier (AHU-201) is able to cool and dehumidify return air from the natatorium air, cool exhaust air, and reheat cold mixed air to meet the supply air temperature setpoint. This effectively allows the water-to-water heat pump serving the geo-thermal system to access reclaimed heat from the dehumidification process at the cost of also needing to reheat the cold, dry mixed air.

A schematic diagram of the dehumidifier is shown below.

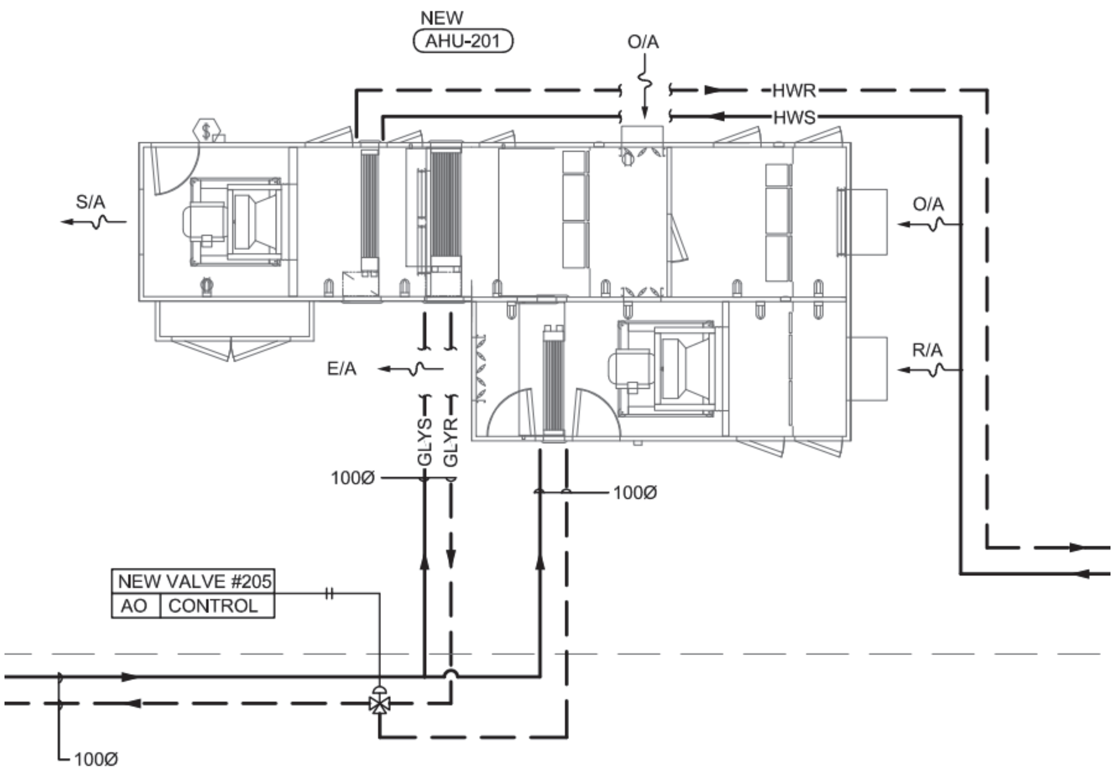

Figure 2: Dehumidifier Schematic Diagram (Source: Dehumidifier IFC Drawings, AME Group, 2019)

.3 Arena Mechanical Systems

The arena's heating and ventilation are both provided by separate packaged air handling units distributed around the north side of the building. Two make-up air units (MUA-1 and MUA-2) provide heated outdoor air to the changerooms underneath the Arena's bleachers, and both have gas-fired heating capacity.

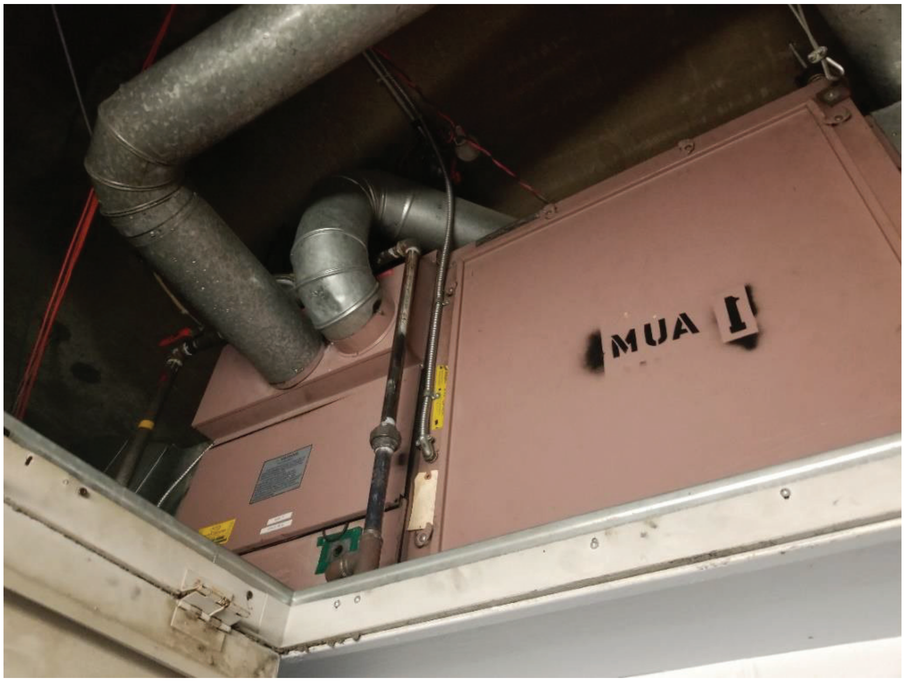

Figure 3: MUA-1 Site Photo

Figure 4: MUA-2 Site Photo

One (1) air handling unit (AHU-1) provides ventilation to the rink lobby area also using gas fired heating and is shown in the figure below.

Figure 5: AHU-1 (Lobby Space) Site Photo

One (1) air handling unit (AH-1) situated adjacent to the Arena provides ventilation to spaces with gas-fed heating between the Arena and the Cardio and Weight Rooms and is shown in the figure below.

Figure 6: AH-1 Site Photo

The Cardio and Weight Rooms themselves are ventilated with gas fired heating by two (2) air handling units situated on the central roof, shown in the following figure.

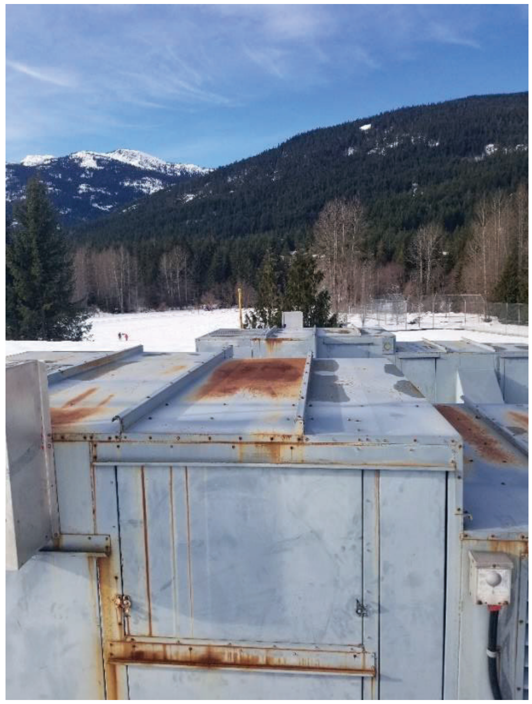

Figure 7: AHU-1 and AHU-2 (Cardio and Weight Room) Site Photo

A summary of ventilation equipment for the Arena is shown in the following table.

Table 3: Arena-Side Ventilation Summary Table

Equipment Tag	Service Area	Supply Airflow
MUA-1	Arena Changerooms	2,700 CFM
MUA-2	Arena Changerooms	4,000 CFM
AHU-1	Arena Lobby Spaces	4,900 CFM
AH-1	Shared Spaces	12,000 CFM
AHU-1	Fitness Spaces	4,000 CFM
AHU-2	Fitness Spaces	2,500 CFM

.4 Known Operational Issues

At time of writing, operational issues are known to exist on site that may be mitigated through the decarbonization measures considered in this study.

Firstly, the air-source heat pump serving the pool's heating system is undergoing recommissioning due to operability issues in cold weather; this is due to the fact that air-source heat pumps do not operate as effectively – or at all – in cold outdoor weather due to derating in their heating capacity and heating coefficient of performance (COP). It is suspected that below outdoor air temperatures of -9°C, the air-source heat pump will not be able to operate at all, meaning that the geo-thermal plant and solar collectors will be the only sources of electrified heating available to the pool. Because of Whistler's climate, these conditions occur regularly, meaning that the boilers are operated often to act as top-up heat to the pool.

Secondly, a recent air tightness test revealed that the Arena's envelope has a significant amount of air leakage – during the test, the targeted test pressure could not be achieved due to excessive leakage from around the glazing at the top of the arena walls. This leakage increases cooling demand on the arena space in summer and increases heating demand in winter due to the loss of conditioned air to the outdoors.

Finally, the desuperheater connected to the refrigeration plant is currently used only to pre-heat water for the resurfacing of the ice rink; according to building staff, the water used for resurfacing often reaches high temperatures through the desuperheater; this is expected to be because the desuperheater has an excess of available heat and currently can only provide its heat to the resurfacing water or be released to the outdoors.

.5 Effect of Pool Air Condition Setpoints

Because the heating systems being analyzed include the heating and dehumidification of natatorium air, it is important to acknowledge the effects of the air condition setpoints in the pool space. Pool spaces require a significant amount of energy, and that amount of energy is largely dependent on what condition the air in the pool space is set to. Put simply, when the pool air condition is warm and humid it is harder for water from the pool to evaporate into the natatorium air and the demand on the dehumidification system and pool heating system decreases, and when the pool air condition is cold and dry water can evaporate quickly and demand on the dehumidification system and pool heating system increases.

In AME's analysis, the demand on the dehumidification system was quantified under the assumption that the pool air would be conditioned to meet a constant dry-bulb temperature setpoint and relative humidity setpoint, which was then adjusted to corroborate with historical utility data.

To ensure that the new system is being quantified fairly, the same pool air conditions were assumed for both calculations for the existing pool heating and dehumidification systems and the various retrofitted versions of the pool heating and dehumidification. If the new systems were to be implemented and the building staff changed the temperature and humidity setpoints in the pool area after the retrofit was complete, the system's energy requirements could shift significantly and therefore have an impact on the expected savings. To compare the system fairly between the base and retrofit case, the same pool air conditions should be assumed.

4.2 Building Energy, Utility Cost, and Emissions

The building's overall energy consumption and current emissions are described in the following sections. This energy consumption reflects the 2019 calendar year, accounting for the fact that building energy usage shifted significantly during COVID-19 lockdown conditions in the 2020 calendar year onward.

.1 Energy Consumption Summary

The energy consumption of MPSC is summarized in the table below.

Table 4: 2019 Energy Usage Summary Table

Utility Type	Consumption (ekWh)	Utility Costs ($)	Emissions (tCO_2e)
Electricity	2,173,026	141,292	21
Natural Gas	1,576,668	43,742	283

.2 Energy Consumption Source Type Breakdown

The energy consumption is broken out by source type in the following figure.

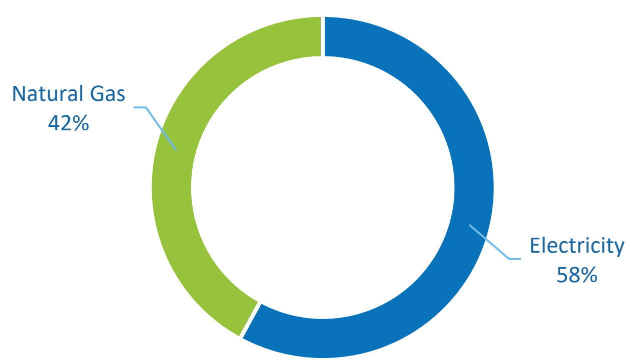

Figure 8: 2019 Energy Consumption by Source Type

As shown in the previous figure, natural gas accounts for 42% of the energy consumed in the building, with the other 58% by electricity.

.3 Utility Cost Source Type Breakdown

The energy utility cost is broken out by source type in the following figure.

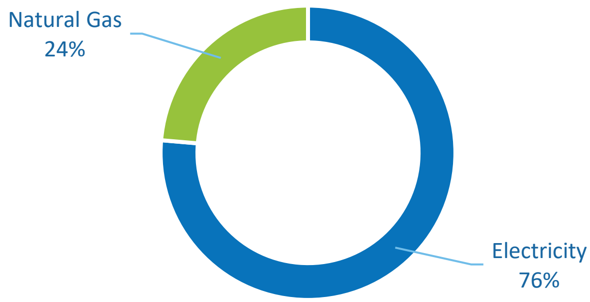

Figure 9: 2019 Utility Cost Breakdown by Source Type

As shown in the previous figure, natural gas costs made up 24% of utility costs in 2019, with the other 76% owing to electricity; this reflects the fact that electricity is more expensive per unit energy than natural gas.

.4 Emission Source Type Breakdown

The energy-related emissions of the building are broken out by source type in the following figure.

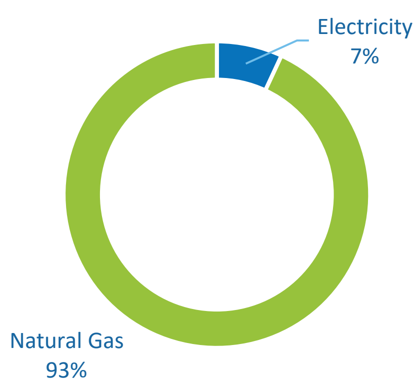

Figure 10: 2019 Emission Breakdown by Source Type

As shown in the previous figure, natural gas accounts for 93% of the energy-related emissions in the building, with the remaining 7% owing to electricity consumption. This shows that even though natural gas represents less than half of the building's energy consumption, it represents a much greater proportion of the building's emissions. This also reflects the fact that electricity is not completely free of emissions.

4.3 Building Retrofit Summary

To provide a holistic summary of the building's priorities for mechanical and envelope upgrades, the following table outlines key priorities that decarbonization measures could help to address.

Table 5: Summary of Building Retrofit Priorities

Key Factor	Description	Methods for Improvement
Air-Source Heat Pump Control Issues	- The ASHP connected to the pool's heating system is being re-commissioned to ensure that it operates as much as possible. - It is expected that low temperature causes significant derating, limiting hours when the ASHP can be operated.	- Other sources of heat that are not required to extract heat from cold outdoor air conditions may be put in place to act as intermediate heat sources in winter. Added forms of electrified heating should no longer rely on extracting heat from the outdoors. - Current geo-thermal heat pump plant and solar collectors are known to mitigate part of the heating demand of the pool, but heat from the boiler plant is known to be required frequently.
Significant Air Leakage from Arena Envelope	- Recent air tightness test revealed that significant air leakage from the arena's upper glazing exists. - Pool air leakage is much lower than the arena.	- Arena glazing may be replaced to mitigate as much air leakage as possible. - Envelope may be upgraded where necessary to minimize heat loss to the environment while also improving the longevity of the building as a whole.
Gas Consumption Less Than 50% of Building Energy Use	- Systems are already in place to electrify the pool heating system. - The Arena's heating systems are not electrified, are at the end of their expected service life, and are planned for replacement.	- To decarbonize the building further, decarbonization measures should focus on spaces not yet retrofitted with electrified options or else allow heat to be recovered between different occupied spaces.
Desuperheater expected to have excess available heat	- The arena's desuperheater is claimed to overheat at times, meaning that an excess of heat is available to be reclaimed.	- Any heat recovery system implemented in the building should plan to include infrastructure to cool the refrigeration plant's desuperheater.

5. KEY INPUTS AND ASSUMPTIONS

To provide greater clarity on key quantities used in the analysis for the proposed measures described in this report, key inputs, assumptions, and exclusions are described in the following sections.

5.1 Key Assumed Quantities

Key assumed quantities are summarized in the following table.

Description	Assumed Quantity	Units	Notes
Natural Gas Emission Factor	49.87 (0.1795)	$kgCO_2e/GJ$ ($kgCO_2e/kWhe$)	Taken from 2020 BC Best Practices Methodology for Quantifying Greenhouse Gas Emissions
Electricity Emission Factor	0.0097 (2.69)	$kgCO_2e/kWh$ ($kgCO_2e/GJe$)	Emission Factor for the 2021 Reporting Year Under the Greenhouse Gas Industrial Reporting and Control Act (GGIRCA)
Natural Gas Charge Rate	7.7	$/GJ	Taken from Historical Utility Data, using 2021 as reference
Electricity Consumption Charge Rate	0.0606 (16.83)	$/kWh ($/GJe)	Consumption charge rate under BC Hydro's Large General Service Rate
Electrical Demand Charge Rate	12.34	$/kW	Demand charge rate under BC Hydro's Large General Service Rate
Pool Area Assumed DB Temperature	29	°C	Pool Area DB Temperature assumed to be maintained as a constant throughout the year
Pool Area Assumed Relative Humidity	90	%	Pool Area Relative Humidity assumed to be maintained as a constant throughout the year

The assumed pattern of the federal and provincial carbon tax applied in the financial analysis is shown below.

Table 6: Assumed Carbon Tax Pattern

Year	Carbon Tax Charge Rate
2021	$40 /$tCO_2e$
2022	$50 /$tCO_2e$
2023	$65 /$tCO_2e$
2024	$80 /$tCO_2e$
2025	$95 /$tCO_2e$
2026	$110 /$tCO_2e$
2027	$125 /$tCO_2e$
2028	$140 /$tCO_2e$
2029	$155 /$tCO_2e$
2030 Onwards	$170 /$tCO_2e$

5.2 Exclusions from Analysis

Specific exclusions from the analysis are summarized in the table below.

Table 7: Summary of Exclusions

Exclusion Label	Description of Exclusion	Rationale for Exclusion
Climate Resiliency-Specific Measures Excluded	- Measures carried out with the specific purpose of mitigating risk against climate disasters such as wildfire or pluvial flooding are not prioritized in this study.	- Due to the retrofitting priorities for the building, the main goals in upgrading the building target the reduction of building emissions through energy conservation via improvements in energy efficiency and fuel switching rather than building new infrastructure made only for improving climate resiliency. - Some of the measures examined for the purposes of energy conservation are also expected to benefit the climate resiliency of the building; these are co-benefits of the measure and are described qualitatively. - Quantitative analysis into climate resiliency of considered upgrades was not pursued.
Scope Three Emissions Excluded from Analysis	- Emissions caused by the implementation of measures that result from activities or assets not owned or controlled by the RMOW are excluded from the analysis.	- Emissions associated with downstream effects of implementation of the proposed measures depend greatly on the method chosen for implementation and are thus not accurately quantifiable in the concept design stage. - Emissions associated with on-site burning of natural gas (Scope One) and off-site electricity generation (Scope Two) with and without the implementation of the proposed measures are included in the analysis.

6. ENERGY CONSERVATION MEASURE (ECM) DESCRIPTIONS

6.1 ECM-1: Arena-Side Heat Recovery

The first measure includes the installation of a heat recovery chiller within the arena-side; this would be done without any interconnection to the pool heating systems.

.1 Base Case

The base case for this measure is considered to be the replacement of existing air handling units serving the arena-side with like-for-like models without hydronic heating connections, such that the ventilation systems serving the arena-side of the building operate similarly to how they currently run and with the same thermal efficiency.

.2 Measure Description

Under this measure, a heat recovery chiller would be installed in the small mechanical room space in the north-west corner of the building; this heat recovery chiller would be installed to provide heating and cooling to the make-up air units and air handling units serving the changerooms, hallways, arena lobby, administrative spaces, and fitness studio. The heat recovery chiller would be connected to a hydronic switchover coil in each of these air handlers; this would allow for any simultaneous heating and cooling between occupied spaces to be used to recover heat from spaces requiring cooling to spaces requiring heating. This system would also connect to the desuperheater in the refrigeration plant as a source of heat and would help pre-heat the arena-side domestic hot water service. This would effectively allow excess heat from the desuperheater to be used to heat occupied space and domestic hot water on the arena-side.

.3 Design Considerations

This system would depend heavily on the desuperheater as a heat source, since simultaneous heating and cooling demand between occupied space is expected to be relatively rare except for in shoulder season conditions. All of the systems connected to the heat recovery chiller would still require full back-up heating capacity, as the amount of heat recovery possible will change hour-by-hour and spaces will still require heating during winter months when only heat recovery from the desuperheater is available.

.4 Principles of Energy Savings

This measure reduces GHG emissions through the improvement of energy efficiency – by retaining as much heat within the building as possible during winter conditions and operating a heat recovery chiller at a favorable coefficient of performance, the heating demand of the building can be met with a lower quantity of energy as well as by a less emission-intense energy type.

.5 Added Climate Resiliency

Although the purpose of this measure focuses on the conservation of natural gas and reduction of emissions in the arena ventilation systems, this measure does include the opportunity to select new air handling units capable of using filters appropriate for use during wildfire conditions.

.6 Energy Savings Results

The energy savings for this measure are summarized in the table below.

Table 8: ECM-1 Energy Savings Summary

ECM No.	Description	Annual Gas Savings (GJ/y)	Annual Incremental Electricity Savings (kWh/y)	Annual Emission Savings (tCO_2e/y)	Annual Utility Cost Savings ($/y)	2030 Annual Carbon Tax Savings ($/y)	Incremental Capital Costs ($)
ECM-1	Arena-Side Heat Recovery	2,794	(39,674)	139	14,706	18,757	$1,472,800

6.2 ECM-2: Interconnection Between Arena and Pool

After the implementation of ECM-1, the opportunity would exist to connect the arena's new heat recovery system to the pool's heating system; this would effectively allow heat to be recovered from the arena's desuperheater to the pool.

.1 Base Case

The base case for this measure would be the same as described under ECM-1.

.2 Measure Description

In this measure, the same scope of work described in ECM-1 would be carried out in addition to implementing two heat exchanger connections would be made: one between the medium temperature header heating the pool and the heating water from the arena's heat recovery chiller, and another between the geo-field's chilled water circulation line and the heat recovery chiller's chilled water supply.

This would have two effects – the heat pump system in the pool's heating system would have access to a new heat source and heat sink from the arena, and the arena's heat recovery chiller would have access to a new heat source and heat sink from the pool. This creates a number of different co-beneficial conditions for the mechanical systems in the building, with several outlined below.

- If the pool does not have enough heat from the geo-field or heat pump, it can be heated by the arena's heat recovery chiller when conditions are favorable.
- If the pool has excess heat available from its dehumidification, it can use its heat pump plant to heat the ventilation and DHW in the arena-side.
- If the geo-field is not being actively cooled by the pool's heat pump plant, then the arena-side heat recovery chiller can cool the geo-field to heat the ventilation in the arena.
- If the pool's heat pumps reach their maximum heating capacity while trying to heat the pool, the arena-side heat recovery chiller would be able to help contribute to the heating load in the pool area.

.3 Design Considerations

The arrangement of this system does not require that the heat recovery chiller is located in the northwest mechanical room. The performance of the system would be very similar if the heat pump plant serving the pool was given additional heating capacity and was cross-connected to heating and cooling services in the arena. At time of writing, it is expected that more space will be available in the arena-side mechanical rooms than in the pool-side.

This measure would require effective controls to ensure that the pool-side heat pumps and the arena-side heat recovery chiller operate in tandem and do not operate counter-productively – without the right controls in place, the heat recovery chiller could 'rob' the pool heat pump plant of its heat and force the pool's back-up boilers to fire unnecessarily.

.4 Principles of Energy Savings

This measure reduces GHG emissions from the improvement of energy efficiency – by allowing the heat recovery system described in ECM-1 to provide heating and cooling to a greater variety of spaces, the building's heating demand can be met by the heat recovery system more often.

.5 Added Climate Resiliency

Although the purpose of this measure focuses on the conservation of natural gas and reduction of emissions in the arena ventilation systems and pool heating systems, this measure still offers the same co-benefit of ECM-1 by allowing the design team to select new air handling units capable of using filters appropriate for use during wildfire conditions.

.6 Energy Savings Results

The energy savings for this measure are summarized in the following table.

Table 9: ECM-2 Energy Savings Summary

ECM No.	Description	Annual Gas Savings (GJ/y)	Annual Incremental Electricity Savings (kWh/y)	Annual Emission Savings (tCO_2e/y)	Annual Utility Cost Savings ($/y)	2030 Annual Carbon Tax Savings ($/y)	Incremental Capital Costs ($)
ECM-2	Interconnection Between Arena and Pool	5,027	(325,626)	248	11,485	33,415	$1,684,200

6.3 ECM-3: Envelope Upgrade

The opportunity exists to have the envelope of the building upgraded to mitigate known air leakage issues around the glazing on the arena-side and small cracks admitting air out from the pool-side.

.1 Base Case

The base case for this measure would be the same as described under ECM-1.

.2 Measure Description

This measure would match the envelope upgrades described in RJC's concept design report; this would include the replacement of windows along the upper wall of the arena with triple-pane windows in addition to replacing EIFS and corrugated metal sections of the outer wall.

.3 Design Considerations

Replacement of the building envelope is expected to have a much higher capital cost per unit of associated energy and emission savings than other capital upgrades in the building; this measure should be considered for implementation more as a way of improving building longevity and maintaining public infrastructure.

.4 Principles of Energy Savings

This measure reduces GHG emissions through the improvement of energy efficiency – by mitigating the amount of air leaking from the building and lowering the amount of heat transfer through the walls of the building, the heating and cooling demand of the building will both be lowered.

.5 Added Climate Resiliency

Although the purpose of this measure focuses on the building's ability to conserve energy by mitigating heat loss through the envelope and air leakage, this measure also improves the climate resiliency of the building by sealing the building's built environment such that the building may be able to better withstand brief extreme heat events. This is possible since the envelope will be able to retain heat more effectively in winter and retain cold conditioned air in summer; if the building is partly conditioned overnight, the building will be better suited to maintain its temperature throughout the following day. This is also expected to improve the longevity of the building significantly.

.6 Energy Savings Results

The energy savings for this measure are summarized in the following table.

Table 10: ECM-3 Energy Savings Summary

ECM No.	Description	Annual Gas Savings (GJ/y)	Annual Incremental Electricity Savings (kWh/y)	Annual Emission Savings (tCO_2e/y)	Annual Utility Cost Savings ($/y)	2030 Annual Carbon Tax Savings ($/y)	Incremental Capital Costs ($)
ECM-3	Envelope Upgrade	1,993	163,083	101	25,961	13,631	$9,034,200

6.4 ECM-4: Electric Boiler

The pool's heating system is known to have issues using its air-source heat pump in cold outdoor conditions, making the prospect of using an electric boiler as an intermediate source of electrified heating considerable since Whistler experiences below-freezing temperatures for a significant portion of the year.

.1 Base Case

The base case for this measure would be the same as described under ECM-1.

.2 Measure Description

This measure would involve placing an electric boiler in the pool's mechanical room and using the electric boiler as an intermediate source of heat for the pool before calling upon the gas-fired condensing boilers as back-up. The system would prioritize heating the pool from excess heat recovered by dehumidifying the pool and from the geo-field and then the system would call upon the air-source heat pump to top up heat to the pool if outdoor weather conditions are favorable before finally activating the electric boilers. The amount of achievable savings from this measure would scale with the amount of electric boiler heating capacity installed – savings assume the installation of a 100kW electric boiler.

This measure would not necessarily seek to replace the existing boiler plant with electric boilers, but rather to have a small amount of electric boiler capacity available to mitigate a base load of natural gas-supplied heating to the pool in winter conditions.

.3 Design Considerations

This measure could require some rearrangement of mechanical equipment in the pool-side mechanical room to allow enough space for the electric boiler and to ensure enough access space is provided to the unit such that it can be maintained. This measure should also be considered with an allowance for an electric upgrade, since an electrical boiler will draw a significant amount of electrical power compared to an air-source heat pump. The amount of space required for the boiler and the amount of power required for the boiler both depend on the heating capacity of the boiler installed.

Because electric boilers act as electric heat sources with a coefficient of performance of only 1.0, they are not expected to save utility costs compared to using natural gas; this is because electricity is significantly more expensive per unit energy than natural gas, and the thermal efficiency of electric boilers is only 100% compared to the higher thermal efficiencies seen in air source heat pumps. Because of this, this measure would only be considered as an investment to directly mitigate emissions from the boiler plant through increased utility costs, as opposed to a retrofit that lowers building utility costs. Electric boilers are able to satisfy high temperatures, and thus the existing boiler plant would be able to operate with any heating water supply temperature and the electric boiler would still be able to assist in providing heating to the building.

.4 Principles of Energy Savings

This measure reduces GHG emissions from direct fuel-switching; a proportion of the heating demand that would have been met by the natural gas boilers will instead be met by the electric boiler. Unlike air-source heat pumps or heat recovery chillers, the electric boiler will provide its contribution to satisfy the heating load with a coefficient of performance of 1.0.

.5 Energy Savings Results

The energy savings for this measure are summarized in the following table.

Table 11: ECM-4 Energy Savings Summary

ECM No.	Description	Annual Gas Savings (GJ/y)	Annual Incremental Electricity Savings (kWh/y)	Annual Emission Savings (tCO_2e/y)	Annual Utility Cost Savings ($/y)	2030 Annual Carbon Tax Savings ($/y)	Incremental Capital Costs ($)
ECM-4	Electric Boiler	1,236	(326,141)	58	(19,647)	7,894	$301,075

6.5 BDL-1: Interconnection and Envelope Upgrade

This bundle combines ECM-1 (Arena-Side Heat Recovery), ECM-2 (Interconnection Between Arena and Pool), and ECM-3 (Envelope Upgrade) to discuss how they may have interactive effects on one another.

.1 Base Case

The base case for this measure is assumed to be the same as the base case described in ECM-1.

.2 Measure Description

This combination of measures would install heat recovery in the arena-side, install a cross-connection to the pool's heating systems from the heat recovery system in the arena, and upgrade the envelope. This would allow the heat recovery system between the arena and pool to satisfy a lower heating demand in the winter and lower cooling demand in the summer. The final top-up heat source in the system would be expected to be satisfied by the gas-fed boilers. This would act as a major upgrade to the building, while both upgrading the infrastructure of the envelope where it is needed as well as decarbonizing the mechanical systems of the arena and pool.

.3 Design Considerations

This combination would still require the existing gas boilers to be in place to act as the last available source of heat for the building; the boilers would keep their current heating capacity, since the achievable amount of heat recovery from the arena-side will shift hour-by-hour.

.4 Principles of Energy Savings

This bundle reduces GHG emissions from the improvement of energy efficiency – by retaining as much heat within the building as possible during winter conditions by recovering heat from the arena desuperheater and by improving the envelope performance, the heating demand of the building can be met with a lower quantity of energy as well as by a less emission-intense energy type.

.5 Energy Savings Results

The energy savings for this bundle are summarized in the following table.

Table 12: BDL-1 Energy Savings Summary

ECM No.	Description	Annual Gas Savings (GJ/y)	Annual Incremental Electricity Savings (kWh/y)	Annual Emission Savings (tCO_2e/y)	Annual Utility Cost Savings ($/y)	2030 Annual Carbon Tax Savings ($/y)	Incremental Capital Costs ($)
BDL-1	Bundle 1: Interconnection + Envelope	5,519	(79,711)	274	32,717	37,049	$10,718,400

6.6 BDL-2: Interconnection, Envelope Upgrade, and Electric Boiler

This bundle captures the same scope of work described in Bundle 1, with the addition of ECM-4 (Electric Boiler).

.1 Base Case

The base case for this measure is assumed to be the same as that described in ECM-1.

.2 Measure Description

This combination would account for the same upgrades described under Bundle 1, with the addition of an electric boiler to act as an intermediate electrified heat source. With these measures combined, the electric boiler would act not only as a top-up heat source for the pool but could also act as a heat source for the arena-side ventilation; this would all be implemented in tandem with an envelope upgrade. This would act as a major upgrade to the building with the addition of another form of electrified heating for the pool.

This measure would not necessarily seek to replace the existing boiler plant with electric boilers, but rather to have a small amount of electric boiler capacity installed to mitigate a base load of natural gas-supplied heating to the pool and the arena's ventilation heating in winter conditions.

.3 Design Considerations

This combination of measures would require extensive controls to ensure that the pool-side heat pump plant and the arena-side heat recovery chiller work co-operatively, that the geo-field, dehumidifier, and air source heat pump are activated as the first sources of top-up heat to the shared heating system, that the electric boiler is activated as an intermediate source of top-up heat, and that the condensing boiler plant is activated as the third and final source of top-up heat. Refer to previous sections for more design considerations for individual measures included in this measure bundle.

.4 Principles of Energy Savings

This bundle reduces GHG emissions from a combination of improved energy efficiency and fuel switching – in addition to retaining heat within the building by recovering heat from the arena desuperheater and improving the envelope, part of the remaining heating demand will be met through an electric boiler before being met by a natural gas boiler.

.5 Energy Savings Results

The energy savings for this bundle are summarized in the following table.

Table 13: BDL-2 Energy Savings Summary

ECM No.	Description	Annual Gas Savings (GJ/y)	Annual Incremental Electricity Savings (kWh/y)	Annual Emission Savings (tCO_2e/y)	Annual Utility Cost Savings ($/y)	2030 Annual Carbon Tax Savings ($/y)	Incremental Capital Costs ($)
BDL-2	Bundle 2: Interconnection, Envelope, and Electric Boiler	5,589	(98,399)	278	29,602	37,502	$11,019,475

6.7 BDL-3: Interconnection, Envelope Upgrade, and Renewable Natural Gas

An alternative to the installation of an electric boiler may be considered without capital costs – the building's purchasing agreements with Fortis BC could be updated to include a supply of Renewable Natural Gas (RNG).

.1 Base Case

The base case for this measure is assumed to be the same as that described in ECM-1.

.2 Measure Description

The opportunity exists to update MPSC's purchasing agreement with Fortis BC to receive RNG instead of conventional natural gas. This would not require any capital upgrades or installation of any secondary fuel lines and would be carried out purely by paying a premium for low emission fuel. RNG is gathered where methane would have been emitted to the atmosphere and is re-distributed as usable natural gas for heating purposes. Because methane has a much higher global-warming potential then carbon dioxide, releasing a kilogram of carbon dioxide has a smaller impact on the environment than releasing a kilogram of methane – thus, renewable natural gas can be a feasible way to decarbonize.

In this combination of measures, any top-up heating from the boilers after heat recovery has been fulfilled between the pool and arena and the air-source heat pump and other electrified heat sources have reached their heating capacity would be provided with RNG. This would effectively decarbonize the remainder of natural gas consumption in the building leftover from the electrification measures implemented.

.3 Design Considerations

RNG comes with several important considerations, starting with the fact that Fortis BC has not established their supply system for RNG to the extent that everyone in the province could switch to RNG; they are working to create a more reliable supply of RNG and are planning to provide a significant minority of their supply of natural gas as RNG by 2030, but at time of writing said effort is still underway. Because the RNG supply system is still in development, the price of RNG is also subject to significant changes; unlike conventional natural gas whose price is kept within a narrow margin year-over-year, the price of RNG could increase by as much as double or decrease by as much as half year-over-year depending on its supply. In addition, the use of RNG as the sole method for decarbonization creates a significant amount of risk since the responsibility of decarbonizing the fuel supply is essentially passed to the utility – if Fortis can no longer provide RNG for any amount of time, then RNG is no longer effective as a decarbonization measure. Because of this, AME recommends using RNG only for gas-fed systems that are called upon as back-up to an electrified source of heat.

In this combination of measures, however, much of the heating demand in the building would already be electrified, leaving a relatively small amount of natural gas consumption. Since the amount of natural gas in question is much lower than it would have been without electrification measures in place, the conversion to RNG can be made at a much lower cost premium. In addition, if the supply of RNG becomes interrupted, the building's emissions will not be as heavily impacted since electrification measures would already be in place. Refer to previous sections for more design considerations for individual measures included in this measure bundle.

.4 Principles of Energy Savings

This bundle reduces GHG emissions from a combination of improved energy efficiency and fuel switching – in addition to retaining heat within the building by recovering heat from the arena desuperheater and improving the envelope, the remaining heating demand will be met by burning a cleaner type of natural gas.

.5 Energy Savings Results

The energy savings for this bundle are summarized in the following table.

Table 14: BDL-3 Energy Savings Summary

ECM No.	Description	Annual Gas Savings (GJ/y)	Annual Incremental Electricity Savings (kWh/y)	Annual Emission Savings (tCO_2e/y)	Annual Utility Cost Savings ($/y)	2030 Annual Carbon Tax Savings ($/y)	Incremental Capital Costs ($)
BDL-3	Bundle 3: Interconnection, Envelope, and RNG	5,519	(79,711)	282	30,940	38,109	$11,019,475

7. FINANCIAL ANALYSIS

This section provides some insight to the financial life of the proposed decarbonization measures. Costs are represented in 2022 dollars.

7.1 Base Case

Before analyzing the expected utility cost and carbon tax cost of the decarbonization measures previously described, it is important to first understand what the expected cost of the base case system would be if only base case decarbonization efforts were carried out.

.1 Building Utility Cost Diagram

Since the carbon tax is expected to triple between time of writing and 2030, the utility cost of carbon will become more and more pronounced over time and would be reflected in increased natural gas prices. This effect is shown in the following cost diagram. Energy consumption is assumed to be consistent year-over-year for the sake of showing the relative impact of the carbon tax.

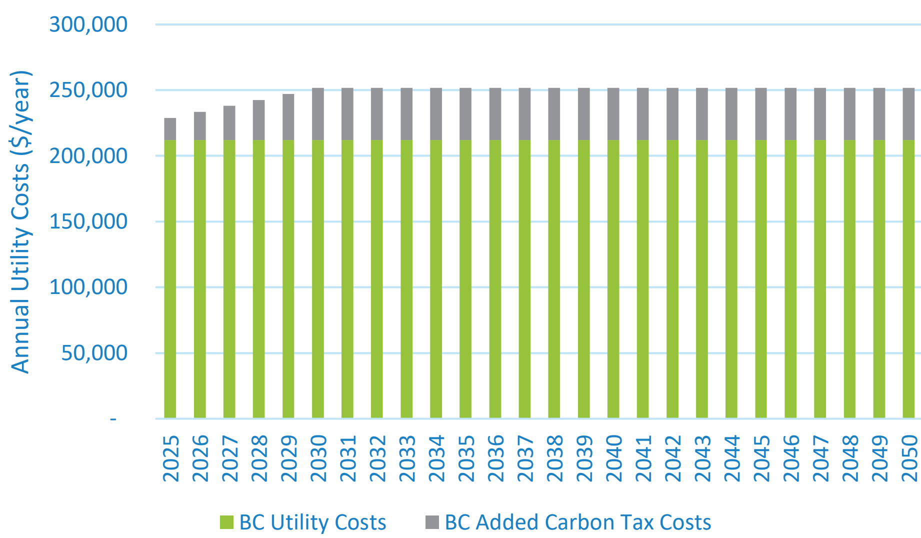

Figure 11: Base Case Utility Cost Diagram

As shown in the previous figure, the carbon tax is expected to represent as much as 16% of the building's total utility costs without implementing any decarbonization measures.

7.2 ECM-1: Arena-Side Heat Recovery Utility Cost Pattern

With the base case utility costs quantified, the utility costs associated with an upgraded system can be examined in a better context. A cost diagram showing the utility costs associated with the upgraded building under ECM-1 is shown in the following figure.

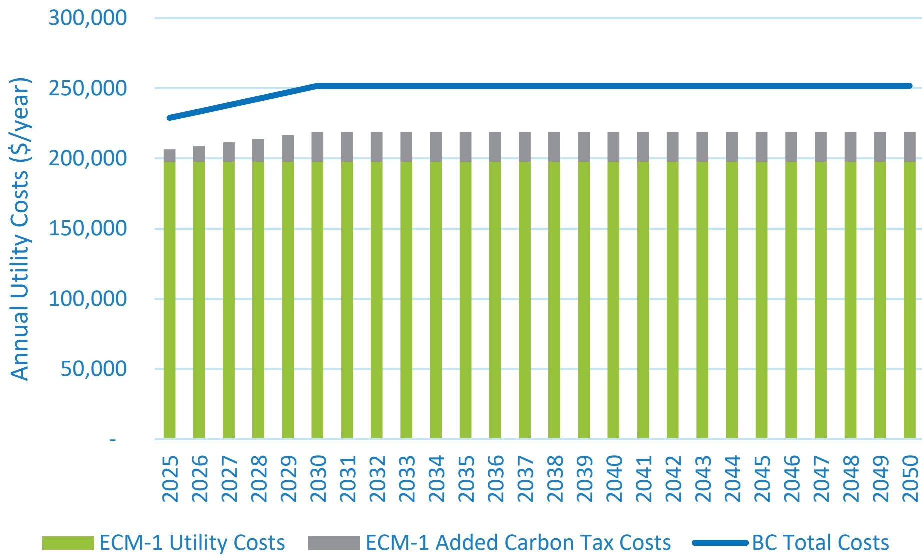

Figure 12: ECM-1 Utility Cost Diagram

As shown in the previous figure, the impact of the carbon tax is reduced significantly compared to the base case, in addition to a small decrease in utility costs. In 2030, the carbon tax would represent 10% of the total expected utility costs, and the overall utility cost is expected to be approximately $32,800 lower than the base case system.

7.3 ECM-2: Arena-Side Heat Recovery Utility Cost Pattern

A cost diagram showing the utility costs associated with the upgraded building under ECM-2 is shown in the following figure.

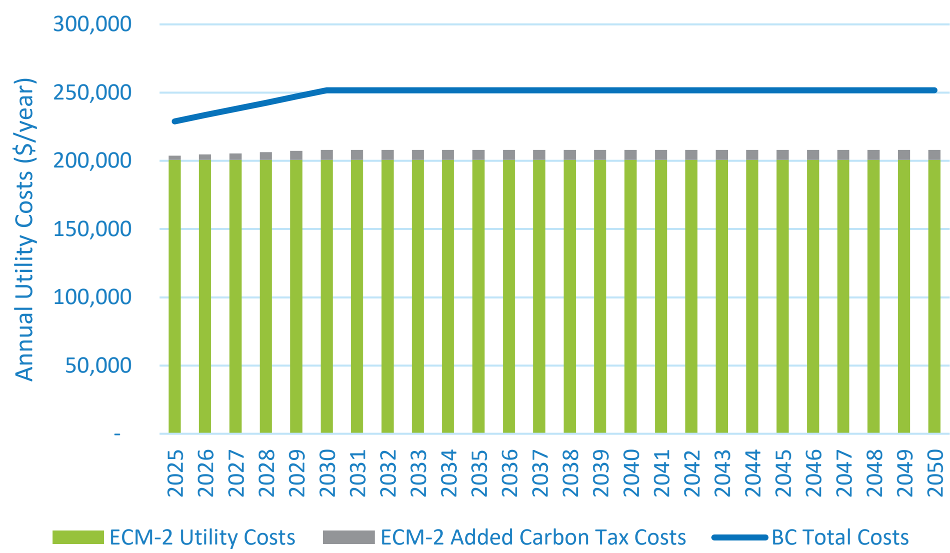

Figure 13: ECM-2 Utility Cost Diagram

As shown in the previous figure, the impact of the carbon tax is reduced significantly compared to the base case, in addition to a decrease in utility costs. In 2030, the carbon tax would represent 4% of the total expected utility costs, and the overall utility cost is expected to be approximately $43,700 lower than the base case system.

7.4 ECM-3: Envelope Upgrade Utility Cost Pattern

A cost diagram showing the utility costs associated with the upgraded building under ECM-3 is shown in the following figure.

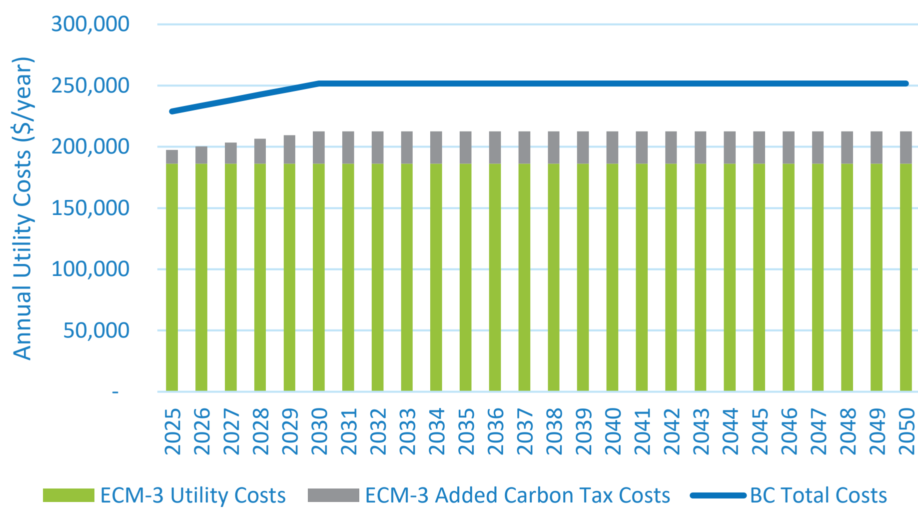

Figure 14: ECM-3 Utility Cost Diagram

As shown in the previous figure, the impact of the carbon tax is reduced slightly compared to the base case, in addition to a decrease in utility costs. In 2030, the carbon tax would represent 12% of the total expected utility costs, and the overall utility cost is expected to be approximately $39,100 lower than the base case system.

7.5 ECM-4: Electric Boiler Utility Cost Pattern

A cost diagram showing the utility costs associated with the upgraded building under ECM-4 is shown in the following figure.

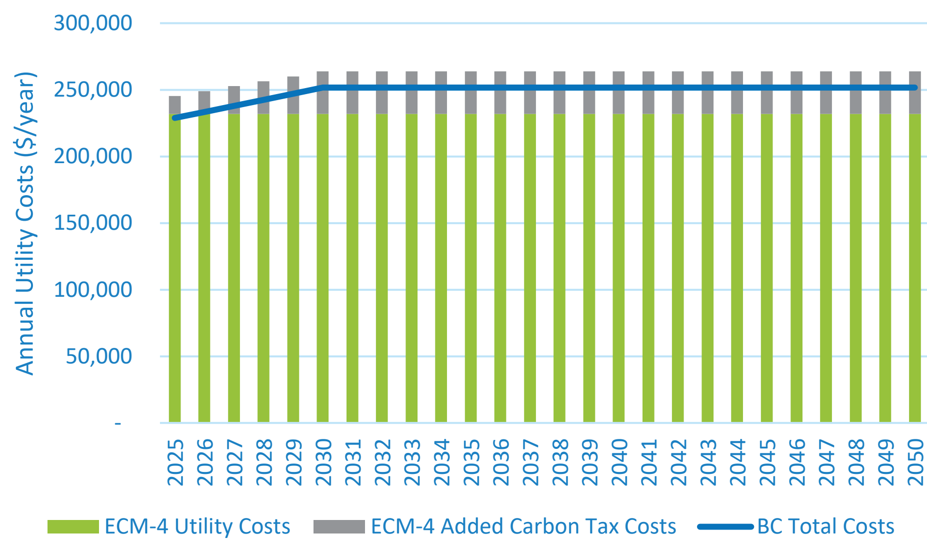

Figure 15: ECM-4 Utility Cost Diagram

As shown in the previous figure, the impact of the carbon tax is reduced only slightly compared to the base case, in addition to a significant increase in utility costs. In 2030, the carbon tax would represent 12% of the total expected utility costs, and the overall utility cost is expected to be approximately $12,000 higher than the base case system.

7.6 BDL-1: Interconnection and Envelope Upgrade Utility Cost Pattern

A cost diagram showing the utility costs associated with the upgraded system under BDL-1 is shown in the following figure.

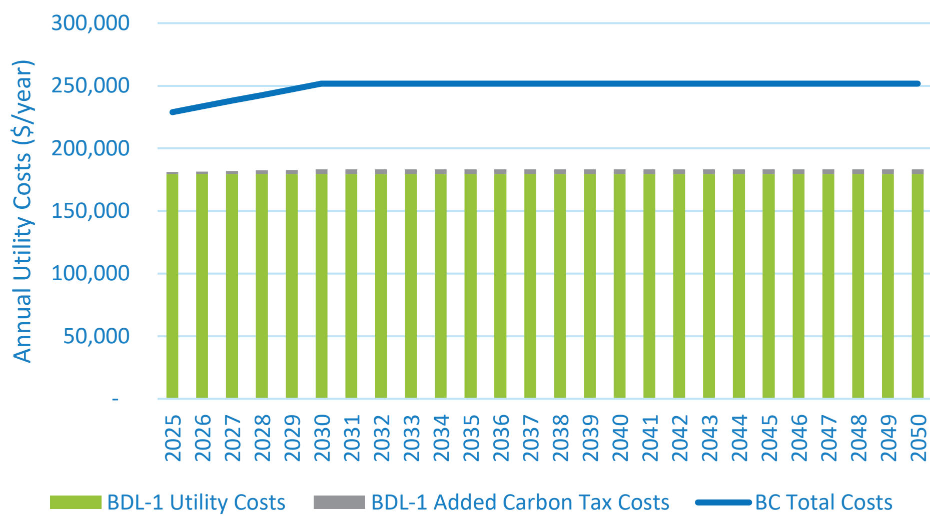

Figure 16: BDL-1 Utility Cost Diagram

As shown in the previous figure, the impact of the carbon tax is reduced significantly compared to the base case, in addition to a significant decrease in utility costs. In 2030, the carbon tax would represent 2% of the total expected utility costs, and the overall utility cost is expected to be approximately $68,400 lower than the base case system.

7.7 BDL-2: Interconnection, Envelope Upgrade, and Electric Boiler Utility Cost Pattern

A cost diagram showing the utility costs associated with the upgraded building under BDL-2 is shown in the following figure.

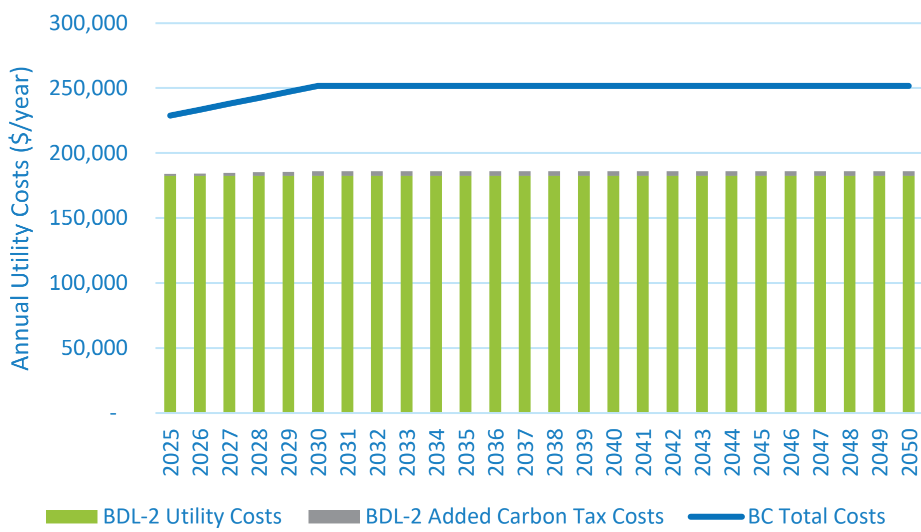

Figure 17: BDL-2 Utility Cost Diagram

As shown in the previous figure, the impact of the carbon tax is reduced significantly compared to the base case, in addition to a significant decrease in utility costs. In 2030, the carbon tax would represent 2% of the total expected utility costs, and the overall utility cost is expected to be approximately $65,700 lower than the base case system.

7.8 BDL-3: Interconnection, Envelope Upgrade, and Renewable Natural Gas Utility Cost Pattern

A cost diagram showing the utility costs associated with the upgraded system under BDL-3 is shown in the following figure.

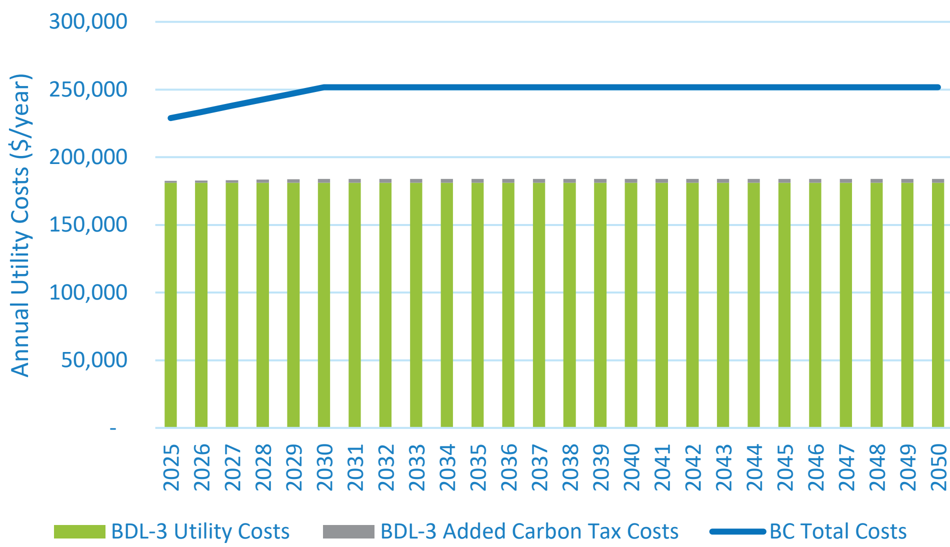

Figure 18: BDL-3 Utility Cost Diagram

As shown in the previous figure, the impact of the carbon tax is reduced significantly compared to the base case, in addition to a significant decrease in utility costs. In 2030, the carbon tax would represent 2% of the total expected utility costs, and the overall utility cost is expected to be approximately $67,600 lower than the base case system.

7.9 Capital Costs of Proposed Measures

The costs outlined in the costing report submitted under separate cover are summarized in the following tables; costs are broken out between the base and retrofit cases for each measure.

Table 15: Base Case Cost Summary

ECM No.	Architectural	Mechanical	Electrical	Total
ECM-1	$82,500	$1,143,900	$-	$1,226,400
ECM-2	$-	$62,400	$-	$62,400
ECM-3	$-	$-	$-	$-
ECM-4	$-	$-	$-	$-
BDL-1	$82,500	$1,206,300	$-	$1,288,800
BDL-2	$82,500	$1,206,300	$-	$1,288,800
BDL-3	$82,500	$1,206,300	$-	$1,288,800

Table 16: Retrofit Case Cost Summary

ECM No.	Architectural	Mechanical	Electrical	Total
ECM-1	$265,700	$2,433,500	$-	$2,699,200
ECM-2	$11,700	$262,100	$-	$273,800
ECM-3	$9,034,200	$-	$-	$9,034,200
ECM-4	$18,975	$175,200	$106,900	$301,075
BDL-1	$9,311,600	$2,695,600	$-	$12,007,200
BDL-2	$9,330,575	$2,870,800	$106,900	$12,308,275
BDL-3	$9,330,575	$2,870,800	$106,900	$12,308,275

The capital costs of proposed measures are shown below alongside the simple payback and percentage GHG savings associated with each measure. Simple payback does not consider inflation and takes the rising carbon tax into account in the following table.

Table 17: Capital Cost Summary

ECM No.	Incremental Capital Costs	Simple Payback (years)	Percentage GHG Savings	Lifetime Cost of Carbon Savings (tCO_2e)
ECM-1	$1,472,800	12.6	40.5%	530
ECM-2	$1,684,200	11.3	79.6%	340
ECM-3	$9,034,200	25+	26.8%	4,474
ECM-4	$301,075	N/A	11.5%	257
BDL-1	$10,718,400	25+	89.3%	1,953
BDL-2	$11,019,475	25+	90.5%	1,983
BDL-3	$11,019,475	25+	92.1%	1,952

The incremental capital costs of the mechanical upgrade scope of work total less than two million dollars, but do not improve the envelope of the building and are thus forced to provide additional heating and cooling to match the heat loss or heat gain through the envelope. While the amount of savings associated with the improvement of the envelope may not be as high per dollar invested as the savings associated with the mechanical upgrade, the improvement of the envelope is an important step in improving the longevity of the building and would mitigate demand on the heating and cooling of the building.

7.10 Cumulative Cash Flow of Proposed Measures

To compare the financial performance of these measures directly, the cumulative savings for each project accounting for capital cost is shown in the following figure. This diagram assumes that 74% of the projects' capital costs will be covered by the CCF program.

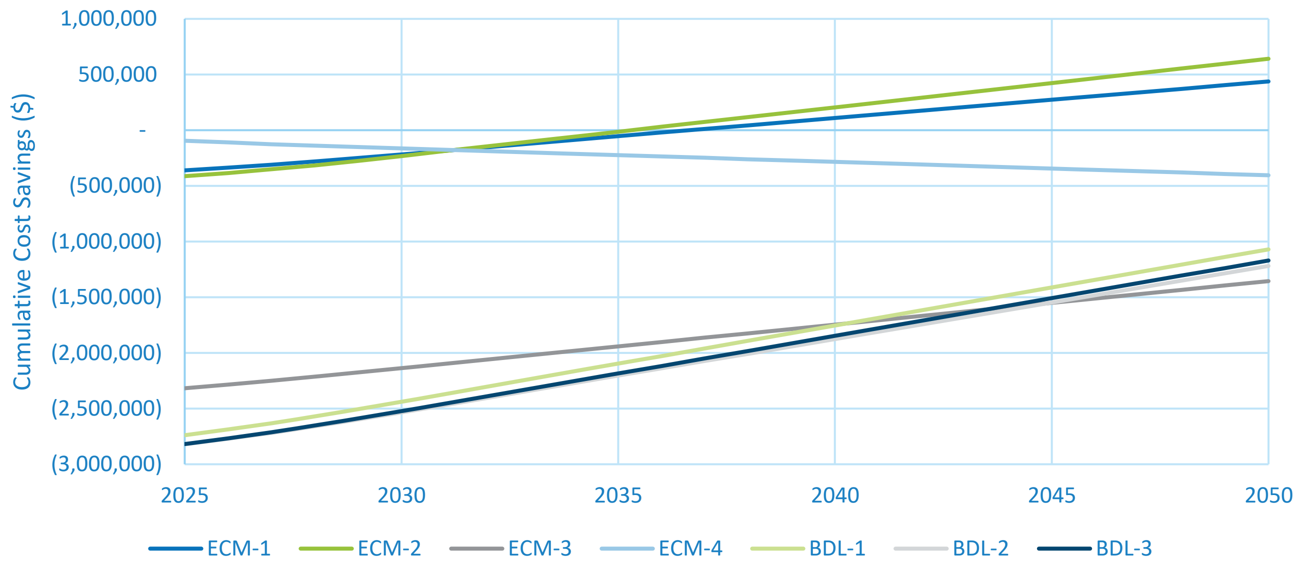

Figure 19: Cumulative Cost Savings of Proposed Measures

7.11 Cumulative Emission Savings of Proposed Measures

To compare the emission savings rate of the proposed measures, the cumulative emissions savings for each measure between 2025 and 2050 are shown in the following figure.

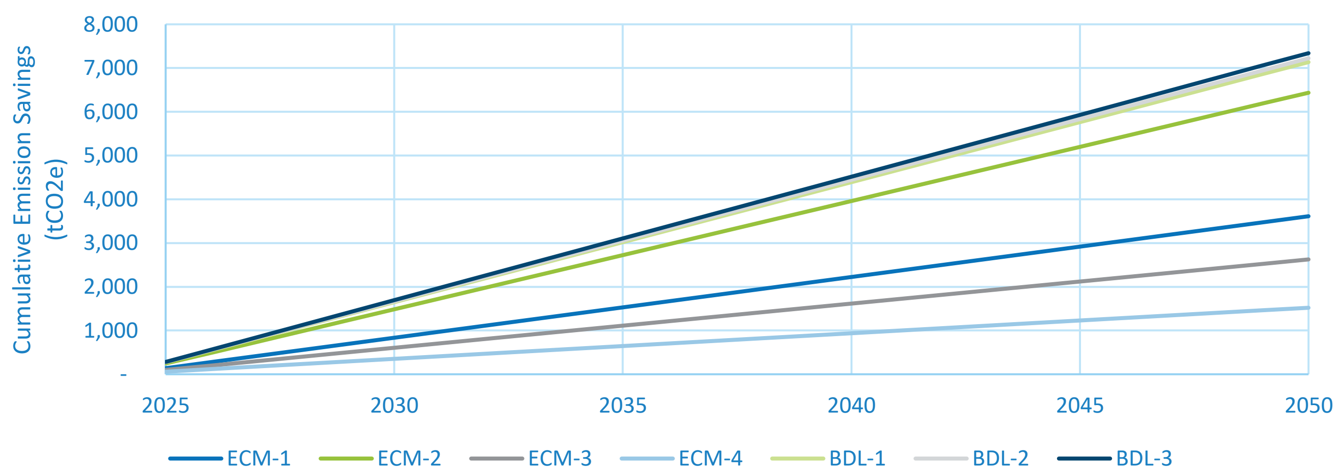

Figure 20: Cumulative Emissions Savings of Proposed Measures

As shown in the previous figures, BDL-3 is capable of achieving the highest rate of emissions savings out of all investigated measures, however it also includes one of the highest capital costs.

8. SOURCES OF KNOWN RISK

As part of the application to the CCF, known sources of risk to the feasibility of implementing proposed measures are required to be outlined with a description of what contingencies have been put in place to mitigate said risks.

Sources of known risk to the feasibility of the measures previously described in this report are summarized in the table below.

Table 18: Summary of Known Sources of Risk

Known Risk to Measure Feasibility	Description of Risk	Description of Contingencies
Supply Chain Limitations	- During COVID-19, the supply chain for common mechanical components has slowed significantly, causing order wait times to extend. - Risk exists if supply chain issues continue to worsen, necessary components of the proposed mechanical systems may not be able to be installed within the required timeframe under CCF.	- This issue is external to the design of the proposed system, and it is not within the scope of this report to predict changes in market conditions over the next five years. - No contingencies in place.
Space Limitations	- The mechanical room space in MPSC is limited. - Risk exists that the equipment chosen to be installed during detailed design may exceed the space available and trigger the requirement for a mechanical room extension.	- This issue depends heavily on the final selection of equipment that would be put in place after detailed design. - Contingency cost allowance is included in any measure that involves the installation of an electric boiler for the re-arrangement of mechanical equipment in the pool-side mechanical room to allow for the installation of an electric boiler. - No other contingency in place.

Known Risk to Measure Feasibility	Description of Risk	Description of Contingencies
Electrical Capacity Limitations	- The proposed measures add a significant amount of electrical demand to the building. - Risk exists that since the equipment installed will require additional power from the grid, they may require an additional amount of transformer capacity, thus triggering an electrical upgrade.	- Contingency cost allowance has been added to any measure that involves the installation of a heat recovery chiller for an electrical service upgrade to provide the heat recovery chiller with its own transformer. - Contingency cost allowance has been added to any measure that involves the installation of an electric boiler for an electrical service upgrade to provide the electric boiler with its own transformer.
Cost Escalation	- During COVID-19, inflation has increased and market prices in BC's lower mainland have increased significantly, especially in late 2021 and early 2022. - Risk exists that the cost to implement the project may escalate between when the Class C estimate was carried out and when the project is tendered.	- Cost details are broken out under the Class C cost estimate, allowing the RMOW to choose a threshold for added escalation cost that they prefer to consider in the concept design stage. - This issue is external to the design of the proposed system, and it is not within the scope of this report to predict changes in market conditions over the next five years. - No other contingencies in place.
Changes in Cost of Electricity and Cost of Natural Gas	- The prices of electricity and of natural gas are expected to change over time . - Risk exists that the changing cost of energy may have an impact on the financial performance of proposed decarbonization measures.	- The cost of natural gas is planned to increase due to the carbon tax, and the effect of the carbon tax has been captured in the financial analysis of proposed measures. - Utility cost rates are considered constant and in 2022 dollars. - No other contingencies in place.

Known Risk to Measure Feasibility	Description of Risk	Description of Contingencies
Changes in Carbon Tax Rate	- The carbon tax rate pattern described previously is based on policy developed by the Canadian federal government and BC's provincial government. - Risk exists that the carbon tax rate may change – either by increasing or decreasing – due to choices made by the federal and provincial governments, impacting the financial performance of proposed decarbonization measures.	- The carbon tax rate used in the financial analysis of proposed measures matches BC's current planned pattern for the carbon tax. - This issue is external to the design of the proposed system, and it is not within the scope of this report to predict changes in government policy over the next five years. - No other contingencies in place.
Changes in BC Grid Emission Factor	- BC's methodology for quantifying emissions from its generated electricity has been under redevelopment to account for importing energy from neighboring high carbon-intensity grids. - In the interim, emission factors from the Greenhouse Gas Industrial Reporting and Control Act (GGIRCA) have been used as reference when quantifying emissions from the BC electrical grid. - Risk exists that as the grid emission factor methodology develops, the emissions related to electricity consumption within BC could increase, thus impacting the emissions savings of proposed measures.	- The latest emission factor under GGIRCA is 9.7tCO_2e/GWh, which is lower than the previous reported emission factor representative of electricity generated within BC. - The emission factor used in this analysis is 9.7tCO_2e/GWh. - Future versions of the BC Best Practices Methodology for Quantifying Greenhouse Gas Emissions are expected to provide further background on this topic, and possibly a different emission factor that would be more applicable for NAC's electricity consumption.

9. CONCLUSIONS AND RECOMMENDATIONS

AME investigated four different upgrades to MPSC's mechanical systems and envelope in partnership with RJC and found that all four decarbonization measures were feasible to carry out and stood to improve the energy efficiency of the building significantly. These upgrades were considered when carried out simultaneously to show the expected performance of the building with multiple upgrades in place at the same time.

Three different combinations of measures were considered, including the implementation of heat recovery in the arena-side alongside an envelope upgrade (BDL-1), further adding partial electric boiler capacity (BDL-2), and using renewable natural gas in place of conventional natural gas (BDL-3). Bundles 2 and 3 represent two different approaches to a similar investment from the RMOW – effectively choosing to pay a premium to offset carbon emissions without improving the energy efficiency of the building to consume a cleaner type of energy to satisfy heating demand. In general, because of the nature of renewable natural gas, it is recommended that the RMOW consider the implementation of Bundle 2 to decarbonize the building. This option also does not forgo the option to use RNG – it is possible to implement Bundle 2 and also choose to pay a premium for renewable natural gas. All the different combinations of measures considered also include the improvement of the envelope, which will help improve the longevity of the building as well as reduce the amount of heat loss during winter and heat gain during summer.

A table showing the expected energy savings for all considered measures and measure bundles is shown below.

Table 19: Summary of System Energy Savings Under Different Upgrade Options

ECM No.	Description	Annual Gas Savings (GJ/y)	Annual Incremental Electricity Savings (kWh/y)	Annual Emission Savings (tCO_2e/y)	Annual Utility Cost Savings ($/y)	2030 Annual Carbon Tax Savings ($/y)	Capital Costs ($)
ECM-1	Arena-Side Heat Recovery	2,794	(39,674)	139	14,706	18,757	$1,472,800
ECM-2	Interconnection Between Arena and Pool	5,027	(325,626)	248	11,485	33,415	$1,684,200
ECM-3	Envelope Upgrade	1,993	163,083	101	25,961	13,631	$9,034,200
ECM-4	Electric Boiler	1,236	(326,141)	58	(19,647)	7,894	$301,075
BDL-1	Bundle 1: Interconnection + Envelope	5,519	(79,711)	274	32,717	37,049	$10,718,400

ECM No.	Description	Annual Gas Savings (GJ/y)	Annual Incremental Electricity Savings (kWh/y)	Annual Emission Savings (tCO_2e/y)	Annual Utility Cost Savings ($/y)	2030 Annual Carbon Tax Savings ($/y)	Capital Costs ($)
BDL-2	Bundle 2: Interconnection, Envelope, and Electric Boiler	5,589	(98,399)	278	29,602	37,502	$11,019,475
BDL-3	Bundle 3: Interconnection, Envelope, and RNG	5,519	(79,711)	282	30,940	38,109	$11,019,475

The AME Group is prepared to assist the RMOW and the CCF evaluation team with any questions they may have regarding the parameters of the analysis carried out in this study; a Preliminary GHG Assessment is included under separate cover for their consideration.

END OF REPORT