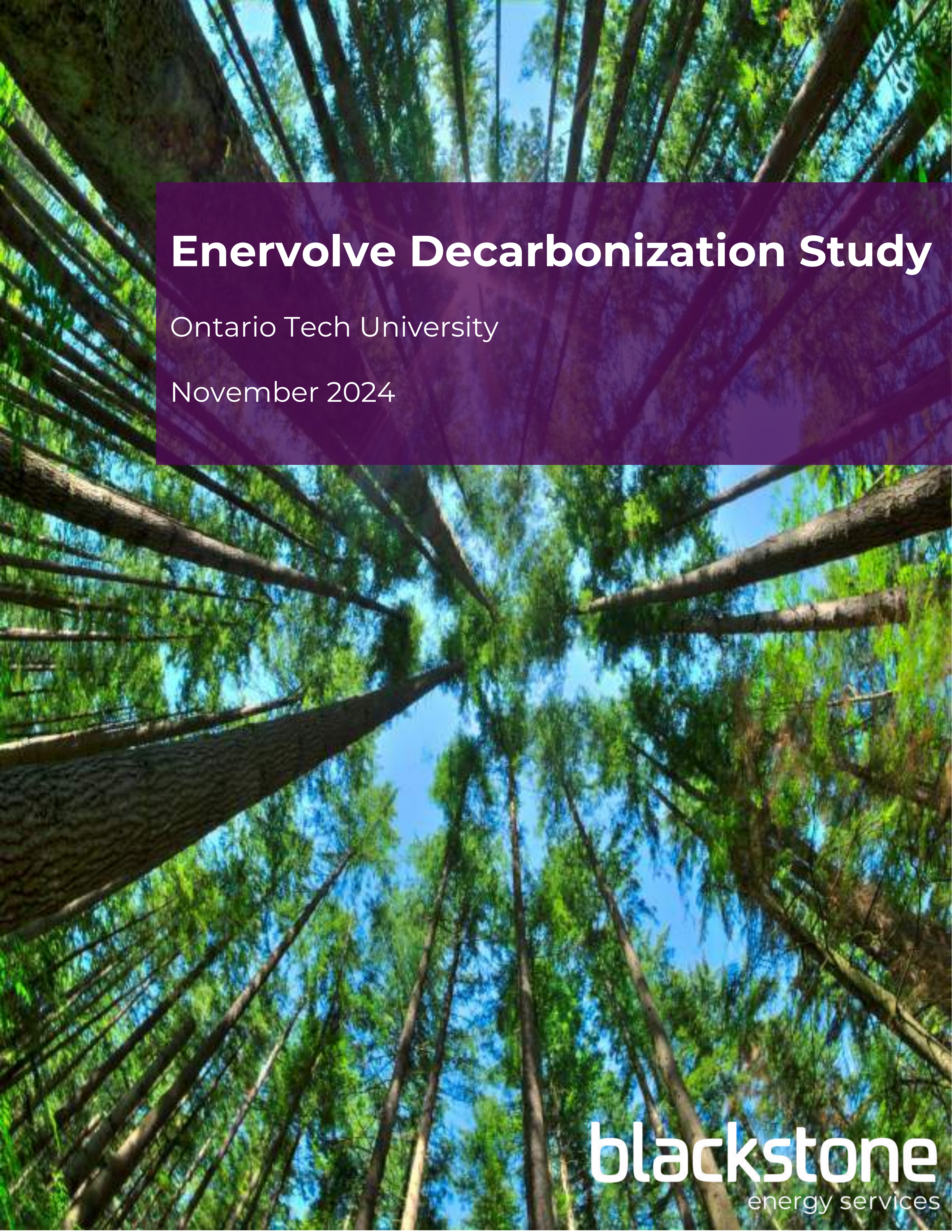
Enervolve Decarbonization Study

Ontario Tech University

November 2024



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Introduction

The transition toward the decarbonization is a further opportunity for Ontario Tech University to continue demonstrating innovation and progressive leadership around responsible energy use and climate action initiatives. As a prominent, technology-motivated higher education institution, Ontario Tech University continues on its trajectory towards sustainability and is on a path to significant and important “teachable” actions that mitigate and prepare for the impacts of climate change.

The University’s Enervolve Decarbonization Study [previously called Greenhouse Gas Reduction Roadmap & Action Plan (GRRAP)], includes all Ontario Tech University campus facilities and sets short-term and long-term strategies for greenhouse gas (GHG) footprint targets.

Compared to the original baseline year of 2022 Ontario Tech University has the targets to:

- Reduce its GHG emissions by 30% by 2030 from 2022 levels
- Achieve net-zero by 2050

This Enervolve study aims to provide strategic direction and options required to reduce emissions at Ontario Tech University over the next 20 years. To reach its GHG emission targets, the University’s Enervolve study must be reflected in its vision, planning, operational and financial strategies.

Ontario Tech University’s policies and plans may include those listed below which may need to be adapted to fully realize their goals and intent:

- Energy Conservation and Demand Management Plan (ECDM)
- Ontario Tech University’s Sustainability Report
- Sustainable Development Goals (SDG)
- Ontario Tech University’s Strategic Sustainability Plan

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Glossary of Terms

Word	Abbreviation	Meaning
Air Handing Unit	AHU	A device used to regulate and circulate air as part of a heating, ventilating, and air-conditioning system.
Baseline Year		A benchmark is used as a foundation for measuring or comparing current and past values over the period of 365 days.
British Thermal Units	BTU	A standard unit of the heat content of fuels or energy sources.
Building Automation System	BAS	The automatic centralized computerized control of a building's heating, ventilation and air conditioning, lighting, and other systems.
Business as Usual	BAU	Scenario if no actions are taken to mitigate or change the current operations and/or building performance.
Canada Green Building Council	CaGBC	Ontario Tech University certifies a Zero Carbon Building Standard that could be used as a guide for carbon-free construction and operations.
Carbon Dioxide	CO_2	A greenhouse gas that results, in part, from the combustion of fossil fuels.
Coefficient of Performance	COP	The Coefficient of Performance (COP) is a number that describes the effectiveness of heat pumps, refrigerators or air conditioners.
Direct Expansion	DX	A system that uses the vapour-compression refrigeration cycle to efficiently cool a building.
Environment and Climate Change Canada	ECCC	Informs Canadians about protecting and conserving natural heritage and ensuring a clean, safe, and sustainable environment for present and future generations.
Electric Vehicle	EV	A vehicle that uses one or more electric motors for propulsion
Energy Conservation & Demand Management	ECDM	The installation of measures, or implementation of practices, to improve energy efficiency. This is a requirement of O. Reg. 507/18: Broader Public Sector: Energy Conservation and Demand Management Plans (ECDM).
Energy Storage		Typically refers to the energy stored by the battery.
Energy Usage Intensity	EUI	The amount of energy consumed relative to a building's physical size is typically measured in equivalent kWh per square foot.
Engineering, Procurement and Construction	EPC	Engineering, procurement, and construction of infrastructure projects.
Electrification		The conversion of fossil fuel-based technologies to electric alternatives.
Equivalent Carbon Dioxide	CO_2e	Measurement of greenhouse gas emissions, relative to carbon dioxide.
Equivalent kilo-watt hours	ekWh	A standard unit of energy consumption that is used to normalize and compare energy sources.
GHG Protocol		GHG Protocol establishes comprehensive global standardized frameworks to measure and manage greenhouse gas (GHG) emissions from private and public sector operations, value chains and mitigation actions.
Greenhouse Gas	GHG	A gas that contributes to the greenhouse effect by absorbing infrared radiation, e.g., carbon dioxide and chlorofluorocarbons.
Global Warming Potential	GWP	A measure of how much heat is trapped in the atmosphere by a greenhouse gas up to a specific time horizon, relative to carbon dioxide.

Global Reporting Initiative	GRI	The GRI is an international independent standards organization that helps businesses, governments and other organizations understand and communicate their impacts on issues such as climate change, human rights, and corruption.
Heating, Ventilation and Air Conditioning +Lighting	HVAC+L	A system that provides heating, cooling, ventilation, and lighting to a building.
Hourly Ontario Electricity Price	HOEP	The wholesale price of electricity is determined in the real-time market administered by the Independent Electricity System Operator (IESO) in Ontario
Independent Electricity System Operator	IESO	Crown corporation responsible for operating the electricity market in the province of Ontario.
Leadership in Energy and Environmental Design	LEED	A green building certification program that is administered by the CaGBC.
Long Term Energy Plan	LTEP	Ontario’s plan that outlines the province’s energy demand, supply, and commitments.
Metric Tonnes	t	A unit of measurement of mass.
Mega Tonnes	MT	A unit of measurement of mass (1 MT = 1,000,000 t).
Photovoltaic	PV	The conversion of light into electricity using semiconducting materials.
Renewable Energy	RE	Generation of energy produced from sources that do not deplete.
Renewable Natural Gas	RNG	Biogas that is captured from decomposing organic waste.
Scope 1		Direct emissions from sources owned or controlled by the University.
Scope 2		Indirect emissions from the consumption of purchased energy generated upstream from the University.
Scope 3		Indirect emissions (not included in Scope 2) that occur in the value chain of the University including both upstream and downstream emissions, like waste, transport, food, and procurement.
Natural Gas/Traditional Natural Gas	TNG	Natural gas is a naturally occurring hydrocarbon gas, or fossil fuel, mixture consisting primarily of methane.
Power Purchase Agreement	PPA	A contract between two parties, one which generates electricity (the seller) and one which purchases electricity (the buyer) for an agreed cost (including maintenance) over a defined time where typically the source of electricity generation is from a renewable power generation system.
Variable Refrigerant Flow	VRF	A system that varies the *flow* of *refrigerant* to indoor units based on demand.
Zero Carbon Building	ZCB	A highly energy-efficient building that is fully powered from on-site and/or off-site renewable energy sources and carbon offsets resulting in an annual net-zero carbon footprint.

1. Executive Summary

The Paris Agreement (originally adopted by Parties during COP21) rules were set at the United Nations Climate Change Conference of the Parties in November 2021. It is a legally binding international treaty on climate change which formally established the world's commitment to hold the increase in the global average temperature to well below 2°C above pre-industrial levels. The Canadian government committed to the Paris Agreement, and it is outlined in our country's Nationally Determined Contribution (NDC). As such all Canadians are obligated to meet the targets outlined, as well as meet the interim goals identified in the Federal Net-Zero Emissions Accountability Act, targeting near net zero by 2050.

To support Ontario Tech University's objectives of leading Ontario's college and university sector in the journey to near net-zero, the university engaged Blackstone Energy Services to create an Enervolve Decarbonization Study to define the necessary strategic planning, technology, implementation timelines, government incentives, utility rate structures, grid emissions, funding, and implementation solution to achieve the University's aspirations on its next phase of the journey toward decarbonization.

Blackstone understands that a cornerstone of Ontario Tech University's mission as a premier Technical University in Canada has been to embrace innovative applications of technology into an efficiently operating, healthy, and comfortable environment for the university's user and visitor community. Originally designed for a target performance of 50% better than the existing Model National Energy Code for Buildings (MNECB), Ontario Tech University's LEED "Gold" standard designs incorporated optimal performance in all aspects of the campus creation and operation, which included:

- Canada's largest (at the time) geothermal heating and cooling system,
- energy recovery wheels to extract and utilize heat from the ventilation exhaust air steam,
- variable air volume and frequency drives to optimize ventilation system performance,
- occupancy based controls to assure health and comfort in occupied spaces,
- as well as innovative envelope upgrades such as green roofs and coated glazing to optimize heat loss/gain impacts.

Blackstone also recognizes Ontario Tech University's on-going commitment to research and adoption of technical advancements which concurrently support Ontario and Canadian Carbon reduction targets, such as:

- Carbon Capture connected directly to combustion exhaust stream, utilizing cutting edge technology from CarbinX.
- Energy Efficient Dehumidification at the ICE Centre replacing fossil fuel with waste condenser heat from the refrigeration cycle, from Novel-Ice.
- Ultra-Violet filtration of gaseous contaminants from fresh air stream allowing a reduction of up to 80% of outside air, from enVerid Sorbent.

The Enervolve Decarbonization Study is a greenhouse gas reduction Roadmap and Action Plan to provide guidance and assistance to the university with moving to the next level of sustainability. The University defined the objectives and outcomes of the Enervolve Study as set out below:

1. Minimum 30% reduction targets of total Scope 1 & 2 emissions by 2030 and net zero by 2050
2. Implementation of a decarbonization program with no annual operating budget increases, leverage grants, incentives and innovative funding structures to create best value for the University
3. Reduce deferred maintenance and replace end of life equipment and systems
4. Project features that support learning and research
5. Generate revenue from on-site renewable energy generation

ELECTRIFICATION OF BOILER PLANTS

- Boiler Electrification
- Decoupling of Central Heating Plant
- Dehumidifier Electrification

ADDITION OF RENEWABLE ENERGY

- Air Sources Heat Pumps
- Solar PV Rooftop System
- Solar PV Ground System
- Solar PV Carport System

CONSERVATION MEASURES

- LED Lighting Upgrade
- BAS Recommissioning
- Controls Upgrade
- Metering

Figure 1. *Initiatives and Associated Buildings*

The timelines shown below depict the steps in the Enervolve Study process that have been undertaken to date along with the steps and provisional dates that will follow to achieve the University's objectives and targets.

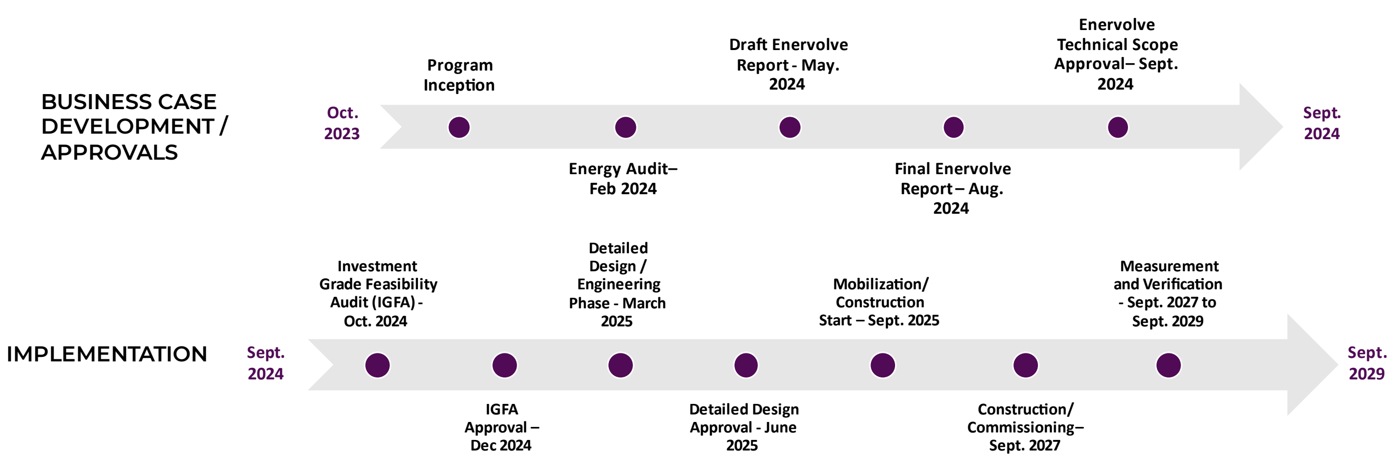


Figure 2*. Business Development and Implementation Phases*

Table 1 below shows the costs and savings for each phase, GHG reduction of each phase as a percentage of the total emissions of the University.

***Table 1**. Details of Proposed Phases – Proposed Project*

Project Phases	Implementation Period	Project Cost	Annual Cost Savings	Annual GHG Reduction in 2030 (tCO_2e)	GHG Reduction % in 2030*	Annual GHG Reduction in 2050 (tCO_2e)	GHG Reduction % in 2050
Phase 1	2025-2035	$19,006,881	$627,957	747	25%	1,932	63%
Carbon Offsets	2049-2050	$33,510	N/A	0	0%	1,117	37%
Total		**$19,040,391**	**$627,957**	**747**	**25%**	**3,049**	**100%**

**Note that the grid emission factor forecast in 2030 is much higher than the forecasted emission between 2031 and 2050. In the year 2031, Ontario Tech University will see a 45% GHG Reduction from a 2022 baseline compared to 25% in 2030*

The two tables below present costs provided by ON Tech University based on their experience on campus with past projects. Table 2 is the "Status Quo" scenario, which assesses measures using historically available financial mechanisms and scheduling parameters. Table 3 is the "Energy Performance Contract" scenario which assess all measures undertaken as a single project to expedite the resultant benefits.

Table 3 lists all recommended measures of the Proposed Project, their costs, cost savings, GHG reduction and incentives.

Table 2. Proposed Project - Status Quo

Measure Number	Measure	Annual GHG Reduction (tCO_2e)	Annual Savings ($)	Total Cost ($)*	Incentives ($)	Phase-in Through DM	Phase 1 target	Phase 2 target	Phase 3 target
ECM#1	LED Lighting Upgrade	45	$73,318	$451,000	$79,000	FY26 & FY27		45	
ECM#2	BAS Re-commissioning, Controls Upgrade	147	$74,725	$794,018	$145,000	FY28			147
ECM#3	Decouple Central Heating Plant from DHW System and Install Electric DHW Heaters	241	-$8,648	$350,000	$0	FY25 & FY26	241		
ECM#4	Electrification of Central Boiler Plant and High Temperature Heat Pump Installation- UB Building	246	-$12,237	$1,300,000	$0	FY25 & FY26	246		
ECM#5	Electrification of Boiler Plant - Sirc Building	70	-$524	$300,000	$0	FY30			70
ECM#6	Electrification of Boiler Plant - Charles Hall	78	-$2,692	$350,000	$0	FY29			78
ECM#7	Replace Existing AHUs with Heat Pump Units - CERL	94	-$4,797	$725,061	$0	FY29			94
ECM#8	Replace the Existing Boiler with Air Sourced Heat Pumps and Modify Existing AHU - CIC	114	-$1,788	$421,000	$0	FY27		114	
ECM#9	Replace the Existing Boiler with DHW Air Sourced Heat Pumps - CIC	100	-$14,744	$650,000	$0	FY28			100
ECM#10	Replace Existing Gas-Fired Desiccant Dehumidifier with High Efficiency Electric Desiccant Dehumidifier - CIC	122	-$4,103	$794,341	$0	FY27		122	
ECM#11	Installation of Heat Pump RTUs - Bordessa Hall	21	-$6,624	$511,000	$0	FY25& FY26	21		
ECM#12	Monitor and Control Plug Loads Across the Campus	36	$22,964	$167,153	$0	FY29			36
ECM#13	Install a 3.71 MW Ground Mount Solar PV System	257	$476,959	$7,226,100	$0	FY30			257
ECM#14	Integration of Airbound Sensor into BAS	62	$23,572	$146,625	$0	FY26	62		
ECM#15	Install Blackpack Metering System	42	$12,571	$104,591	$0	FY28			42
Total		**1,675**	**$627,952**	**$14,290,888**	**$224,000**		**570**	**280**	**824**

Table 3. Proposed Project - Energy Performance Contract

Measure Number	Measure	Annual GHG Reduction (tCO_2e)	Annual Savings ($)	Total Cost ($) *	Incentives ($)
ECM#1	LED Lighting Upgrade	21	$73,318	$599,830	$79,000
ECM#2	BAS Re-commissioning, Controls Upgrade	98	$74,725	$1,056,044	$145,000
ECM#3	Decouple Central Heating Plant from DHW System and Install Electric DHW Heaters	273	-$8,648	$465,500	$0
ECM#4	Electrification of Central Boiler Plant and High Temperature Heat Pump Installation- UB Building	287	-$12,237	$1,729,000	$0
ECM#5	Electrification of Boiler Plant - Sirc Building	74	-$524	$399,000	$0
ECM#6	Electrification of Boiler Plant - Charles Hall	85	-$2,692	$465,500	$0
ECM#7	Replace Existing AHUs with Heat Pump Units - CERL	106	-$4,797	$964,331	$0
ECM#8	Replace the Existing Boiler with Air Sourced Heat Pumps and Modify Existing AHU - CIC	124	-$1,788	$559,930	$0
ECM#9	Replace the Existing Boiler with DHW Air Sourced Heat Pumps - CIC	110	-$14,744	$864,500	$0
ECM#10	Replace Existing Gas-Fired Desiccant Dehumidifier with High Efficiency Electric Desiccant Dehumidifier - CIC	135	-$4,103	$1,056,473	$0
ECM#11	Installation of Heat Pump RTUs - Bordessa Hall	24	-$6,624	$679,630	$0
ECM#12	Monitor and Control Plug Loads Across the Campus	19	$22,964	$222,313	$0
ECM#13	Install a 3.71 MW Ground Mount Solar PV System	138	$476,959	$9,610,713	$0
ECM#14	Integration of Airbound Sensor into BAS	49	$23,572	$195,011	$0
ECM#15	Install BlackPAC Metering System	37	$12,571	$139,106	$0
Total		**1,580**	**$627,952**	**$19,006,881**	**$224,000**

**Table 2 and 3 presents costs estimated by ON Tech U and these costs are different from original estimates by Blackstone*

The graph below depicts the combination of the three Pillars over the proposed project. By executing all these initiatives, Ontario Tech University will achieve their 30% GHG emissions reduction target by 2031 from 2022 levels and move towards near net-zero GHG emissions by 2050.

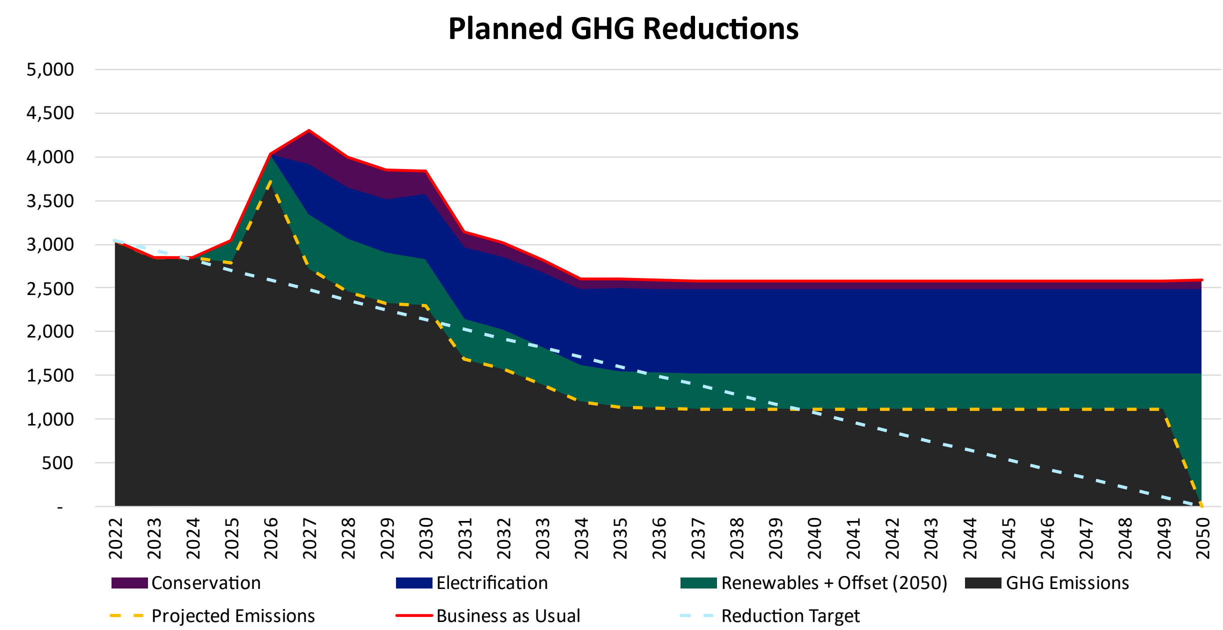


***Figure 3**. Ontario Tech University Emissions Profile*

Figure 3 depicts the University's annual carbon footprint up to 2050, using Ontario's forecasted electricity and natural gas emission factors published by Canada Infrastructure Bank (CIB) and Environment and Climate Change Canada (ECCC). The University's future annual carbon footprint is subject to these factors and its profile will experience a few "bumps", such as the ones in the 2026-2030 period, which are reflections of the anticipated increase in natural gas use for electricity generation in Ontario.

After implementation of both Phases of the Proposed Project, Ontario Tech University will still have a Net-Zero Gap of approximately 1,117 tons, the vast majority of which will consist of the University's electricity consumption (HVAC and process equipment) and a very minor part of the natural gas consumption of the equipment which was not feasible to be electrified.

To bridge the Net-Zero Gap, Blackstone recommends the following options to be considered:

- In addition to proposed maximized onsite solar PV capacity, consider purchasing additional renewable electricity annually through a Virtual Power Purchase Agreements (VPPAs) as they become legislated in Ontario and achieve net-zero state.
- Alternatively, Ontario Tech University could buy carbon offsets to overcome Net-Zero Gap. Based on the anticipated Net-Zero Gap of 1,117 tons, carbon offsets will cost Ontario Tech University about $33,510 annually by 2050.

Carbon offsets are not a preferred option by Blackstone to reach net-zero state, however due to the current unavailability of VPPAs in Ontario, Blackstone is suggesting proceeding with Carbon Offsets. If the legislation surrounding VPPAs changes in the future, the situation will be re-examined and VPPAs could be recommended as a preferred option.

2. Recommendations

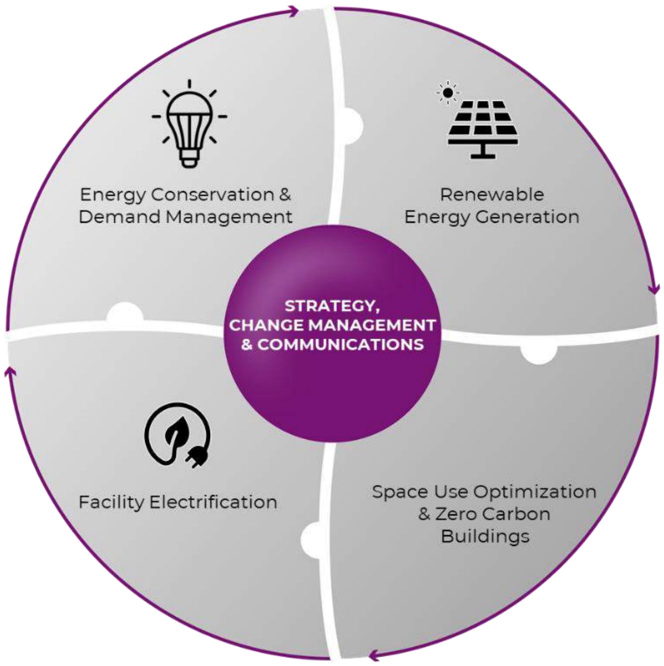


Figure 4. *Strategy, Change Management & Communications Wheel*

It is recommended that Ontario Tech University moves ahead with the following actions items listed below, under all four Pillars, to support the Enervolve Decarbonization Study.

Pillar 1: Energy Conservation & Demand Management (ECDM)

- Complete an ECDM plan and update in 5-year intervals as required by Ont. Reg. 25/23. The current ECDM plan is planned to be finalized by end of June of 2023.
- Ensure budget allocation to support the implementation of measures identified in ECDM plans.
- Review the ECDM annually so opportunities for energy conservation and deep energy retrofits stay current and evaluated for implementation.
- Review facilities' condition reports on an annual basis and assign a budget for facilities improvements.

Pillar 2: Space Use Optimization & Zero Carbon Buildings

- Undertake a space use optimization study by 2025 to further assess how to maximize the efficiency of existing spaces.
- People counting technology is being phased in between now and 2027 to baseline the schedule and provide data to the BAS for HVAC optimization.

- Develop space use policies by 2030 to minimize underused space and maximize the space utilization rate within all University facilities.
- Develop a master plan by 2030 that has space optimization as a guiding principle.
- By 2025, develop design and construction standards to drive high-performance indices and ensure Net-Zero Carbon as the minimum standard for new builds and major renovations.

Pillar 3: Facility Electrification

- Commit to the electrification of facilities' equipment, wherever practical, through the recommended Phase 1 and Phase 2 projects, including heating, process and kitchen equipment.
- Explore alternatives for fossil fuels for process-related fossil fuels' using equipment as technologies becomes available.

Pillar 4: Renewable Energy Generation

- Maximize installations of solar photovoltaics, including rooftop, ground mount and carport and implement geothermal energy to the most feasible capacity through the recommended Phase 1 and Phase 2 projects.

General Sustainability Initiatives

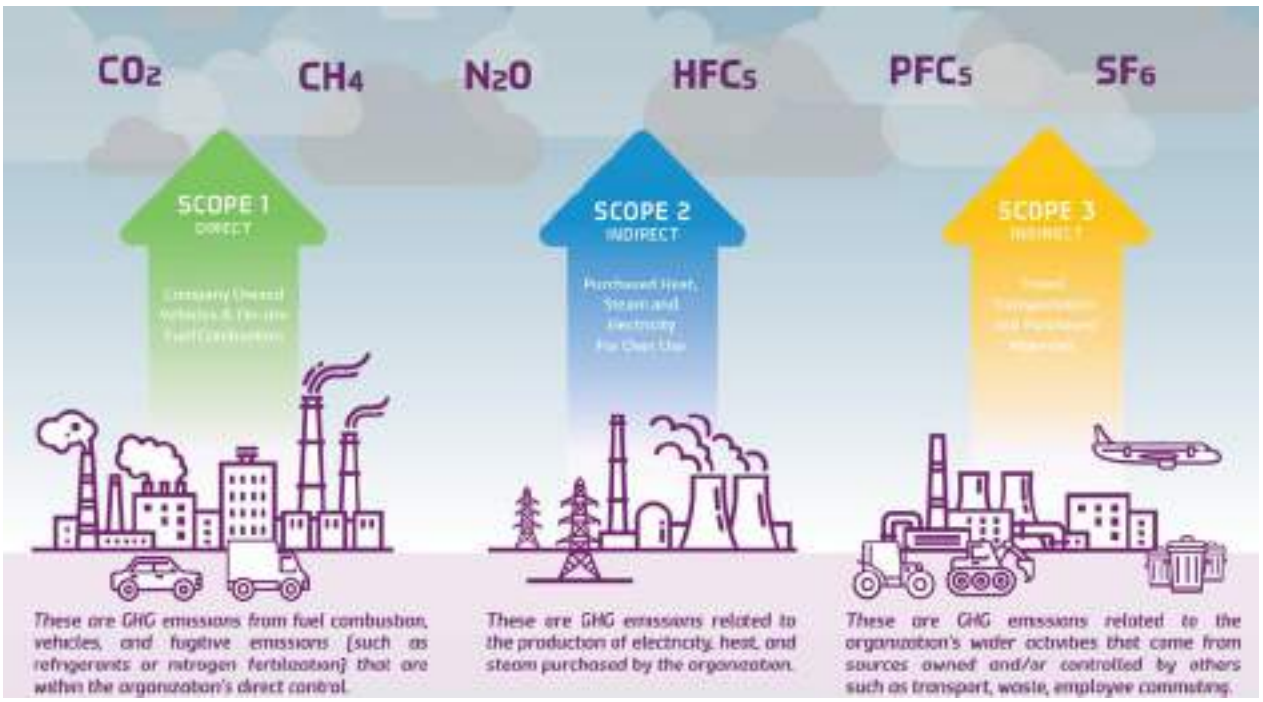
It is recommended that the University continues to support a low carbon future and promotes sustainability.

- Communicate SDG branding guide and refreshed 5-year SDG sustainability plan across campus activities (Economic, Social and Environmental)
- Continue to monitor and achieve alignment between the sustainability plan and the University's GHG reduction targets (addition of Energy Dashboard and the addition of Renewable energy management and technical specialist programming will be key elements of this initiative)
- Plan and budget for the installation of Electric Vehicles (EV) charging stations
- Limit food waste generation and look into composting units
- Strengthen awareness programs about energy and waste management for employees, staff, and students.
- Expanding and improving our Community Garden to support Accessibility needs of university the community.

3. Ontario Tech University's GHG Footprint

3.1. Scope of Emissions

Ontario Tech University's Enervolve Study quantifies GHG emissions by source, outlines the scenarios for emission reduction and provides the University with a roadmap to reach its reduction targets. GHG emissions are accounted for according to the GHG Protocol Standard, which is the global standardized framework to measure and manage GHG emissions from private and public sector operations. GHG emissions considered for the Enervolve Study are categorized by three types of emissions – Scope 1, Scope 2, and Scope 3. In the following sections, only scope 1 and 2 emissions are discussed, calculated, and addressed and Scope 3 emissions are calculated and discussed separately in *Section 9.1.*



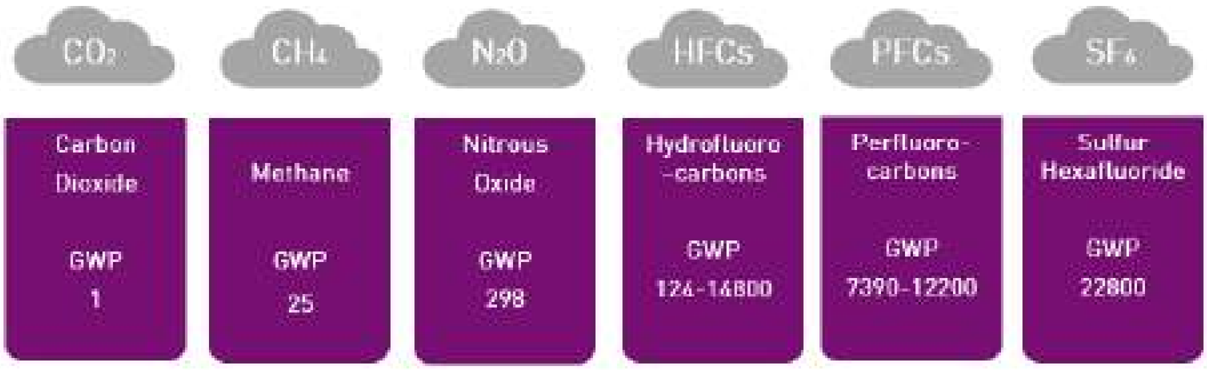
Source: GHG Protocol[1]

Figure 5. *GHG Emissions and Scopes*

GHG emissions released from Ontario Tech University's operations may include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Each gas has a global warming potential (GWP) that is expressed in terms of CO_2 equivalent or CO_2e. The GWP of GHGs is a measure of how much heat a GHG traps in the atmosphere. The Enervolve Study accounted for emissions from Scope 1, and Scope 2 and calculated the GWP relative to tonnes of carbon dioxide equivalent (tCO_2e). For example, for every tonne of methane released, about 25 tonnes of equivalent CO_2 is released as the GWP for methane is 25. Each GHG must be converted to equivalent CO_2 for calculations and reporting.

[1] Greenhouse Gas Protocol: http://ghgprotocol.org/about-us

The global warming potentials (GWP) associated with these six common GHGs are depicted in Figure 6 below.



Source: National Inventory Report 1990 –2019: Greenhouse Gas Sources and Sinks in Canada

Figure 6. *Common Greenhouse Gases and Respective Global Warming Potentials*

The Scope boundaries, activities that were included in the GHG emissions calculations for Ontario Tech University, were selected based on the available data and discussions with the Facilities and Construction Management office and are summarized in Table 4 below.

Table 4. *GHG Emission Scopes & Sources*

Scope of Emissions	Definition	Source of Emission
Scope 1	Direct emissions from sources owned or controlled by the University	• Natural Gas • Refrigerants • Fleet Fuel • Aviation Fuel • Biomass
Scope 2	Indirect emissions from the consumption of purchased energy generated upstream from the University	• Purchased Electricity • Water
Scope 3	Indirect emissions (not included in Scope 2) that occur in the value chain of the University include both upstream and downstream emissions, like waste, transport, food, and procurement.	• Waste • Transport • Procurement

Stationary sources such as natural gas, were considered in the GHG emissions calculations for Scope 1 emissions. Scope 2 emissions in Ontario Tech University are generated from purchased electricity. The share of the University's GHG emissions in 2022 is illustrated in Figure 7.

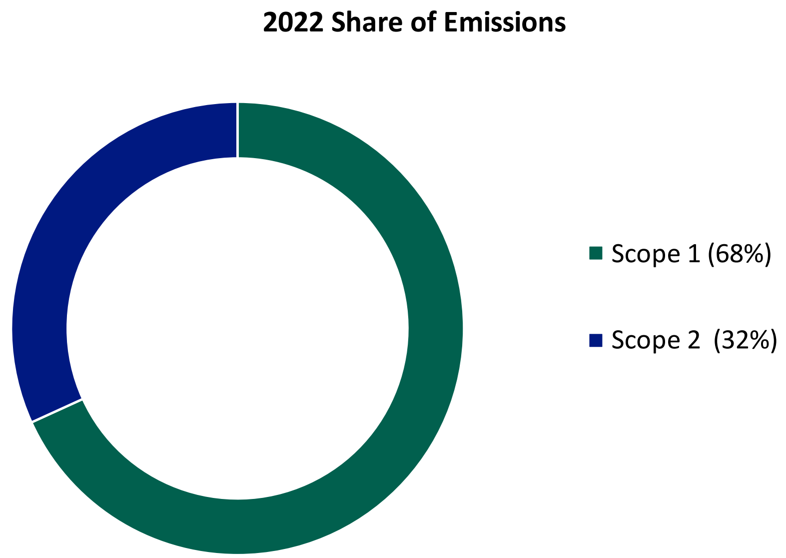


***Figure 7**. 2022 Share of Emissions for Ontario Tech University*

Scope 1 and Scope 2 emissions are directly under the University's operational control driven by energy use and facility management. Scope 3 emissions are dependent on human and social behaviour and can best be addressed by awareness and policy implementation across the corporation and community.

3.2. GHG Emissions Baseline

The following table summarizes the GHG emissions in the baseline year and the resulting absolute targets set by Ontario Tech University (in metric tonnes of carbon dioxide equivalent – tCO_2e).

***Table 5.** Baselines, Current and Target Emissions for Ontario Tech University*

GHG Emissions (tCO_2e)	2022 (Project Baseline)	2030 (30% reduction from baseline)	2050 (100% reduction from baseline)
Scope 1	2,079	1,455	0
Scope 2	970	679	0
Total	**3,049**	**2,134**	**0**

EF and Quantification Method Source: National Inventory Report 1990 –2019: Greenhouse Gas Sources and Sinks in Canada

3.3. Historic Emission Trends

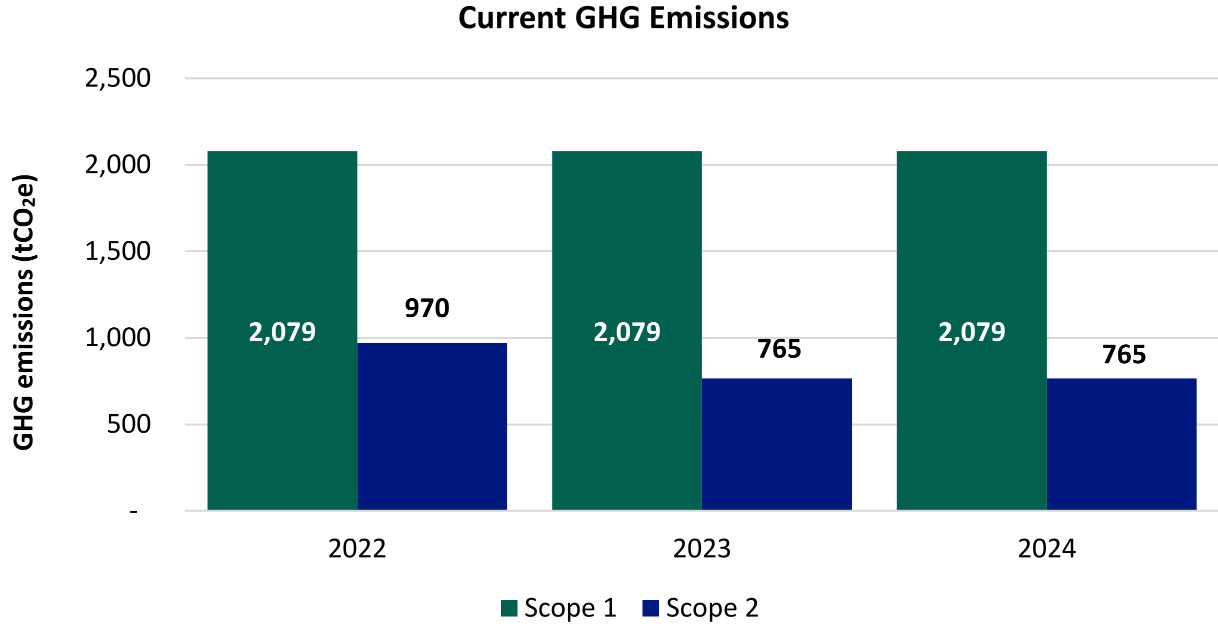


Figure 8. *Historical Emissions Trends for Ontario Tech University*

Figure 8 above shows the annual GHG emission trends from the baseline year of 2022 through to 2024. The fluctuations of scope 2 emissions are due to the grid emission factor variations.

3.4. Growth

In 2022, Ontario Tech University's total area was 1,124,592 sq. ft. When analyzing data from the baseline year-to-date and forecasting trends to estimate Ontario Tech University's expected facility size growth by 2030, 2040 and 2050, the most important factor to consider is the increase in the University facilities' square footage. As the square footage increases, it is expected that total GHG emissions will increase as well.

For Scope 1 and 2 emissions, it is assumed that electricity and natural gas consumed per square foot are constant (2022 levels). As square footage increases, the emissions rise proportionally though neglecting (directly) any energy conservation measures in any specific building.

3.5. Business as Usual (BAU) Emission Forecast

The following assumptions were considered to model Ontario Tech University's forecasted emissions. Growth assumptions are based on the information provided by the University and Blackstone's previous experience with similar types of facilities.

Following discussions with Ontario Tech's facilities team, it was agreed that future expansions would pursue LEED Gold standards or be near net-zero. As a result, it was assumed that developments taking place between 2030 and 2039 will have an Energy Use Intensity (EUI) 40% lower than the university facilities' EUI in 2022. Future developments from 2040 onwards will be considered to be net-zero.

Table 6. *Growth Assumptions for Ontario Tech University*

Annual Growth Assumptions	Ontario Tech University
Facility Growth (sq. ft)	300,000 Sq.Ft growth in 2030. 150,000 every 5 years thereafter.
Student Population Growth	42% growth in 2030 21% every 5 years thereafter.
Employee Population Growth	15% growth in 2030 15% every 5 years thereafter

The figure below demonstrates the business as usual (BAU) increase in Ontario Tech University's total forecasted GHG emissions compared to the University's target emissions level. It is expected that, by 2030, Ontario Tech University's total Scope 1 and Scope 2 emissions will be 3,836 tCO_2e, which is ~1,702 tCO_2e above its target for that year. Keeping with this trend, Ontario Tech University's total scope 1 and 2 emissions will be 2,588 tCO_2e in 2050 if no conservation or GHG mitigation strategies are implemented, this amount will be 2,588 tCO_2e above the GHG target of 2050. These findings are further explained in the graph below.

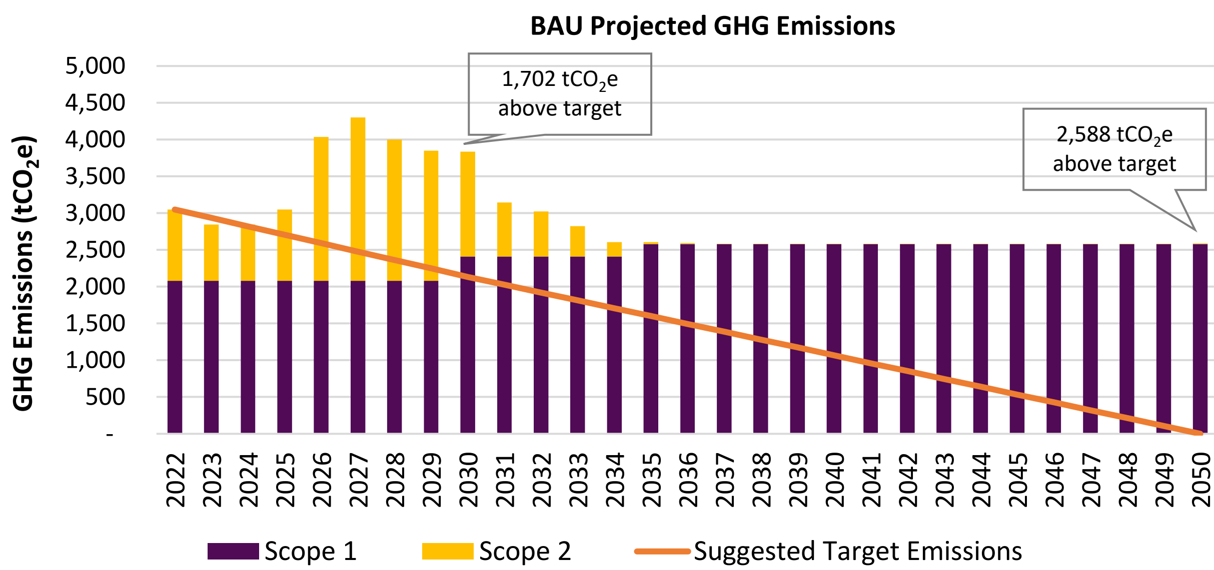


Figure 9. *Projected Business as Usual GHG Emissions*

4. Pillars of Carbon Reduction Roadmap

To reach Ontario Tech University's carbon reduction target, the following factors were analyzed in conjunction with a study of their HVAC+L infrastructure, utility portfolio, projected facility size growth and the potential for renewable energy generation. To meet its 2030 and 2050 GHG emissions targets, the University's Enervolve Study will be centred around the following four Pillars, as previously mentioned.

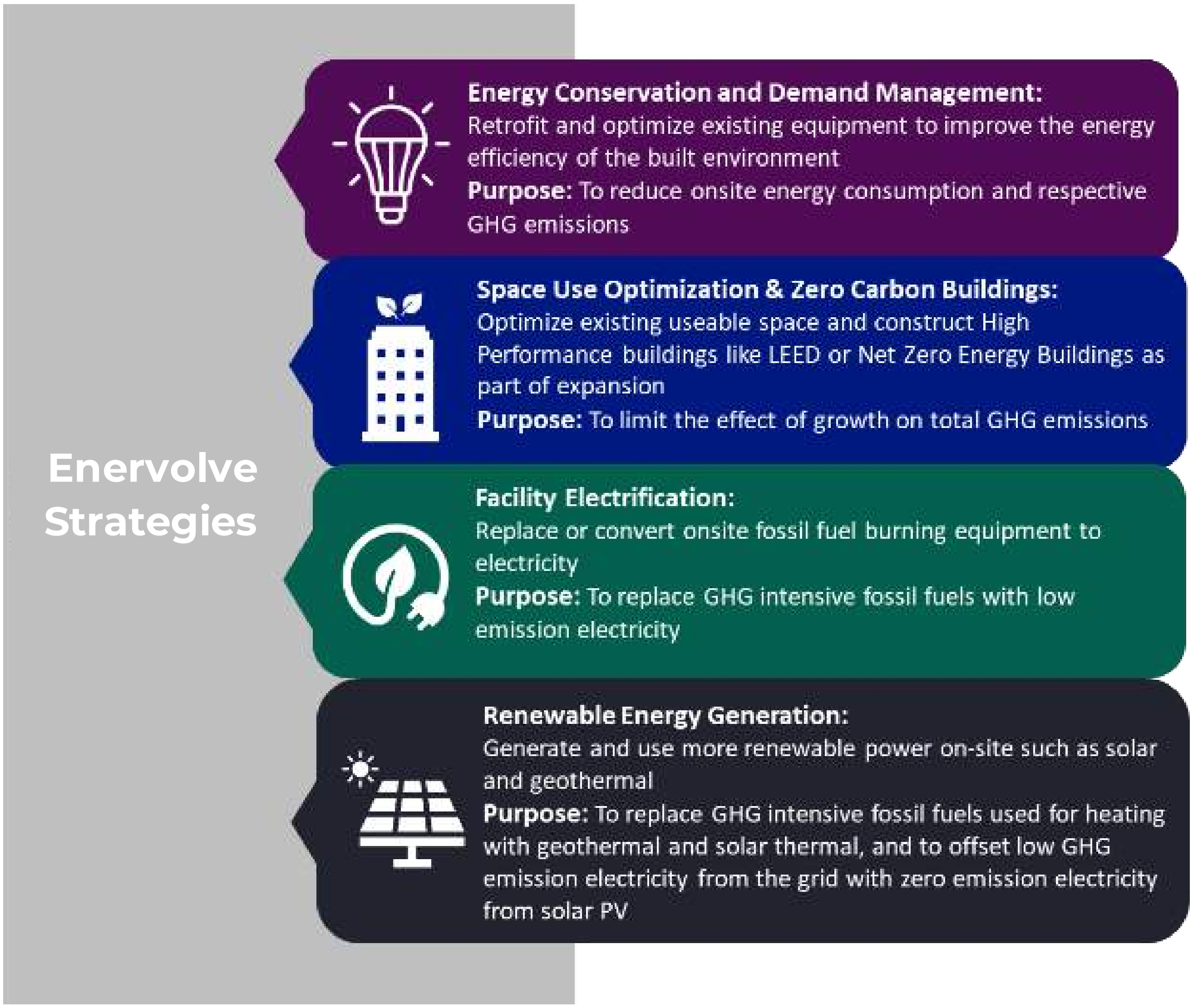


Figure 10. *GHG Reduction Pillars for the Enervolve*

4.1. Pillar 1: Energy Conservation & Demand Management

Energy Conservation and Demand Management (ECDM) refers to Ontario Tech University's ongoing commitment to energy management and the improvement of the University-wide energy efficiency. ECDM measures reduce Scope 1 and Scope 2 emissions through facility upgrades, energy efficiency improvements and renewable energy projects. The estimated savings and GHG reductions associated with the implementation of the ECDM measures are summarized in the table below.

Table 7. *Pillar 1 Measures Summary*

ECDM Summary	Project
Total Investment in Conservation	$2,212,304
Electricity Savings (kWh)	3,270,602
Gas Savings (m^3)	52,359
Total Utility Savings ($)	**$207,150**
GHG Reduction (tCO_2e)	**225**

Ontario Tech University should continue to be committed to creating a culture of ECDM and should update the ECDM Plan on a five-year renewal timeframe. To implement all measures identified in the EDCM Pillar, Ontario Tech University would need to invest $2,212,304. Once completed, the ECDM measures will save electricity and natural gas and reduce GHG emissions by 225 tCO_2e annually. The explanation of measures covered under the ECDM Pillar can be found in *Appendix 1 – Measures Summary Report*.

4.2. Pillar 2: Space Use Optimization & Zero Carbon Buildings

It is important for Ontario Tech University's spaces to be well maintained, efficient, resilient, and have the flexibility to support new demands. Space use optimization and zero-carbon building designs provide opportunities for Ontario Tech University to meet the needs of its users while remaining in alignment with its GHG emission reduction targets.

4.2.1. Zero Carbon Buildings

Developing zero carbon buildings for the new construction or renovations will largely contribute to mitigation planning of Scope 1 and 2 emissions. The design, and operation of new and renovated spaces can have a significant impact on total GHG emissions for a long time. Environmental performance measures that promote sustainable new and retrofit development have a significant impact on the energy, GHG and comfort characteristics.

Buildings in the portfolio tend to be retained for long lives meaning a structure built today will still be in use past 2050 – designs now will impact carbon loads in a time when low to zero carbon buildings will be the norm and carbon fees could be very high relative to the cost of the actual fuel itself. Low to zero carbon building (L-ZEB) designs will help Ontario Tech University to reduce its carbon presence now and continue to keep GHG levels low as the building ages.

There are several existing L-ZEB standards and guidelines the University can refer to and tailor to their own needs and circumstances. A dominant concept is to define absolute performance metrics for new builds and renovations. This refers to defining fixed energy and GHG performance as units/m^2, such as kWh/m^2 and kg CO_2/m^2. Selecting these performance indices with Ontario Tech University's GHG goals for 2030 and beyond will guide new developments and renovations to assist in meeting the targets without compromising the path.

For example, the Toronto Green Standards, British Columbia Step Program and Canadian Green Building Council (CaGBC) – all with best practices standards, have been shown to drive high-performance construction without causing insurmountable incremental costs while yielding reduced life cycle energy and carbon costs. These typically reference the current Building Code requirements and are updated at the same time the Codes are.

These standards differ slightly but are all focused on designing high-performance buildings that can be augmented (or in some cases, totally) by renewable energy sources. The more energy-efficient a building is constructed to be, the less energy is required to power the building which also means any renewable energy will have a more significant impact.

With high-performance design goals, the architectural/engineering teams would be required to pursue L-ZEB concepts from the beginning. For example, by considering solar panel location, shading and designs with surfaces at a specific angle to optimize the solar access. Other considerations such as roof gardens or green walls would enhance these buildings with carbon sequestration and rain surge mitigation by green space. Location and orientation of the building on the site considering natural ventilation and daylighting can be addressed as an energy-saving concept early in the design process.
In general, the standards should promote passive design features along with high-performance design elements in the envelope to keep energy and GHG levels to their lowest possible.

Benefits of an L-ZEB design/renovation are:

1. Reduced energy and carbon costs
2. Improved thermal autonomy
3. Improved resilience against extreme weather events
4. Improved and consistent thermal control
5. Attention to and use of daylighting
6. Improved ventilation efficacy
7. Improved and consistent comfort levels
8. More consideration for the impact on the surrounding environment – exterior lighting, bird impacts, water retention, heat island, public transportation

The New Buildings Institute studied the cost and savings from the construction and operation of ZCB. In the study, costs were separated into two categories – 1) the incremental costs for energy conservation measures and 2) the costs for the purchase and installation of renewable energy systems. By increasing energy efficiency, the number of renewable energy systems (and therefore the cost) will be reduced. The Institute also extended the framework to retrofits and refurbishment of existing buildings to net-zero carbon by considering the design strategies listed in the figure below.

***Figure 11**. Design Considerations for High Performance Buildings*

In 2018, it was determined that the average cost of a LEED building in Ontario was 9% higher than a standard new construction following standard building code. A ZCB is estimated to add approximately 13% to the cost premium of LEED buildings. The differences in cost for Ontario Tech University expansion are estimated in Table 8 below.

***Table 8.** Capital Cost Considerations for Zero Carbon Buildings*

Construction Type	% Cost Increase VS. Building Code	
	2018 $	2028 $
Building Code	-	-
LEED Gold Construction	9%	8%
ZCB Construction	23%	21%

Although construction of a ZCB comes with a cost premium of 13%, there are long-term financial savings in building the Zero Carbon Standard. A typical ZCB has an annual utility and maintenance cost savings of approximately 26% when compared with a LEED construction project[2]. This is shown in Table 9 below.

***Table 9**. Comparing LEED & Zero Carbon Buildings*

	LEED Construction	Zero Carbon Buildings	Savings
Addition to University (sq. ft)	100,000	100,000	-
Estimated Construction Cost Increase	9%	23%	-
Estimated Construction Costs	$29,500,000	$33,300,000	-$3,800,000
Annual Natural Gas and Electricity Utility Cost ($/sq. ft)	$1.49	$0.97	26%
Estimated Annual Utility Expense	$148,532	$96,546	$51,986
Simple Payback (Years)	-	-	48
Simple Payback with Utility Rate Escalation (Years)	-	-	34

Investing an additional $3,800,000 to construct a ZCB would generate an annual utility cost saving of $51,986 and would result in a 48-year payback based on additional construction costs and at current utility rates. However, when accounting for the escalation of utility rates, the payback for a ZCB goes down to 34 years.

Consideration must also be given to the cost of carbon and how it will increase over the next 9 years. In all cases, we recommend a life cycle cost analysis be followed that includes the cost of carbon and best estimates for the cost of utilities. The comparison timeframe should be 15 years minimum. Note that current photovoltaic warranties are 25 – 30 years with an 80% of nameplate at end of the warranty.

[2] Canada Green Building Council & WSP, 2019: Making the Case for Building to Zero Carbon.

Case Study 1: Zero Carbon Building

Completed in Fall 2018, “evolv1” is a three-story, 110,000 sq. ft commercial multi-tenant office building and one of 16 participants in CaGBC’s Zero Carbon Building pilot program.

Figure 12. *Evolv1 in Waterloo, ON*

Building Highlights

- Modelled as zero carbon balance for future operations
- Incorporated a highly efficient energy and ventilation system to meet a defined threshold for thermal energy intensity
- Designed onsite renewable energy systems capable of providing a minimum of five percent of building energy consumption

The building’s design includes elements aimed at maximizing its energy efficiency and producing more energy than it consumes:

- High-performance building envelope
- Geo-exchange/variable refrigerant flow (VRF) HVAC system
- Triple pane glazing
- Solar wall for preheated ventilation
- Combination of a carport and roof-mounted photovoltaics producing 700kw of electricity for the grid
- Three-story green wall to improve indoor air quality

Estimated Construction Cost:

$318/sq. ft (without interior fit-out).

4.3. Pillar 3: Facility Electrification

To meet your 2030 and 2050 GHG emission targets, Ontario Tech University must transition away from fossil fuel-based energy consumption and move towards low-carbon alternatives. Total facility electrification would entail the complete conversion of onsite equipment, including natural gas-fired boilers and HVAC equipment and any natural gas cooking and process equipment wherever practical.

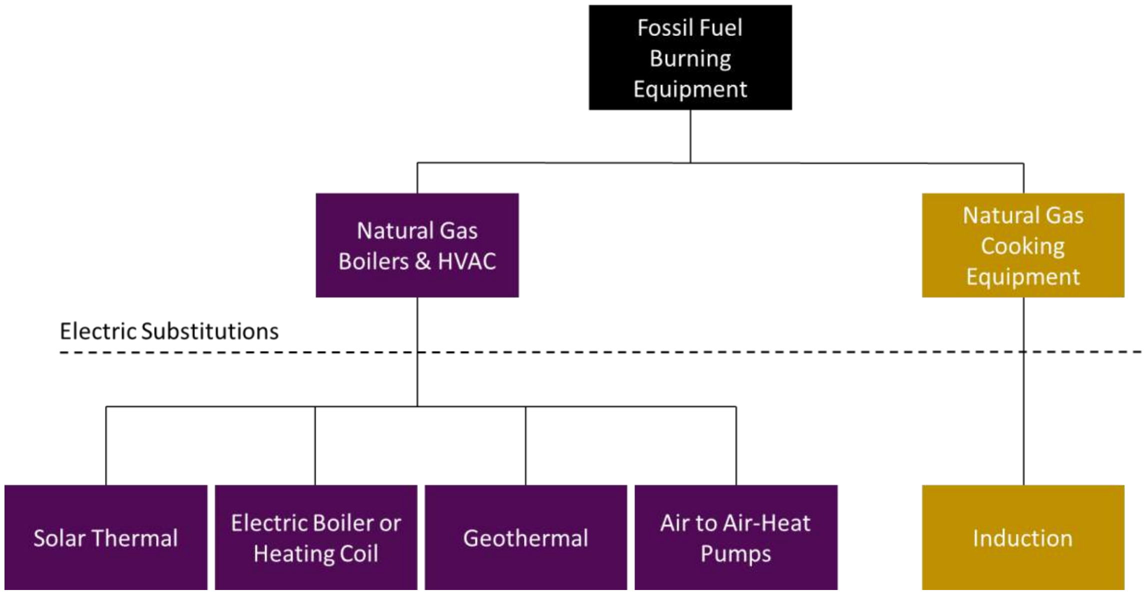
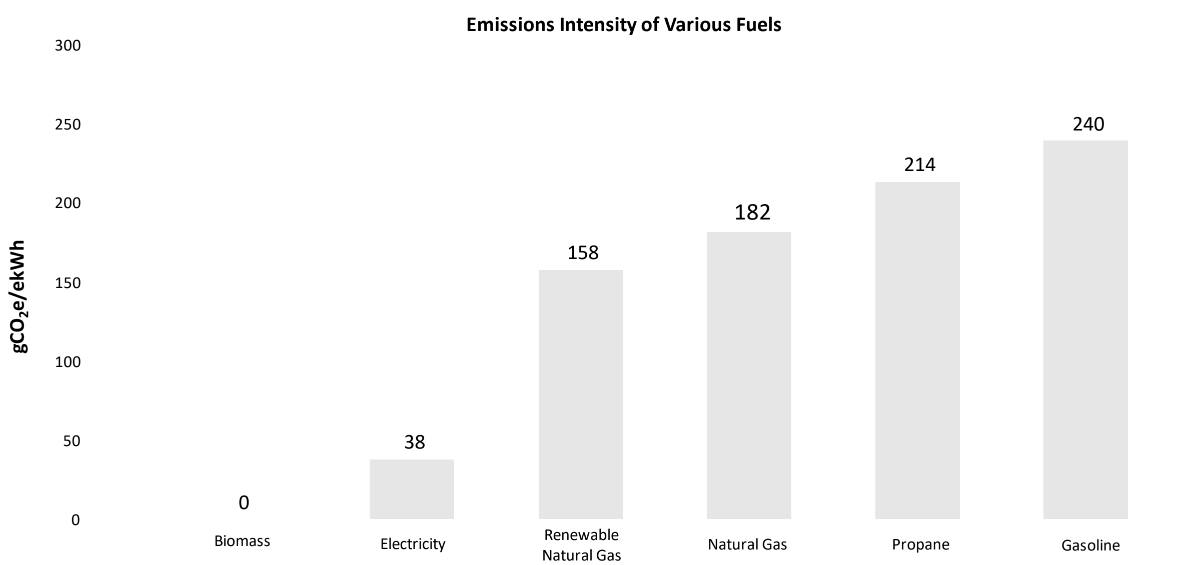


Figure 13. *Electric Equivalents for Traditional Equipment*

When comparing natural gas and electric systems, electric systems produce fewer CO_2e emissions per kWh consumed. Comparatively, 1 kWh of electricity would emit 38g of CO_2e (as per CIB forecast) while 1 equivalent kWh (ekWh) of natural gas would emit 182 g of CO_2e. The carbon content of various fuels converted to equivalent kWh is represented in Figure 14.



Source: National Inventory Report: Greenhouse Gas Sources and Sinks in Canada.

Figure 14. *Emissions Intensity of various Fuels for Equivalent Energy Output*

The electrification action was planned based on the expected asset end of life characteristics using ASHRAE standards and applied to Ontario Tech University's equipment list. For example, as each natural gas-fired boiler approaches the end of life, the study considered the cost and carbon reduction associated with replacing it with an electric equivalent or high-efficiency natural gas replacement. Under the electrification scenario, depending on the current age of the equipment, the natural gas-fired equipment would be replaced at the end of life with electric equipment.

As part of Pillar 2, replacing equipment at the end of its life expectancy creates a decision point for Ontario Tech University to assess whether the equipment should be replaced with electric equivalents or conventional natural gas systems. The following table shows the life expectancy of equipment and the last date of potential installation for fossil fuel burning equipment.

***Table 10**. Fossil Fuel Burning Equipment Expected Life*

Fossil Fuel Burning Equipment	Expected Life (Years)[3]	Last Date of Potential Installation / Replacement
Boilers	20	2025/2030
Make-up Air Units / Air Handling Units – Interior Installation	25	2025
Make-up Air Units / Air Handling Units – Exterior Installation	15	2035
Cars / Trucks	10	2040
Cooking Equipment	15	2035

**Expected Life - ASHRAE Equipment Life Expectancy Chart*

Under electrification actions, Ontario Tech University will increase its electrification efforts and reduce its GHG emissions from natural gas-based equipment. The types of equipment in Ontario Tech University that make up the electrification measures are hot water boilers and rooftop units (RTUs).

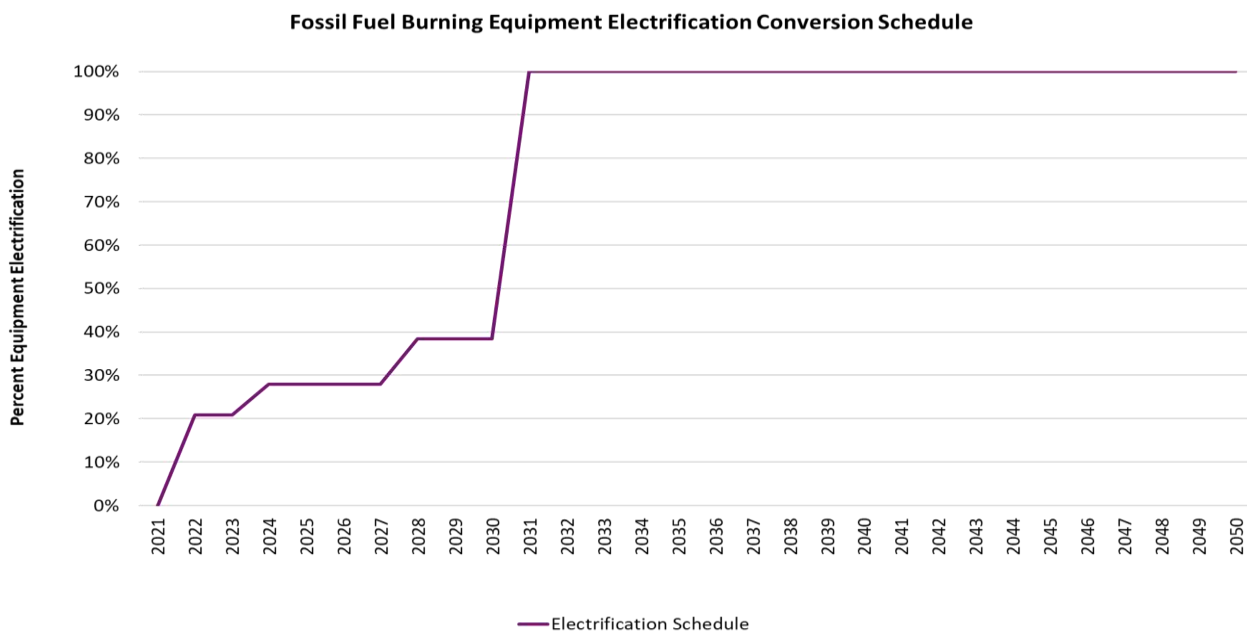


***Figure 15.** Fossil Fuel Burning Equipment Electrification Conversion Schedule*

[3] ASHRAE Equipment Life Expectancy Chart

4.4. Pillar 4: Renewable Energy Generation

Solar photovoltaic (PV) is a proven, low-maintenance and cost-effective form of renewable energy. Blackstone's investigation and estimates indicate Ontario Tech University could install total capacity of 3.19 MW of solar ground mount systems on the property and save 3.6 million kWh of electricity annually. This estimate is based on the information available during the period of this study and the actual number could vary depending on multiple factors such as changes to the master plan or parking plans.

With the vacant land available to Ontario Tech University for expansion, a combination of PV systems and battery energy storage systems could potentially be a viable clean energy solution.

Ground mount systems provide a great opportunity to produce renewable power when space constraints on a building are a concern. Carport and ground mount solar PV systems are a highly visual symbol of Ontario Tech University's plan to sustainability and portray them as actively looking for low-carbon solutions.

The limiting factor for renewable energy generation is the space requirement per kilowatt (kW) installed. Solar PV is typically net metered to the local grid system. The amount produced would contribute to lowering Ontario Tech University's Scope 2 emissions by reducing the amount of electricity it purchases from the grid. Case Study 2 in the following pages elaborates on the building integrated and building applied photovoltaics (BIPV and BAPV) systems, which are recommended to be considered for future buildings and buildings' expansions.

For more details on these technologies and proposed measures, please refer to *Appendix 1 - Measures Summary Report.*

Case Study 2: Building Integrated & Building Applied Photovoltaics (BIPV & BAPV)

Recent PV technology improvements are making building integrated and building applied photovoltaics more available (BIPV and BAPV). The difference between the two is that BIPV is when the PV is a part of the building such as embedded into the windows or forms the actual envelope, whereas BAPV is when the PV system is mounted onto the building such as the roof or vertical racking onto a wall. This technology could be applicable on the curtain walls of the Science, UB, Library and Engineering buildings.

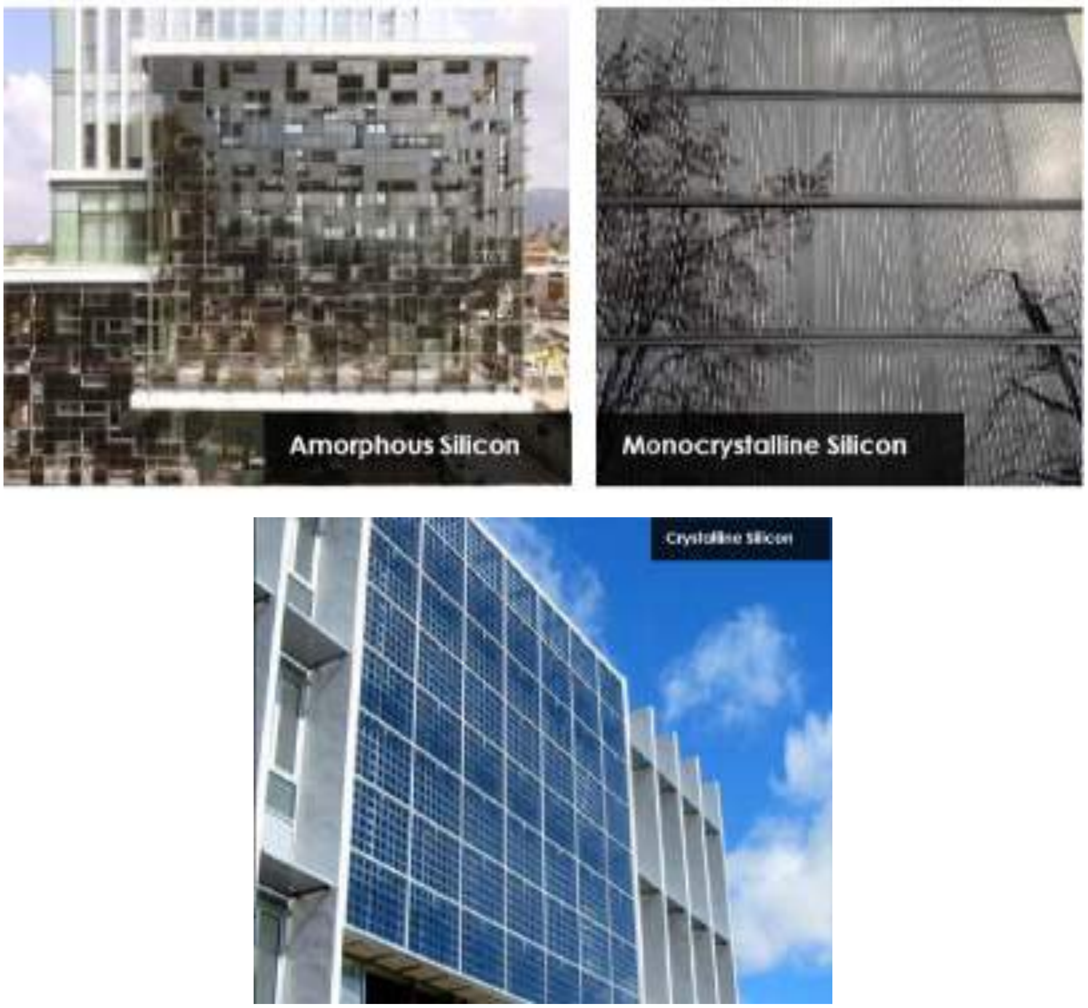


Figure 16. *Examples of BIPV & BAPV*

Case Study 2: Building Integrated & Building Applied Photovoltaics (BIPV & BAPV)

Some examples of BIPV – the PV modules are a part of the envelope. These can be customized with a range of transparencies and limited colours. The lower left image shows crystalline modules; the right is amorphous.

BIPV applications are typically considered from the start of a new building as the architect is generally the lead to make sure the “look”, style and appropriate design teams are involved – i.e., structural, electrical. If an envelope BIPV system is being considered, the existing wall will be removed and the new BIPV envelope installed. Other examples of BIPV are the skylight and window style of BIPV, which will require a structural survey as well and best coordinated with a design team to ensure compatibility with the building style and envelope integrity.

An alternate version is the building applied PV or BAPV. In this case, the PV array is mounted onto the structure. A fixed or ballasted PV array on a roof is an example of this arrangement and is very common. Wall-mounted PV can be hung onto the wall using a racking system or used as an awning over windows to provide some shading as well as power.

Figure 17. *Examples for mounting of BIPV & BAPV*

Case Study 2: Building Integrated & Building Applied Photovoltaics (BIPV & BAPV)

BIPV and BAPV Considerations

BIPV systems are used as cladding or window units. The design possibilities are in keeping with the envelope designs available. There are curtain walls, skylights, canopy, ventilated facades, and floors. They are usually constructed as sandwiched PV between the glass so can be a substitute for conventional architectural glass. They offer energy production, lighting (depending on transparency), infra-red and UV filters, acoustic and thermal characteristics.

The PV module is either amorphous or crystalline cells. Amorphous can be supplied in a variety of shapes, sizes, colours, and transmission from 0% to 30%. These have a consistent colour across the complete face of the glass. Due to the transparency, the power ranges from ~57 W/m^2 at 0% to about 28 W/m^2 at 30%. Crystalline silicon PV can also be customized but is usually configured as square to rectangular shapes. These look more like conventional PV modules with cells spread across the face. This also means they always let some light through even at high cell densities. They range from ~15% to 38% transparency. The power is dependent on the cell density.

Production Potential

The graphs below illustrate a sample output for an amorphous array, 100 m^2, 5.7 kW, 0% transmission, 4,000 kWh/yr. and a crystalline array, 100 m^2, 3.5 kW, 15% transmission, 2,756 kWh/yr, both mounted on a vertical wall, facing due south.

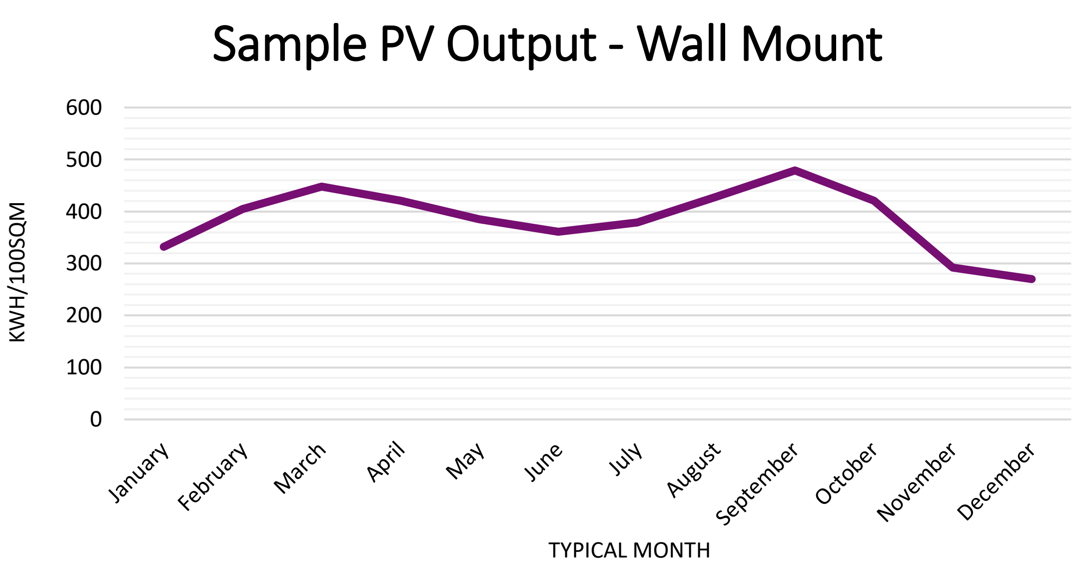


Figure 18. *Sample amorphous wall 100m2 BIPV at 0% transmission, 5.7 kW, 4,000 kWh/yr.*

Case Study 2: Building Integrated & Building Applied Photovoltaics (BIPV & BAPV)

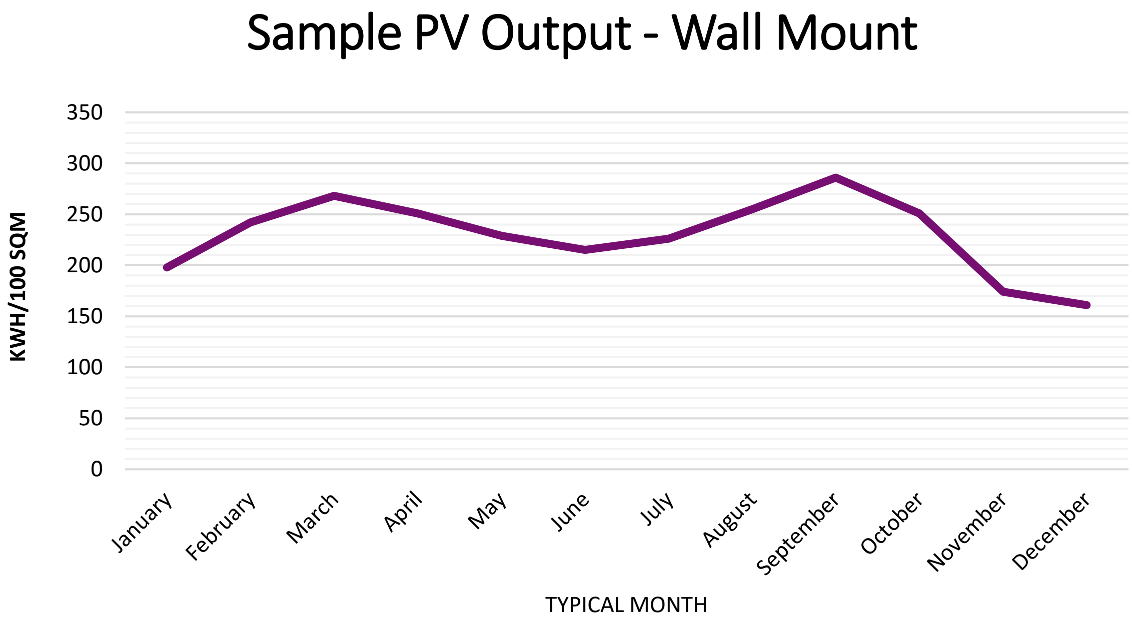


Figure 19. *Sample crystalline wall 100m2 BIPV at 15% transmission, 3.5 kW, 2,756 kWh/yr.*

Cost Considerations

Of the BIPV applications, a fully integrated PV envelope will be more expensive due to the structural elements required to complete the wall. Though a sample has been shown above for 100 m^2, most BIPV systems are at or above 1,000m^2 before the benefits of scale are available. An estimated cost for a full BIPV wall can be expected to be between $1 million and $1.5 million depending on the fastening system. A wall mounted BAPV can be expected to cost about half of a BIPV but is more dependent on the structural integrity of the existing wall.

As for any PV system, the connection must be evaluated before deciding to go forward with an installation. This is done early in the design process in coordination with the local distribution company.

4.5. General Sustainability Initiatives

The four Pillars will reduce Scope 1 and 2 emissions that result from the energy used by Ontario Tech University facilities. To reduce Scope 3 emissions, from waste, Ontario Tech University will need to support general sustainability initiatives that typically require staff and students' engagement which will be explored further in *Section 9.*

The University should ensure that all policies are aligned with the Enervolve Study and the goal of encouraging a low carbon future. For example, banning single-use plastics and continuing initiatives to limit food waste.

4.6 Sustainability Indicators

Climate change is recognized as a risk for financial and sustainability modelling. Markets and society are increasingly aware of the costs and risks of climate change and the results of inaction to mitigate the effects. Establishing a strategy will help with managing the risks associated with environmental, societal and governance dimensions for Ontario Tech University.

This Enervolve Study is a part of the strategic planning and combines with their sustainability plans and efforts to align with current programs that are being used as benchmarks for acknowledging the efforts. The UN Sustainable Development Goals (SDG) are another recognized platform for this. Elements of this Enervolve Study support the UN SDG categories that relate to clean energy, resiliency, and action.

Figure 20. *UN Sustainable Development Goals*

5. GHG Emissions Reduction Scenarios

For Ontario Tech University to meet its emission reduction targets, it must implement programs to support the four Enervolve Study Pillars. Based on the combinations in which the Enervolve Study Pillars are implemented, two Phases for the University to advance towards carbon neutrality, are presented.

5.1. Phase 1: Energy Conservation, Electrification and Renewables

Ontario Tech University implements Pillars 1, 3 and 4 – Energy Conservation and Demand Management, Electrification and Renewable Energy Generation. Efforts under this scenario lead to deviating from business-as-usual operations considerably. Between 2025 and 20235, Ontario Tech University will:

- Implement proposed electricity and natural gas conservation ECDM measures, electrification and renewable technologies, as indicated in Table 3
- Complete an ECDM Plan and update it every five (5) years
- Create a Measurement & Verification (M&V) plan and start to measure performance of implemented measures.

6. Net-Zero Gap

Blackstone's analysis of Ontario Tech University's current and future GHG emissions from 2022 to 2050 suggests that, based on the current forecast of Ontario electricity grid emission factors, Ontario Tech University will have net-zero gap by 2050 of approximately 1,117 tons.

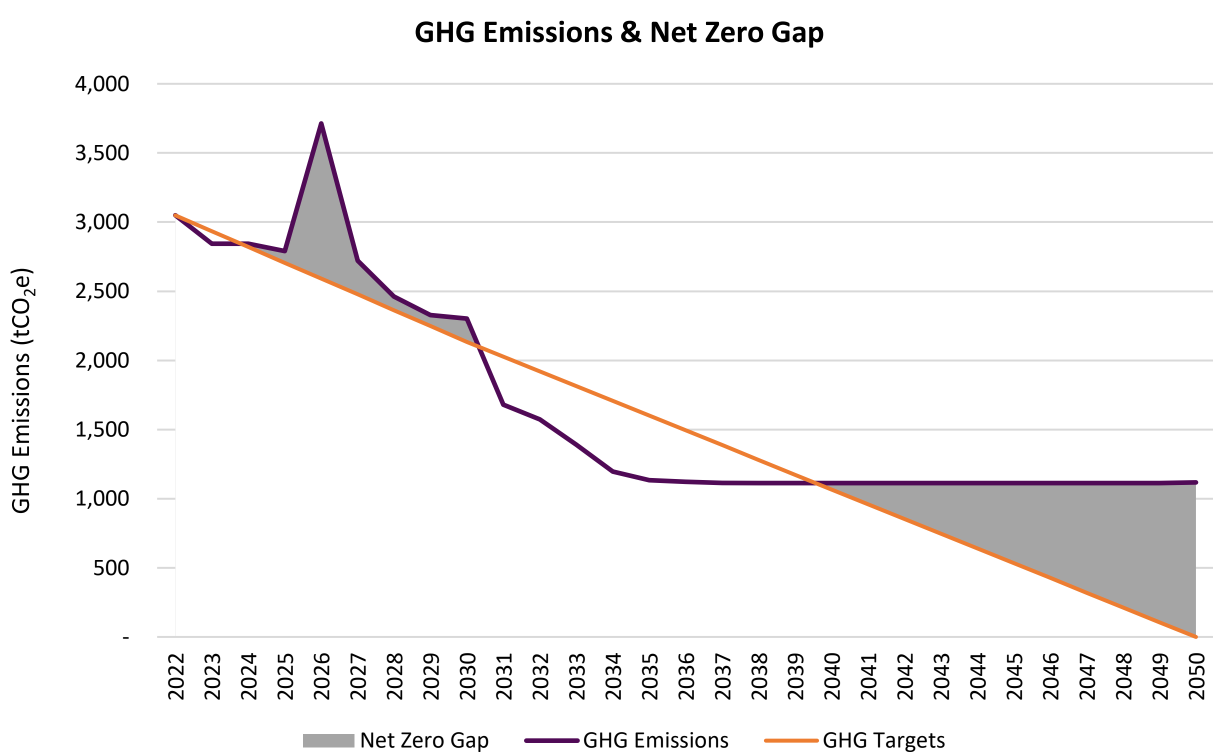


Figure 21. *The Net-Zero Gap Based on Ontario Tech University's GHG Reduction Plan*

Figure 21 shows the gap between Ontario Tech University's GHG emissions and its reduction plan (Proposed Project). The Net-Zero Gap will depend on the amount of energy Ontario Tech University produces using renewable energy, and/or the degree of decarbonization that Ontario's electrical grid would have to undergo, for the University to achieve carbon neutrality.

The Net-Zero Gap will either increase or decrease depending on factors including the University facility asset expansion, the adoption of high-performance building designs for both new and renovation projects, engagement by staff and the evolution and timely acceptance of low carbon solutions.

In the case of the Net-Zero gap, Ontario Tech University's Net-Zero Gap could be addressed by emerging technologies and changes to the Ontario electrical grid. To address the Net-Zero Gap, Ontario Tech University should consider the following options, which will each be explored in more detail below:

- Renewable Generation
- Grid Carbon Intensity
- Renewable Natural Gas
- Carbon Offsets
- New low carbon Technologies
- Virtual Power Purchase Agreement (VPP)

6.1. Renewable Generation

In addition to renewable generation becoming more affordable, the energy density of renewable generation systems is increasing. Significant advancements are being made in the amount of electricity that is produced per square foot of renewable PV panel, which would increase the amount of electricity Ontario Tech University can produce on its sites. The University may have the opportunity to produce renewable energy at an offsite location if the regulatory barriers to Virtual Net Metering are removed. Ontario Tech University could then install renewable generation capacity offsite using increasingly common power purchase agreements. The renewable electricity produced would be fed into the grid and the renewable generation would be credited to the University as an offset to balance the electricity is consumed (e.g., the increase due to electrification of HVAC).

6.2. Grid Carbon Intensity

The existing carbon grid intensity determines the amount of carbon produced per electricity unit consumed. In Ontario, since 2014, there have been significant reductions in carbon grid intensity because of the closing of coal plants. If carbon grid intensity is lowered, this would assist Ontario Tech University in reaching its net-zero target. However, in upcoming years there would be an increase in carbon intensity due to refurbishment (in the near term) and possible phasing out of nuclear from the Ontario electricity grid. In some situations, the grid needs to be supported – e.g., during hot summers when AC is in use, and typically through gas-fired "peaker" plants. These episodes increase the emissions significantly and can be tracked by using what is called the "marginal emissions" factors. For example, the marginal factor in Ontario is almost 5x the annual factor. This level of tracking is recommended when PV systems are used as they tend to provide power when the sun shines the strongest and AC loads are the highest. However, emissions factors are typically provided annually which "buries" any effect of the marginal emissions.

6.3. Renewable Natural Gas

Renewable natural gas (RNG) is a low-carbon alternative to traditional natural gas (TNG). It is produced from biosources such as food waste, sewage, or other organic materials. RNG is currently expensive, several times more expensive than traditional natural gas, and is difficult to source in large quantities. However, in the future RNG will be more readily available. Several Ontario municipalities and major gas distribution companies are investing in RNG facilities. There is potential for the market to supply renewable natural gas through the existing distribution system, which would greatly impact the need for and cost of conversion to electrification. Lastly, as carbon taxes are increased, the price gap between RNG and TNG will be reduced.

6.4. Carbon Offsets

To address the Net-Zero gap, Ontario Tech University could consider purchasing carbon offsets to reduce its carbon deficit after optimizing ECMs and renewable energy impacts. A carbon offset is a credit for greenhouse gas (GHG) reduction achieved by one party that can be purchased to offset another party's emissions, typically ranging from $15 to $60 per tonne depending on the location and type.

The university is advised to purchase Core Carbon Principles (CCP) labelled carbon offsets from transparent and internationally recognized registries based on science-based protocols and methodologies. Blackstone, a registered broker, actively participates in key voluntary carbon market registries, including Paris Agreement-compliant units on the REDD.plus (Reducing emissions from deforestation in developing countries) platform and offsets from the four main international voluntary carbon registries: Verra, Gold Standard, Climate Action Reserve, and American Carbon Registry. Additionally, following best-market practices from the International Carbon Reduction and Offset Alliance (ICROA) and the Voluntary Carbon Market Integrity Initiative (VCMI) for reporting on the usage of carbon credits is recommended.

Blackstone provides offset credits from projects designed to prevent or address leakage and permanence/reversal issues, ensuring permanent and measurable impacts. Our projects do not generate emissions for subsequent reduction, removal, or destruction, and they adhere to industry best practices such as those from the Integrity Council for Voluntary Carbon Market (ICVCM) to avoid leakage emissions and potential negative environmental or socio-economic impacts.

Notably, Blackstone was the first company to purchase UN-based REDD+ result units for voluntary emissions reduction towards our Net-Zero targets. These units are recognized as some of the most credible credits available, with each RRU representing the removal of one tonne of CO2 from the atmosphere and saving two rainforest trees. REDD+ enables developing countries to receive payments in exchange for protecting their forests, providing a significant impact.

We recommend reviewing the use of carbon credits to help close any net-zero gaps in 12-months' time once standards are established.

6.5. New Technologies

There is of course an “unknown” factor when it comes to the availability and viability of future clean technologies. Energy technology trends suggest that the alternatives to create low-carbon electricity are improving, becoming more efficient and less expensive. However, is it difficult to predict the rate at which new technologies will make their way onto the market and which will be technically suitable to reduce the Net-Zero Gap. For example, air-source heat pumps can now maintain high-performance ratios (coefficient of performance >1.0) at outdoor temperatures below freezing which makes them candidates for HVAC replacements. Some examples of emerging technologies are discussed in Case Study 4, in the following pages.

6.6. Power Purchase Agreement (PPA)

To reduce the carbon intensity of the electricity provided by the grid, power purchase agreements (PPAs) can be applied between Ontario Tech University as the buyer and a second party as the seller to provide offsite electricity generated by renewable power and will be shipped through the Ontario grid. This partnership is contracted to last for a set time, 15-20 years, with the power cost set for that period. Ontario Tech University is not responsible for the site. Partnering with a renewable energy provider reduces the carbon content of the organization through the carbon credits they can gather through the PPA.

These are also considered “virtual” in that they are not on the organization's property or in many cases connected to their loads (other than through the transmission and distribution grids). The concept is gaining traction across North America and is currently available in Alberta only. Until the time that these agreements are legislated in Ontario, Ontario Tech University should maintain awareness of any changes to the VPPA model. This option is recommended to be considered once VPPAs are allowed for in Ontario.

These are contracts and as such should be dealt with by experts in the PPA field. Following below is a general outline (consolidation) of the considerations a PPA will cover based on Blackstone experience:

- Generator Credit Review: Credit review is a key element of the PPA process. Both counterparties must have comfort that the other can fulfill its commitments to the other over the long term. Blackstone can help Ontario Tech University ensure that the counterparty has the financial capacity to finance, build and operate the renewable project over the long-term, or the duration of the PPA. On the other hand, Blackstone has also been a developer of renewable projects. In this regard, Blackstone assesses the credit of the off-taker to determine if they have the long-term ability to pay for the agreed upon commodity purchase price.
- Proof of Financing: An assessment is performed of the generator’s financing to ensure the project is financeable and can construct, or, if not, what the barriers are and corresponding strategy and timelines for resolution.
- Right of Access: In its analysis of the PPA, Blackstone will ensure that the generator has the firm, uninterrupted right to exist on the property where it exists. This involves a generator-landlord lease review and an examination of non-disturbance agreements.
- Project Assessment: Blackstone will assess the ability of the generator to achieve stated energy production goals. As a renewable project developer, we understand and focus on this aspect; it is the basis of an energy project’s long-term viability.

- Commercial Terms / Locational Pricing: Blackstone's core skill set is that of energy commodities manager. We have a long track record of providing wise tactical and strategic commodities pricing advice to our client base. We will use this skill set to ensure Ontario Tech University receives sharp pricing terms with the PPA counterparty, taking into consideration locational pricing where applicable, while also paying special attention to termination terms and conditions.

The contract terms are comprehensive and include chapters such as:

1. General Terms and Conditions
2. Sale and Purchase of Energy Environmental Attributes (and Replacement Attributes, if applicable)
3. Development of the Project
4. Operation and Maintenance
5. Term
6. Default and Termination
7. Credit Support
8. Data, Metering and Measurement
9. Representations, warranties and Covenants
10. Indemnification and Insurance
11. Other Covenants
12. Confidential Information
13. Force majeure
14. Change in Law
15. Audit
16. Dispute Resolution
17. Assignments, Change of Control
18. General

The main contract will include Schedules such as:

1. Project, Site and Strike Price
2. Form of Purchase Guaranty
3. Form of Letter of Credit
4. Insurance Requirements
5. Approved Third Parties

7. Financing Net-Zero

This section of the Enervolve Study outlines the required steps and financial implications of Ontario Tech University meeting its 2030 and 2050 GHG targets, as well as the recommended program delivery model. The proposed measures require significant capital investment and may have utility cost implications or savings. It should be noted that measures such as converting from natural gas to electricity will increase operational costs, as the electricity is more expensive than natural gas. The increase in operational costs is accounted for in the total annual cost savings. The financing model was run under the assumption that all measures are to be developed and implemented between 2025 and 2027.

7.1. Capital Costs Required

The investment and associated costs and benefits include the following:

Table 11. Investment Costs and Benefits Associated

Program Information	
Implementation Year	**2025-2027**
Total Investment in ECDM, Renewable Energy and Electrification	$19,006,881
Total Annual Cost Savings	$627,952

7.2. Financial Details

7.2.1. Capital Investment Required

For Ontario Tech University to meet its 2030 and 2050 GHG targets, it is vital to reduce the consumption of natural gas. Hence, the recommended GHG reduction program prioritizes energy conservation, the implementation of renewable energy systems and electrification measures. To develop plausible investment strategies for the implementation of these projects several factors must be considered. These include the current cost of technology, utility prices and incentives or funding avenues, which in some cases do not immediately provide a sound business case for facility electrification and ultimately carbon reduction.

Table 12 and Figure 22 below depict further financial details.

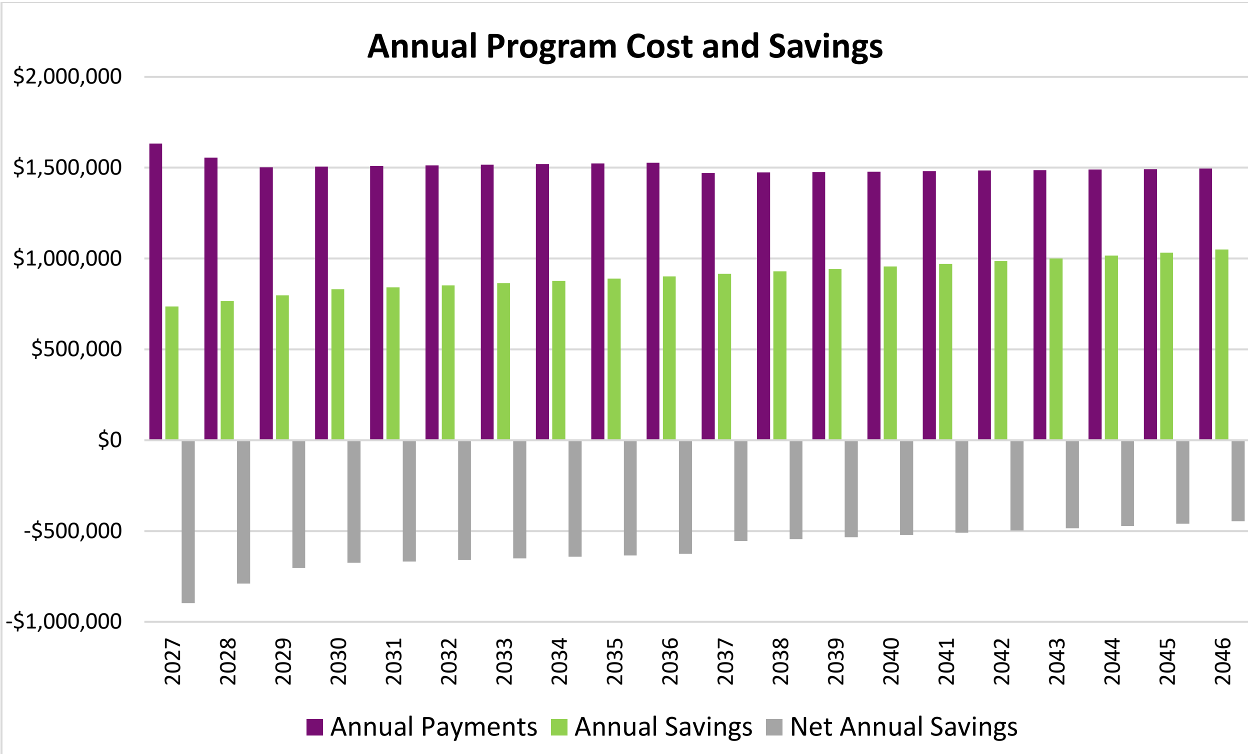


Figure 22. *Cumulative Net Cash Flow for Phase 1*

Table 12. *Investment Costs and Benefits for Phase 1*

Program Information	
Implementation Period	**2025-2027**
Total Investment	$19,006,881
Total Annual Cost Savings	$627,952
Construction Period (Years)	1.5
Construction Interest Rate (CIB Funding)	3%
Term (Years)	20
Term Re-Payment Interest rate (CIB Funding)	2.5%
Estimated Term Cost Savings	$18,163,964
Estimated Term GHG Savings	36,288 tons
Total Term Cumulative Cash Flow	-$11,969,230

With a Federal GHG reduction target of 40% by 2030, Federal government has $9.1B available for sector-by-sector GHG reduction projects, fudding various incentive programs to stimulate GHG reduction initiatives. One of the currently available programs, LCEF (Low Carbon Economy Fund), is providing annual incentives up to 50% of the total eligible project costs for public institutions. For the proposed Ontario Tech University program.

7.2.1. Proposed Delivery Model

Blackstone team has extensive experience in developing fully funded, cashflow positive models implemented in public institutions. We are proposing **Managed Energy Service Agreement (MESA)** delivery model to achieve your 2030 GHG reduction target.

Through MESA, Blackstone will develop, design and construct proposed energy & carbon reduction project (Phase 1) with no upfront capital required. With MESA program, the University will own the assets and project related financial savings, if required, can be guaranteed by an energy savings warranty to eliminate the risk of savings shortfalls and ultimately ensure the financial performance of the business case/project is achieved.

MESA Process Steps

1. MOU executed with basic terms and conditions of project scope and commercial terms (if applicable)
2. Managed Energy Services Agreement (MESA) is executed upon review and acceptance of Final Service Program Feasibility Study
3. Tri-party Funding agreement is executed as part of the MESA contract
4. Blackstone mobilizes and implements project measures as set out in Schedule "B" Project Schedule. Monthly progress draw requests are approved by client, an invoice is then issued to funder for payment with signed Progress Draw Approval Form.
5. Project is completed and accepted by client. Service Payments begin and are paid by client to a joint account that is owned by Blackstone and the Funder, which the Funder has power of attorney over.
6. The contract performance period is commenced, and savings are measured and verified. In the event of a confirmed savings shortfall, the construction period savings are used to offset financial shortfall.
7. If the construction period savings are liquidated to cover the savings shortfall, the Energy Savings Warranty claim is registered and the underwriter pays the shortfall claim to the loss payee, which in this case is the client.

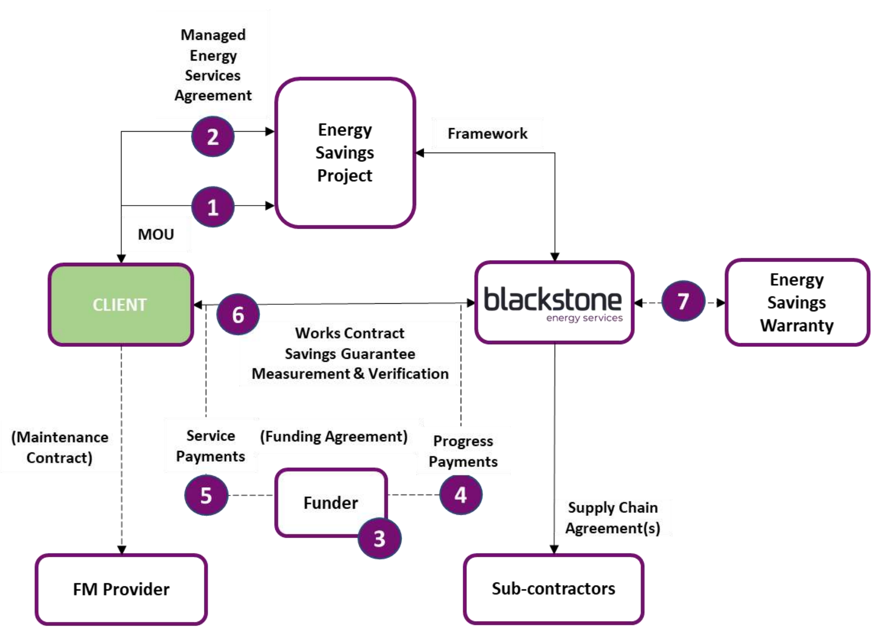


Figure 23. Managed Energy Services Agreement (MESA) Delivery Overview

7.2.1. Canada Infrastructure Bank (CIB) Public Retrofit Initiative

The CIB Public Retrofits Initiative provides financing for decarbonization retrofits in privately and publicly owned commercial buildings in Canada through an investment of up to $2 billion. The Initiative is part of the Canada Infrastructure Bank's (CIB's) $10 billion Growth Plan that aims to stimulate jobs for Canadians and strengthen Canada's economy through new infrastructure investments. By increasing levels of public and private investment in infrastructure, the CIB's Growth Plan will contribute to Canada's competitive, connected, and resilient economy. The program overview is shown below.

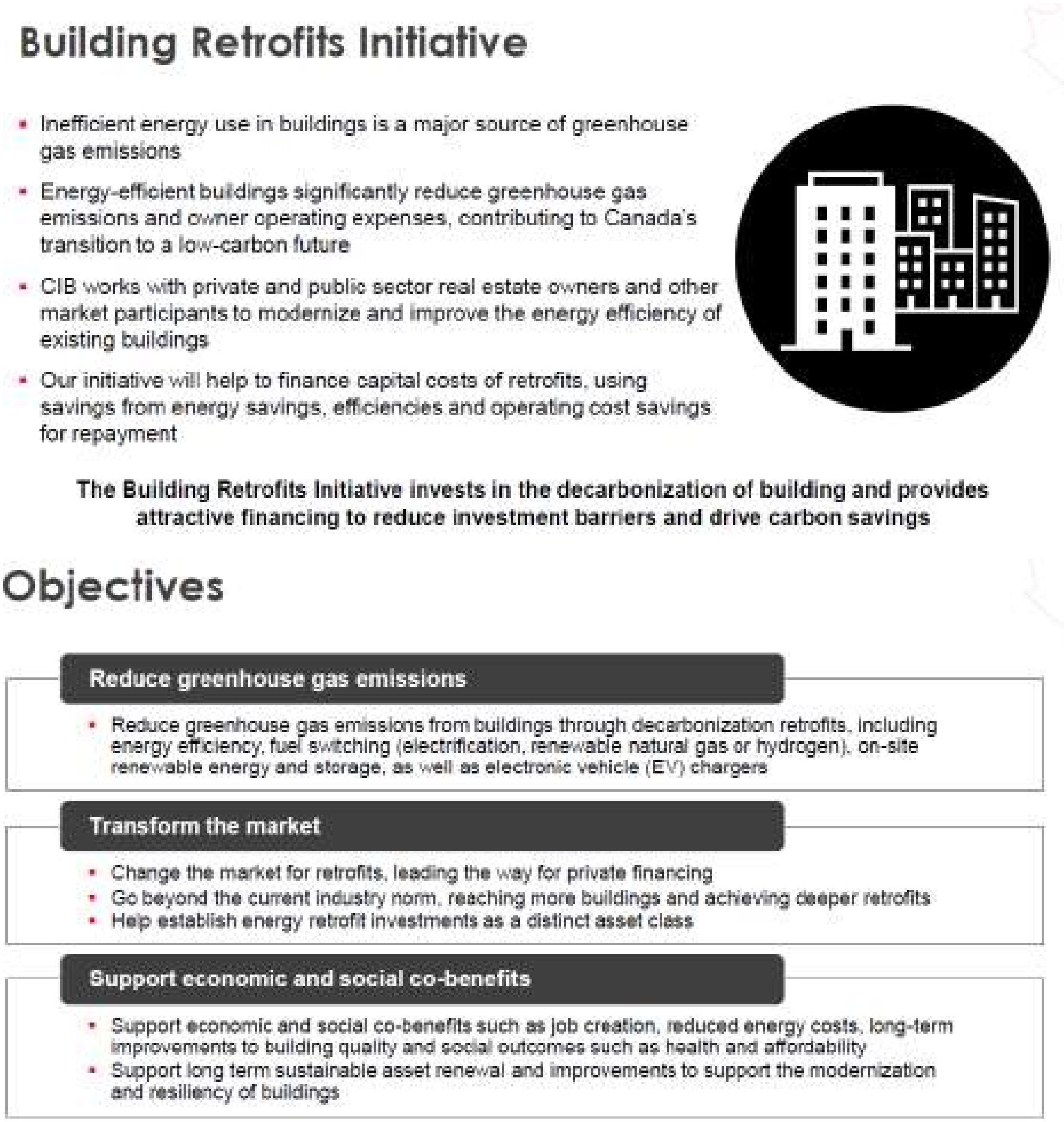


Figure 24. *Buildings Retrofits Initiative Overview and Objectives*

The Initiative offers long-term, high leverage, below-market interest rate investments for public and private sector building retrofits that substantially reduce GHG emissions. Financing can apply to investments in large individual projects, or a pool of investments originated by a retrofit aggregator. To encourage the market to pursue deep retrofits that go beyond the industry norm, the Initiative requires that all projects achieve a minimum level of GHG savings while offering more favourable financing terms (more affordable capital and longer payback periods) for projects that target deeper savings.

CIB's standardized core Initiative offering is a $25M or greater debt product that requires a minimum 30% of equipment investment. CIB debt is extended based on the forecasted savings derived from improvements to buildings as the primary source of repayment, with one source of recourse being energy performance guarantee contracts applied to the savings forecasts.

All proposals and retrofit projects are required to meet eligibility requirements and undergo a technical and financial due diligence process. Interest rates of CIB funding currently range from 2.25% - 4.25% for terms of up to 25 years depending upon the level of GHG savings that can be achieved by the project. Minimum required GHG reduction per project is 30%. Example scenarios of the CIB program are illustrated below

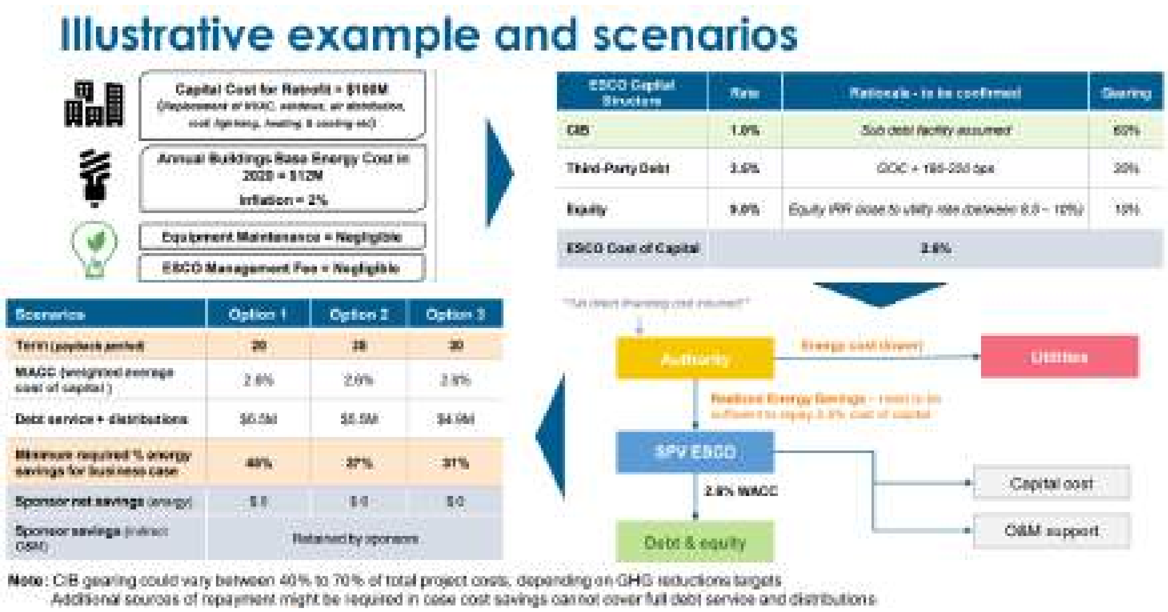


Figure 25. *CIB Examples and Scenarios*

7.2.2. Public-Private Partnership and Energy-as-a-Service (EaaS)

To reduce their energy and carbon footprint, public and private sector facility operators and owners are increasingly exploring and leveraging innovative business models that create new opportunities for their organization to finance energy-efficient building technologies, renew infrastructure, and renew or construct net-zero ready buildings. Traditional models previously used to address these opportunities include pay-for-performance contracts, energy savings performance contracts, power purchase agreements, and on-bill financing.

One innovative business model gaining interest offers energy-as-a-service (EaaS). This represents a shift from client-owned equipment toward a model where the service provider maintains ownership and the customer pays for the services provided by the project or program. The maintenance of the equipment is also the responsibility of the service provider. Blackstone anticipates that with the integrated nature of much of the EaaS infrastructure and assets, a hybrid model of collaborative maintenance will emerge to share resources and expertise producing better outcomes for all stakeholders in this critical area of operations.

This financial solution helps organizations implement complex carbon, energy, and water efficiency projects with no upfront capital expenditure. The provider designs the project scope finances the material and construction costs maintain (in partnership with the client) project equipment/systems & buildings (if applicable) and monitor the performance to validate energy and operational savings as shown in the figure below.

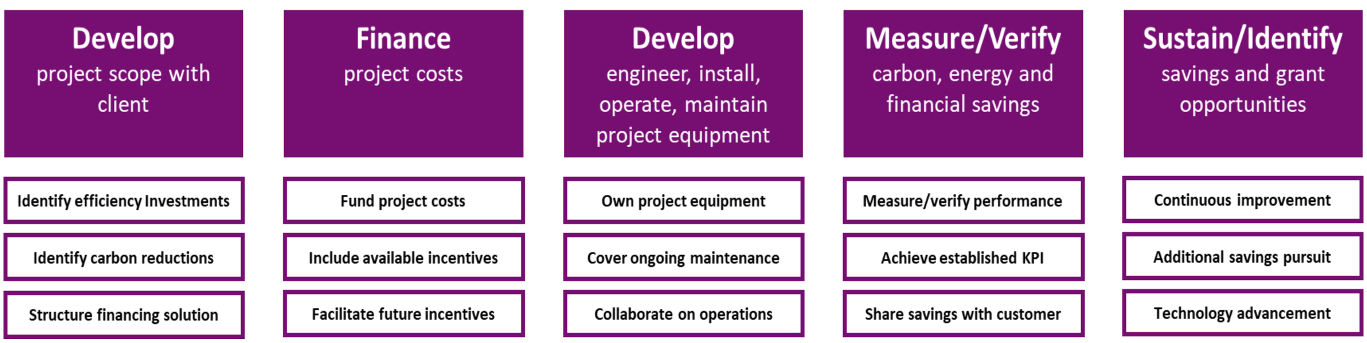


Figure 26. *Roles Overview of Energy-as-a Service Provider*

The client pays back the project/program costs through a monthly, quarterly, or annual fee for the services received. The payment is generally based, directly or indirectly, on the energy, maintenance and other quantifiable operational savings realized on the client's fiscal operating plans. Experience in Europe and the US to date with this service-based model suggests energy-related and operational savings potential up to 20–25% can be achieved to create the value for the service provider and clients to develop a mutually beneficial EaaS agreement.

EaaS solutions are typically comprehensive and include green infrastructure renewal initiatives such as district heating systems, geothermal, heat pumps, solar PV, lighting retrofits, upgrades to HVAC and other equipment, building automation and controls, energy storage, Electric Vehicle charging systems and building envelope upgrades.

The EaaS Model

The figure below shows the structure of a typical EaaS relationship.

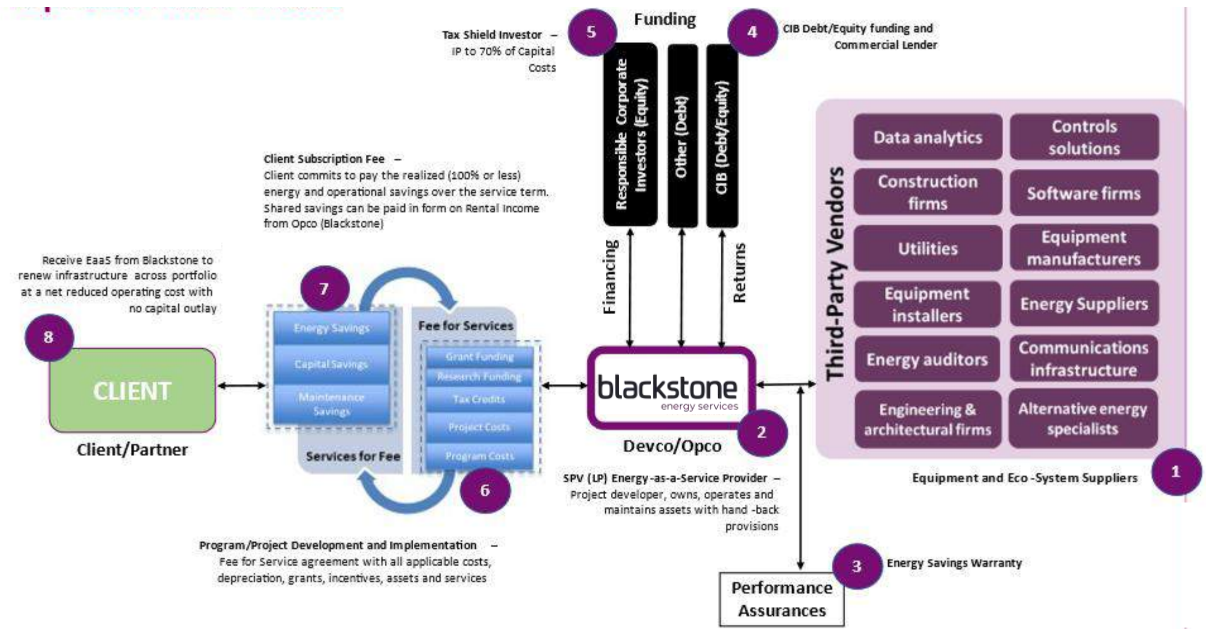


Figure 27. *EaaS Relationship Structure*

The EaaS model usually shifts the burden of financing, owning, installing, and managing the performance of an energy asset from the client to the service provider. Before any energy-related or operational saving measure(s) or services are implemented, the service provider conducts or arranges for detailed investment grade feasibility assessments to establish the business case for the client and provider. Once the project or service scope is finalized and construction completed, a measurement and verification (M&V) analysis determine the actual savings. The client is responsible for a service fee, typically based on the units of energy or operational savings associated with the project or program of works.

The payment can be structured either as a percentage of the customer's utility budget or as a fixed amount that may include deemed operational savings. In any case, the client's payments are below its current utility and operating budget and the provider promises a certain level of savings and adjusts payments if it is not realized. At the end of the contract period (generally 10 to 30 years), the client can purchase the equipment at fair market value, have the provider remove it, or extend the EaaS contract.

Large buildings, or a portfolio of smaller buildings that add up to a bigger footprint, provide an opportunity for greater energy savings and represent an ideal situation of the EaaS contracting process.

The Benefits

The EaaS model can provide valuable services to commercial, municipalities, facilities, and higher education clients. This section offers a preliminary list of benefits.

First-Cost Savings

Many organizations hesitate to divert capital from essential business objectives to invest in building retrofits. The EaaS model can be a good fit for organizations that want to pursue deep energy and carbon infrastructure renewal without using their finances. Under an EaaS agreement, the service provider obtains equity funding and secures third-party funding to pay for all project costs, so the client has no upfront expenses or internal capital outlay and can use their funds for other projects.

Off-Balance-Sheet Financing

EaaS offerings are typically designed as an off-balance-sheet financing solution. The use of service payments allows businesses to shift energy and carbon infrastructure renewal projects from an expensive asset that they must buy, own, maintain, and depreciate to an operating expense similar to a standard utility bill or power purchase agreement.

Since the provider owns the energy equipment, clients have no debt on their balance sheet and their bottom line is improved. Thus, they can secure the energy and services they need with fewer uncertainties because the provider has assumed the risk for achieving energy and operational savings.

Deeper Operational and Maintenance Savings

The cost savings from the projects are calculated and guaranteed using agreed-upon M&V protocols. Because the EaaS paradigm generally relies on the pay-for-performance model, it offers potential operational efficiencies and positive cash flow from energy, water, and maintenance cost savings. The pay-for-performance nature, along with maintenance and verification of project savings, reduces the performance risk for clients and may encourage more-persistent savings and implementation of newer green infrastructure and clean technologies.

Clients have the additional benefit of being able to finance multi-measure deep green infrastructure retrofits with long simple payback periods. EaaS projects may include capital-intensive investments in HVAC upgrades with motor, pump, and boiler replacements, energy management systems, and distributed renewable energy resources. These measures offer greater energy savings, can optimize comfort and tackle carbon reduction targets. However, they are difficult to fund under traditional financing sources due to their lower return on investment.

As the EaaS providers are responsible for the energy equipment, they pay for periodic maintenance services to encourage long-term reliability and performance. The level and structure of such service vary by project type and client needs. By rewarding a third-party provider for successfully managing operations, clients reduce the risks and challenges associated with implementing, managing, and monitoring new technology. Installing more-efficient equipment with continuous maintenance may also mitigate the risk of unplanned events.

Lower Operational Risks

EaaS vendors provide access to experts who can design the project scope and install, maintain, and verify the performance of the efficiency measure. Clients have a lower risk of paying for underperforming equipment because vendors guarantee energy savings at a known cost and can attract large grants and incentives which can be used to lower capitals costs and ultimately service payments.

Long-term agreements allow clients to secure a fixed lower price for energy throughout the contract if the service provider can achieve the promised savings.

7.3. Factors that Influence Cost

In choosing its path to net-zero emissions, Ontario Tech University will need to consider several factors that influence project costs, including:

- Replacement Cost
- Operational Cost
- Forecasted Utility Cost
- Cost of Solar/renewables
- Carbon Tax
- Funding Opportunities
- Utility Rate Structure
- Supporting Infrastructure Costs
- Emerging Technology Costs

7.3.1. Replacement Cost

Electrification would be a mitigation solution from Blackstone to reduce GHG emissions from burning fossil fuel equipment by replacing the equipment with electric equipment. As an example, there are multiple hot water and steam boilers in Ontario Tech University that could be replaced with electric boilers at the end of their life. As the tax on carbon-based fuels increases, the cost difference between natural gas equipment and non-fossil fuel-based equipment and other fuel sources will decrease. An example of this is presented in Case Study 3.

Case Study 3: Cost of Heating – Natural Gas vs. Electric Boilers

Table 13 lists the specifications of an industry-standard natural gas boiler and the specifications of the electric equivalent.

Table 13. *Comparing Electric & Natural Gas Boilers*

2 million BTU Natural Gas Boiler (Space Heating Application)		
Specifications	**Natural Gas Boiler**	**Electric Boiler**
System Size	2 Million BTU	510 kW
Boiler Efficiency	87%	100%
Estimated Installed Cost	$95,000	$45,000
Estimated Equipment Life (Years)	20	25
Annual Maintenance Cost	$500	$125
Annual Utility Consumption	59,883 m^3 of gas	515,680 kWh
Utility Cost (including Carbon Price)	$0.34/$m^3$	$0.103/kWh
Estimated Annual Operating Cost	$20,860	$53,240

The table above shows the equivalent electric boiler capacity required to produce the same energy (BTU) output as a natural gas boiler (510 kW electric boiler to a 2 MBTU natural gas boiler). The significant difference lies in utility consumption and costs. An electric boiler requires 515,680 kWh to produce the same heat output as a natural gas boiler, which requires only 59,883 m^3 of gas to produce the same output.

Ontario Tech University is planning to electrify natural gas fired boilers based on equipment lifecycle assessment. The boilers installed in 2003 will have higher priority as they’re near their end of useful life. The targeted date for the replacement of these boilers is 2025. The targeted date for the electrification of the boilers, installed in 2010, is 2030.

7.3.2. Operational Cost

The cost to operate traditional equipment using fossil fuels is significantly less than using electricity. Converting all fossil fuel burning equipment onsite would result in an increase in operational cost, or total annual utility expenditure, in Ontario Tech University. This cost increase is already included in Total Annual Cost savings.

Figure 28 compares the current price for several fossil fuels and their respective GHG emissions factors. Natural gas is inexpensive compared to other fuel sources. On an equivalent cost per unit of energy ($/ekWh), the prices for electricity and natural gas do not intersect under current market rate forecasts. Other technologies like heat pumps provide an example of how existing technology is becoming more cost-effective. One of these technologies, geothermal heat pumps are recommended as part of Phase 1 of the program. Heat Pump technologies are shown in Case Study 4 on the following page.

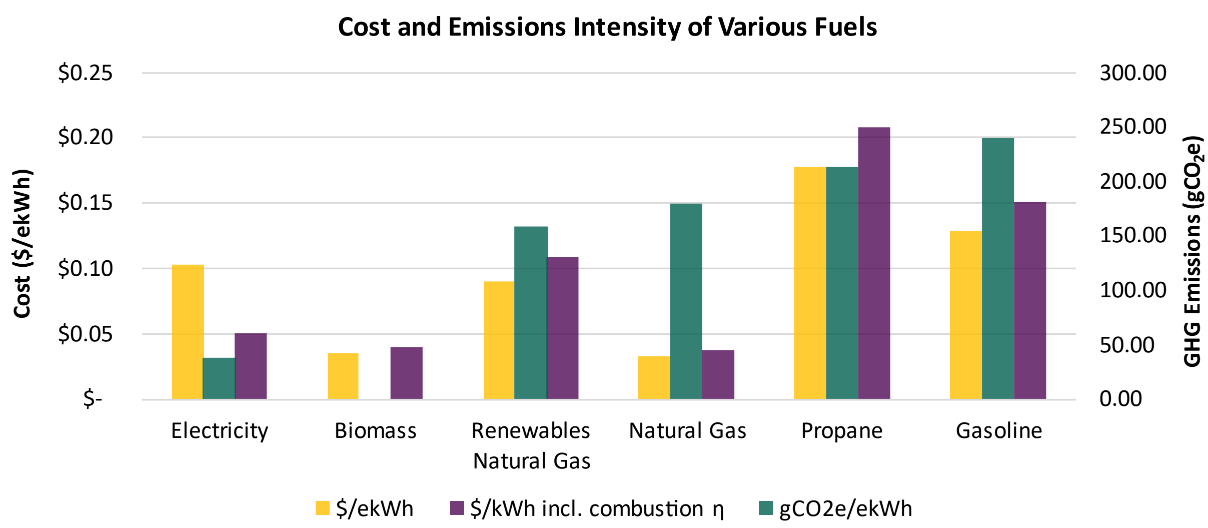


Figure 28. *Cost & Emission Intensities of Various Fuels*

Case Study 4: The Case for Heat Pump Technology

Heat pumps exchange energy by extracting heat from an outside source (geothermal, solar thermal etc.) and pumping it into space. Heat pumps can also be scaled to service a wide range of building types and applications. Heat pumps are more energy-efficient than natural gas burners and electric resistance heating coils. Air source heat pumps are capable of operating at outdoor temperatures below freezing at >1.0 annual coefficients of performance.

Heat pumps with Variable Refrigerant Flow (VRF) systems can provide simultaneous heating and cooling and multiple zone control. Outdoor units are connected to indoor fan coil units via refrigerant pipes and can be integrated with smart building technology and BAS. A typical VRF system is demonstrated in the figure below:

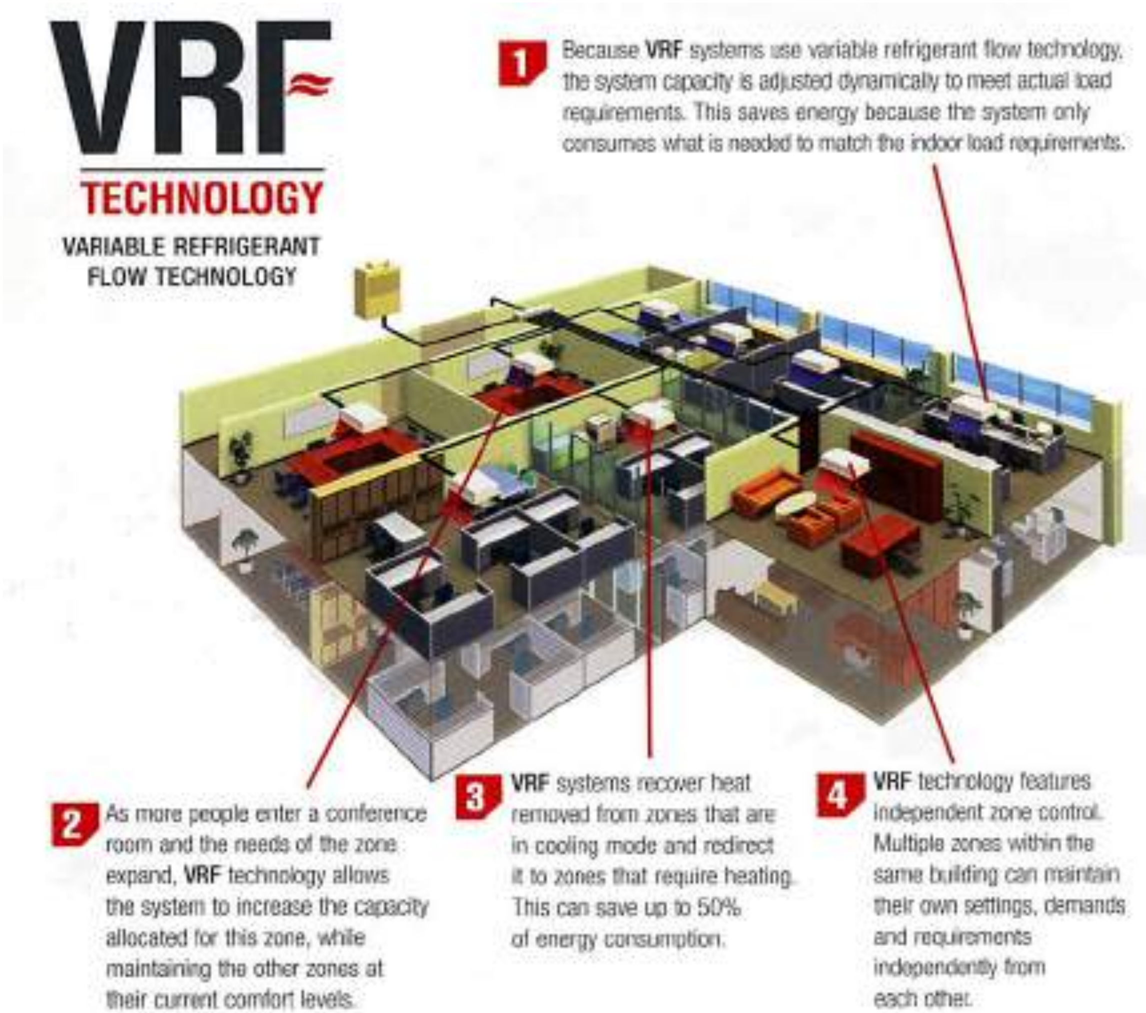


Figure 29. *Variable Refrigerant Flow Technology*

Case Study 4: The Case for Heat Pump Technology

Price

Today, using a heat pump can cost twice as much as traditional packaged rooftop units that consist of direct expansion (DX) cooling and natural gas burners. However, heat pump technology is becoming increasingly cost-effective and, according to the National Energy Board, costs could drop 10% to 20% by 2025 to 2030, and 20% to 30% by 2040. These numbers line up with the forecasted replacement HVAC replacement schedule listed throughout this Enervolve Study.

Heating

Depending on outdoor air temperature, a heat pump can achieve COP as high as 3.4 in heating mode, meaning the heat pump can produce 3.4 kW of heating energy for every kW of electricity consumed.

As outdoor air temperature drops below 0°C, the efficiency of heat pumps drops significantly and may require additional support from either an electric heating coil, a natural gas burner or a larger heat pump capacity. For example, at sub-zero temperatures, a 20-ton heat pump may only produce the heating equivalent of a 15-ton heat pump. Advances in heat pump technologies are targeting lower ambient temperatures with high COPs.

Cooling

High-efficiency heat pumps or DX units provide substantial energy and utility cost savings compared to traditional standard efficiency DX cooling applications, as demonstrated in the example below. Depending on outdoor air temperature, a heat pump can achieve Integrated Energy Efficiency Ratio (IEER) as high as 18.6 (COP of approximately 5.4), meaning the heat pump can produce 5.4 kW of cooling for every kW of energy consumed.

Example: 20-Tonne Heat pump RTU Annual Operating Costs

The following table shows the difference in annual operating costs associated with using a 20-ton heat pump instead of an RTU that has 15-ton DX cooling and a natural gas burner, based on current electricity and natural gas utility rates. The case is based on a theoretical 5,000 sq. ft space with one exterior wall in the Greater Toronto Area. The assumed operating schedule is Monday to Friday from 7 AM to 5 PM.

Table 14. *Comparing Heat Pumps with Natural Gas Burning Equipment*

Technology	Cooling Energy ($)	Heating Energy ($)	Fan Energy ($)	Total Annual Energy Cost ($)
Rooftop Unit + Gas Boiler	$1,014	$1,026	$1,688	$3,728
20-ton heat pump	$460	$4,377	$434	$5,271
Heat pump savings	$554	-$3,351	$1,254	-$1,543

Case Study 4: The Case for Heat Pump Technology

Relatively low prices of natural gas compared to electricity prevents electric heat pumps from yielding cost savings compared to high-efficiency natural gas furnaces. A 20-tonne electric heat pump is more expensive to operate annually than a rooftop natural gas unit based on current electricity and natural gas utility rates. However, improvements to heat pump technology and an increased cost of carbon will make heat pumps a cost-competitive alternative to natural gas equipment[4]. The cost of carbon has been mentioned a few times in this report and must be taken into consideration when comparing natural gas and electric systems. A life cycle cost assessment is recommended when this comparison is being made, over 15 years minimum and including the costs of carbon. The technology cost curve mapped against technology efficiency is illustrated in Figure 30.

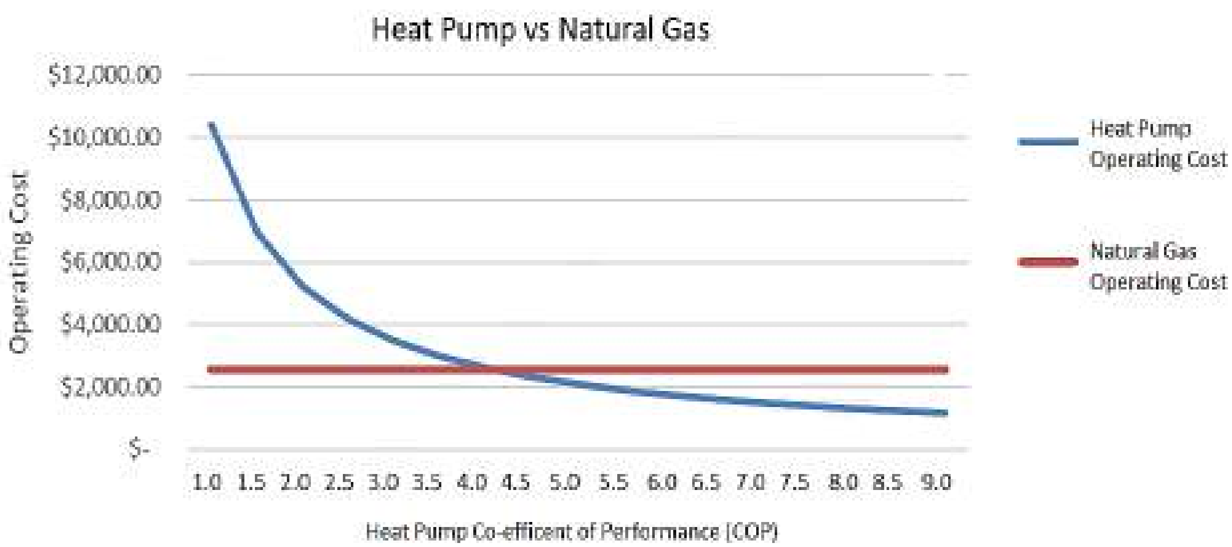


Figure 30. *Technology Cost Curve for Heat Pumps*

[4] Graham Cootes (P.Eng.), HTS Toronto. Email: graham.coote@hts.com

7.3.3. Forecasted Utility Cost

Natural Gas

This report forecasts the costs of natural gas from 2023 to 2050, including commodity, utility and carbon charges. Cost forecasts are based on a per unit rate ($/GJ) which can be applied against expected consumption. All natural gas cost forecasts are based on current known information and expectations in both the commodity and regulatory environment, which are subject to change.

Commodity

Commodity costs are forecasted to increase slowly out until 2050. Investors are trending away from investments into fossil fuels which will result in less drilling and fewer rigs. Longer term this will mean lower production of natural gas which will push prices up. Demand for natural gas will remain a wild card, as consumers wait for cost effective alternatives to move away from fossil fuels. In the meantime, power generation and Liquefied Natural Gas (LNG) exports will continue to drive increased demand for natural gas.

Utility Charges

Utility charges are forecasted for a lower threshold user in the Enbridge franchise network. For this exercise we have assumed a total annual consumption profile for each rate type. Accounts on a different rate, or with a different load profile, could yield a different per unit rate for delivery fees depending on several factors. It is also expected that as part of the Enbridge and Union Gas merger, that rate types may change or disappear as the two utilities are further integrated, which could alter costs. The transportation fees are the same regardless of the rate and are shown on a separate line item. Therefore, the total utility cost for each delivery rate is the summation of each rates respective delivery fees and Dawn transportation costs. Utility fees are published on a quarterly basis which are approved by the Ontario Energy Board (OEB). Expectations are that Enbridge will slowly increase utility delivery rates over time to account for the increased cost of providing services to its client base. These charges include transportation from Dawn to Enbridge CDA.

Carbon

Ontario currently falls under the Federal Carbon Backstop pricing program which sets an escalating price of carbon out until 2030. Under this scheme the price per GJ of carbon will rise from $1/GJ in 2019 to approximately $8.50/GJ in 2030. Canada has committed to a net-zero emissions target by 2050, which experts predict will required a price on carbon of $300/Ton ($15/GJ) by 2050. Carbon rates post 2030 have yet to be finalized, but Blackstone is forecasting a steady increase of rates between 2030 and 2050 which is built into the forecast table. As per the current political environment, we believe that this is the most likely scenario, but federal carbon pricing and targets could be changed by the government. Carbon rates go up every April, so we have prorated the $/GJ carbon price into each calendar year, based on a standard head driven load profile. Carbon costs are the same regardless of the utility rate.

Electricity

Electricity costs in Ontario have three main components: Hourly Ontario Energy Price, Global Adjustment (GA), and utility distribution charges. Regulated Price Plan (RPP) rates (Tiered & Time of Use) are generally set by the Ontario Energy Board (OEB) twice per year; but HOEP, GA, and utility distribution charges remain the backbone of how these rates are set. The Ontario electricity market differs from other Canadian jurisdictions because a large portion of electricity costs faced by consumers is outside of HOEP. The largest cost line item on electricity bills, which generally accounts for at least 50% of total costs, comes in the form of the GA mechanism. GA is used to cover the cost of building new assets, maintaining existing infrastructure, and delivering conservation and demand management programs.

Ontario continues to maintain a diverse electricity supply mix for its generation capacity:

- 34% from nuclear
- 28% from natural gas
- 23% from hydro
- 13% from wind
- small amounts from biofuel and solar* (**Solar generation is abundant in the province; however, most of it is not grid connected).*

Hourly Ontario Energy Price (HOEP)

Despite the diverse supply mix in Ontario, natural gas pricing continues to play a prominent role in determining HOEP as natural gas generators are often the marginal units setting price in Ontario – particularly in summer and winter. To showcase this, there has been approximately an 80% correlation between Ontario electricity prices and Dawn natural gas prices over the last four years. This is forecasted to continue for the next several years as the province will still rely heavily on natural gas generation while Ontario's electricity supply stack undergoes major changes.

HOEP is projected to steadily rise on an ongoing basis, particularly due to increasing demand across all sectors in the province as well as less available baseload nuclear supply. In 2026, prices are expected to increase by a more significant margin as a greater number of nuclear generators will be out of service, with the Pickering units scheduled to be retired in 2026 on top of three other units undergoing refurbishment. Prices drop back down slightly in 2027 as 2026 represents the peak of nuclear unavailability, before showing an overall slow upward trend going forward. After many years of decreasing demand in the province, we are now entering a period of increasing demand across all sectors – residential, commercial, industrial, and agricultural. Also playing a role will be the emergence of significant transportation electrification. All of this will result in a projected 2% average annual increase in peak demand as reported by the Independent Electricity System Operator (IESO).

Global Adjustment (GA)

GA is also projected to experience modest gains through the evaluation period as the cost of running the Ontario electricity grid is expected to increase. This will be in large part a result of many generation contracts ending, for which replacements will be required to ensure adequate supply. With demand increasing and baseload nuclear generation decreasing, a supply gap will emerge for which new capacity must be installed – factoring into higher projected GA costs. Additionally, the implementation of new conservation and demand management (CDM) plans will contribute to rising GA costs over time.

Utility Distribution Charges

Utility distribution rates in Ontario are projected to steadily increase over time, in big part due to the capital investment required to meet climate goals.

Summary

Primarily driven by rising demand in the province as well as increased distribution charges, the cost of electricity is forecasted to increase steadily increase across all line items out until 2050.

Natural Gas & Electricity Cost Forecast

Table 15. *Natural Gas & Electricity Cost Forecast*

Year	Natural Gas Cost ($/GJ)	Electricity Cost ($/MWh)	Year	Natural Gas Cost ($/GJ)	Electricity Cost ($/MWh)
2023	$12.31	$136.27	**2037**	$20.12	$179.21
2024	$11.81	$139.66	**2038**	$20.58	$182.53
2025	$12.42	$143.16	**2039**	$21.05	$185.92
2026	$13.17	$146.89	**2040**	$21.52	$189.38
2027	$14.09	$149.53	**2041**	$23.09	$192.92
2028	$15.10	$152.23	**2042**	$23.65	$196.52
2029	$15.97	$154.99	**2043**	$23.98	$200.20
2030	$16.85	$157.80	**2044**	$24.31	$203.96
2031	$17.37	$160.67	**2045**	$24.64	$207.80
2032	$17.82	$163.61	**2046**	$24.98	$211.72
2033	$18.28	$166.60	**2047**	$25.32	$215.72
2034	$18.73	$169.66	**2048**	$25.66	$219.80
2035	$19.19	$172.78	**2049**	$26.00	$223.97
2036	$19.65	$175.96	**2050**	$26.37	$228.23

Natural Gas Forecast Notes & Assumptions:

- Commodity charges assumes gas purchased at Dawn
- Utility charges are forecasted based on a standard low volume Enbridge customer
- Carbon Costs are as laid out but the Federal government out until 2030, and expected increases post 2030 to stay on track with $300/ton by 2050

Electricity Forecast Notes & Assumptions:

- Total electricity cost incorporates Hourly Ontario Energy Price (HOEP), Class B Global Adjustment (GA), Regulatory charges, and Delivery charges
- Regulated Price Plan (RPP) rates are set at levels that would mimic these prices over the long-term
- Utility charges are based on a standard low volume electricity consumer

7.3.4. Carbon Tax

Carbon Pricing Outlook

The Pan-Canadian Approach to Pricing Carbon Pollution, released in October 2016, set a "federal benchmark" requiring all provinces and territories to implement carbon pricing systems with a certain level of stringency, while also ensuring the provinces and territories have the flexibility to design their own policies. It applies to Manitoba, Nunavut, and Yukon, with other provinces implementing their own policies. The backstop has two components: a fuel charge and an Output-Based Pricing System (OBPS) for large industrial emitters, which is a regulated emissions trading programme. Canada's 2022 carbon price is $50/tCO2-eq and will increase by $15/tCO2-eq annually to reach CAD 170/tCO2-eq in 2030.

The Government of Canada has committed to return all direct proceeds collected in Ontario, under the federal carbon pollution pricing backstop system through direct payments to families (Climate Action Incentive Payment) and investments to reduce emissions, save money, and create jobs.

Ontario

Effective January 1, 2022, the OBPS was removed from Ontario and replaced by Ontario's own Emissions Performance Standard (EPS). Under the program, the price of carbon was $50/tCO2-eq in 2022. On August 26, Ontario released proposed changes to the Emissions Performance Standards (EPS) program for 2023-2030 to meet the benchmark set by the federal government. The Ministry is proposing to align the EPS program and the price of excess emissions units (EEUs) with the minimum carbon price set out in the updated federal benchmark. This means the price of EEUs set out in the EPS Regulation would be $65/tCO2-eq in 2024 (e.g., for the 2023 compliance period), and would increase by $15/tCO2-eq per year to $170/tCO2-eq in 2031 (e.g., for the 2030 compliance period).

Under the EPS, funds collected from payments for excess emissions units are required to be used primarily for GHG reduction initiatives, particularly in the sectors regulated by the EPS program. The funds can also be used to administer the related regulations.

Table 16. *Effect of Carbon Price on Natural Gas Costs*

Effect of the Federal Carbon Backstop	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Federal Price on Carbon ($/t$CO_2$e)	$20	$30	$40	$50	$65	$80	$95	$110	$125	$140	$155	$170
Federal Price on Carbon ($/m^3)	$0.039	$0.059	$0.078	$0.098	$0.127	$0.157	$0.186	$0.215	$0.245	$0.274	$0.303	$0.333
Actual Price of Natural Gas ($/ekWh)	$0.025	$0.027	$0.029	$0.031	$0.057	$0.070	$0.083	$0.096	$0.109	$0.122	$0.135	$0.149

7.3.5. Utility Rate Structure

The utility rate structures differ for natural gas and electricity consumption. For natural gas, rates are based on consumption. For electricity, rates consider how much electricity (demand) is required, for how long (kWh) and when the electricity is consumed (time of use). The University consumers who have a demand of more than 1 MW (and less than 5 MW) can opt into being "Class A" consumers to reduce their global adjustment (GA) charges. In Ontario, the GA charge is a significant component of electricity bills. It covers the cost of building new electricity infrastructure in the province, maintaining existing resources and providing conservation and demand management programs. GA currently represents approximately 80% of the total price of electricity.

Ontario Tech University is a Class A customer jointly with Durham College for the North Campus and Class B for the downtown and farm.

To determine the full cost of an ECDM or renewable energy measure, the potential increase of Ontario Tech University's total electrical cost should be considered if the Class rating is impacted. For this document, modelling was based on a Class A consumer rate and each measure is evaluated on a case-by-case basis to evaluate if projects will impact Class A rating.

7.3.6. Supporting Infrastructure Costs

In addition to the cost to upgrade infrastructure, further investments may be required to upgrade supporting electrical systems at Ontario Tech University. It is likely that as each piece of HVAC equipment is converted to fully electric, the supporting electrical infrastructure will also need to be upgraded. This will have cost implications.

8. Barriers and Considerations

The following section outlines the barriers and considerations that will impact Ontario Tech University's path to achieving 100% GHG reduction from the 2022 level. As the University moves towards carbon neutrality, each issue should be seriously considered.

8.1. Physical Space Available for Renewal Projects

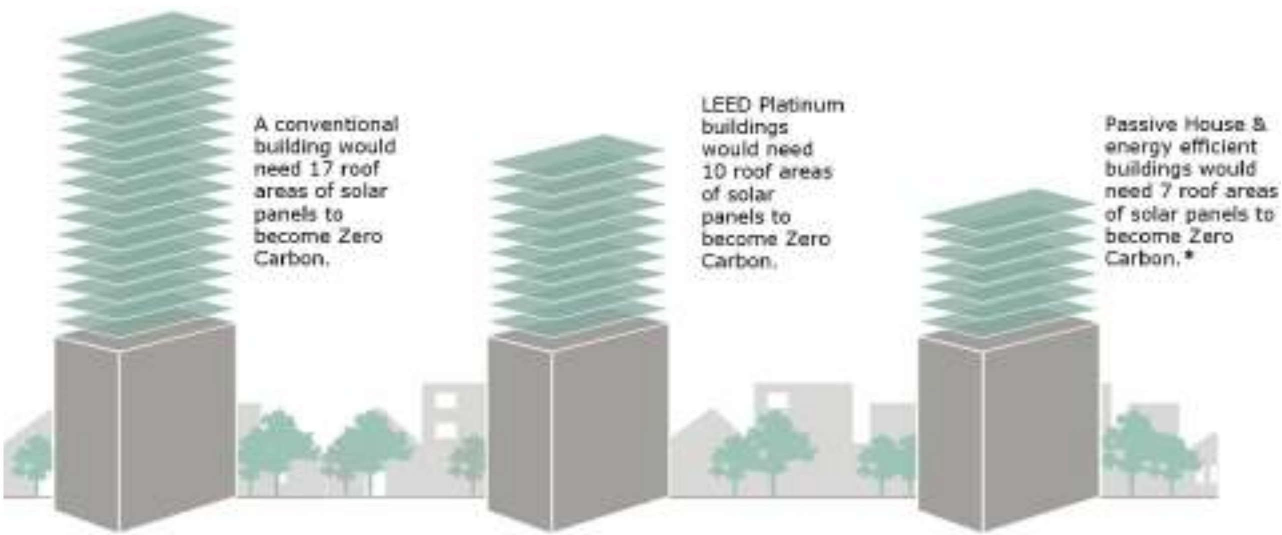
Barrier

Solar PV is a proven and cost-effective form of renewable energy. However, its utility can be limited by the amount of physical space it occupies.

Consideration

Based on the solar review for Ontario Tech University, there is space to accommodate approximately 3.19 MW of ground mount solar. This would generate approximately 3.6 million kWh of electricity.

The more energy-efficient the building is the fewer solar panels required to make it zero carbon. Figure 31 shows the correlation between energy-efficient building design and future renewable energy requirements in terms of solar panels[5].



* The equivalent of seven roof areas of solar panels can be found in future advancements in technology and scale jumping.

Figure 31. *Energy Efficient Building Design*

8.2. Virtual Net-Metered Renewable Energy Generation

[5] New Buildings Institute: Net Zero and Living Building Challenge Financial Study: A cost comparison report for buildings in the District of Columbia

Barrier

As shown in Figure 32, virtual net metering for renewable energy generation would allow Ontario Tech University to produce renewable energy offsite that could be credited against the energy use in their facilities. However, virtual net metering is currently not permitted by the IESO.

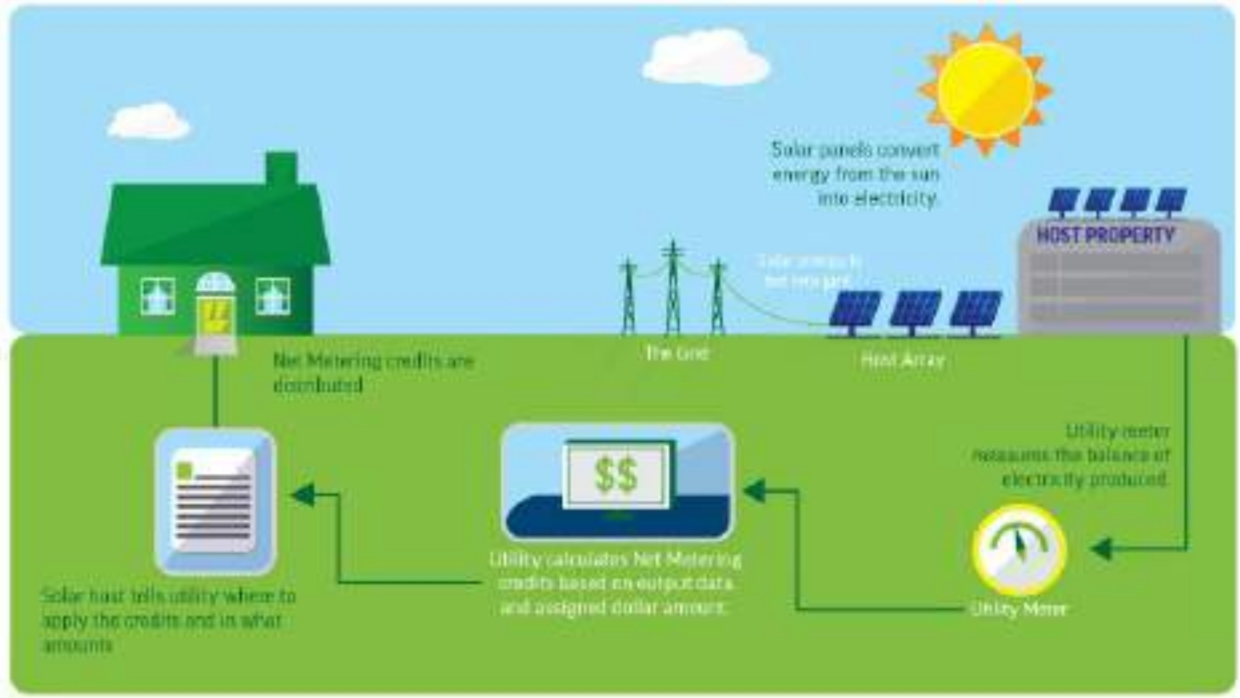


Figure 32. *Virtual Net-Metering Model*

Consideration

Virtual net metering is a bill crediting system administered by the local electricity distribution company that allows the owner of a power-generating asset to be in a different geographic location than that of the actual power-generating asset. With virtual net metering, the owner of the power generating asset might not be the direct consumer of the electricity generated but would still take ownership of the environmental attributes associated with the generation with the local distribution company. The local distribution company would credit Ontario Tech University's monthly utility bills for the electricity generated by the renewable generation system. Virtual net metering would eliminate the need for physical space requirements for onsite generation and help the University meet its 2050 target. However, as mentioned it is not currently permitted by the IESO. It is recommended that the University considers this option should it become permitted in the province.

8.3. High GHG Factor for Refrigerants

Barrier

Although installing heat pumps and high-efficiency chillers decreases GHG emissions, increases refrigerant use. Refrigerants are prone to leakage and are carbon-intensive.

Consideration

When electric equipment is installed – specifically chillers, heat pumps and refrigeration equipment – the updated technology requires refrigerants as part of the cooling process. Refrigerants are fluorinated gases, which create GHG emissions. Refrigerants are used onsite when the technology is installed and are refilled annually as a small portion of the refrigerants can leak out. Leakage is dependent upon the operating efficiencies of the equipment and is included in Ontario Tech University's annual Scope 1 emissions profile.

The refrigerants have a high global warming potential (GWP) and are expressed relevant to CO_2 emissions. The more electrification, the higher the emissions from refrigerants. However, fossil fuel-based equipment is still significantly more carbon-intensive and emits substantially more carbon per GJ produced and consumed.

8.4. Grid Carbon Intensity

Barrier

For both Phase 1 and Phase 2 considered, Ontario Tech University will continue to be reliant on grid-provided electricity for a portion of electrical needs. It is difficult to project the carbon intensity of Ontario's utility-provided electricity.

Consideration

The carbon intensity of the electrical grid, as measured in grams produced per kWh consumed (g/kWh), is determined by the source of electricity production. Compared to other provinces, Ontario's electricity is relatively low carbon. It is predominantly supplied by non-emitting sources of power generation, including hydroelectric and nuclear.

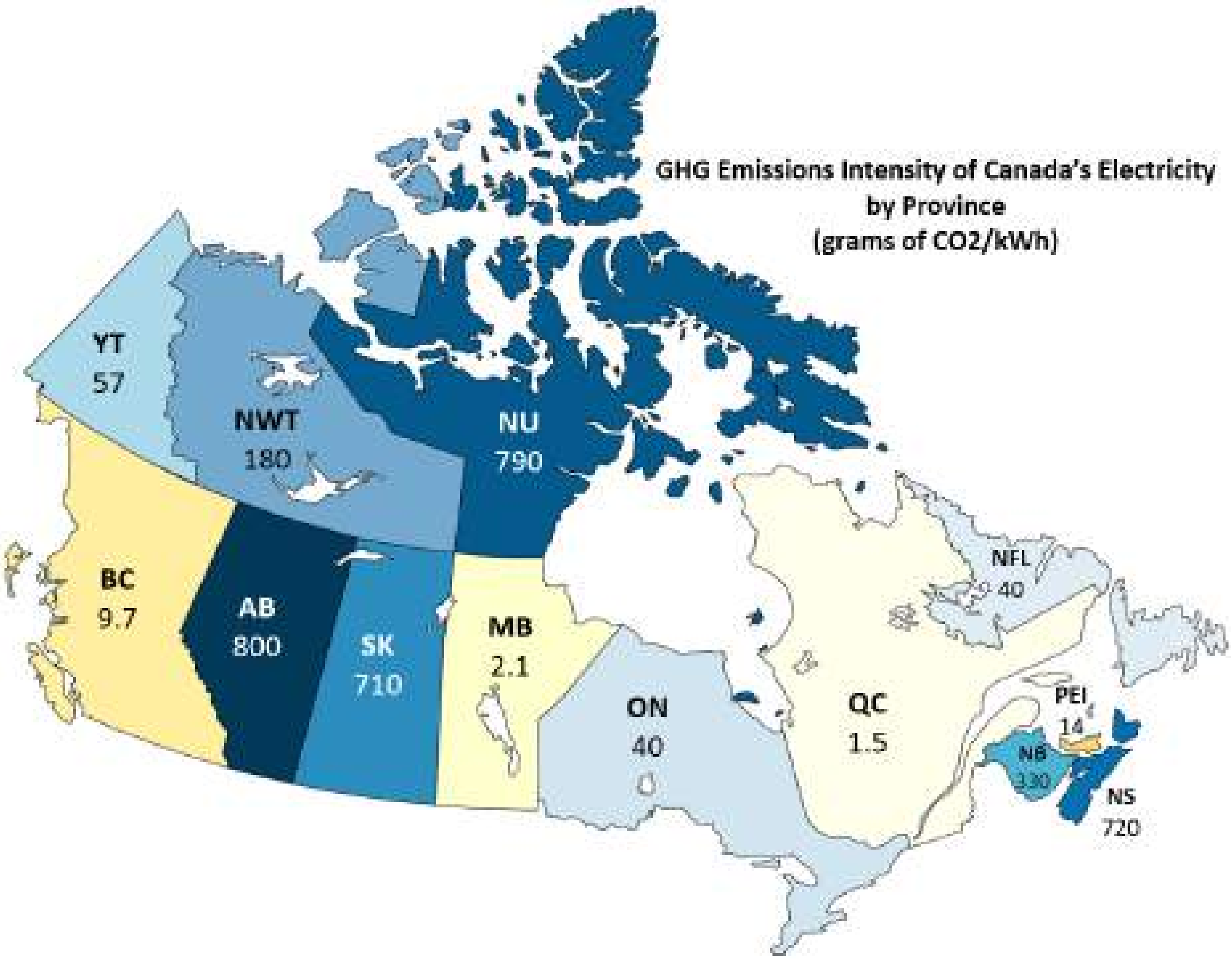


Figure 33. *Emission Intensities of Electrical Grids across Canada (2019)*

The electricity generation in Ontario is mostly powered by nuclear and hydroelectric plants. This has rendered the province with a carbon frugal electric grid – about 0.000038 tCO_2e/kWh or 38 grams of CO_2e/kWh in 2022. This is one of the lowest emissions intensities of electric grids across all Canadian provinces (see Figure 33). The electrical mix of Ontario's grid is illustrated in Figure 34.

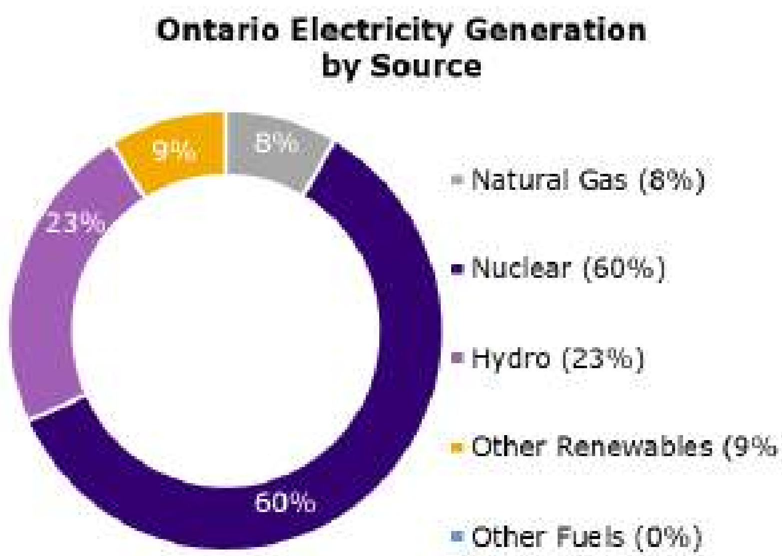


Figure 34. *Electricity Generation Mix in Ontario*

According to Environment and Climate Change Canada (ECCC), natural gas combustion provides approximately 8% of all electricity generation in Ontario. It also accounts for approximately 97% of the total GHG emissions for electricity generation. If Ontario was to replace existing natural gas generators with either nuclear or renewable energy, the GHG emissions intensity of electricity would reduce significantly, thereby reducing Ontario Tech University's onsite emissions and eliminating the need to invest in its renewable energy production.

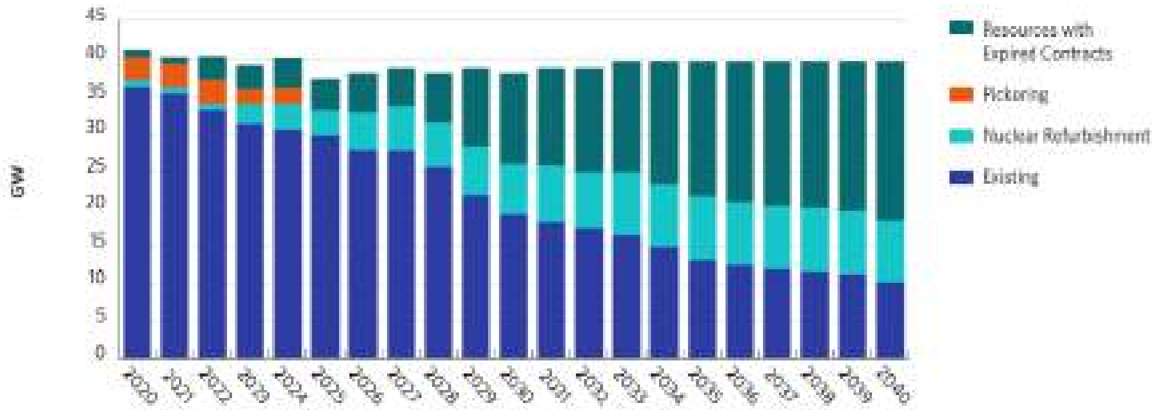


Figure 35. *Ontario's Installed Power Capacity*

The IESO procures Ontario electricity generation contracts. The 2019 IESO LTEP outlined Ontario's current electricity procurement contracts, including expiration dates. In Ontario, natural gas-fired electricity plants currently provide the peak energy requirements in the province and are the main contributor to the GHG emissions of the electrical grid. The last natural gas-fired generation is contracted to end between 2038 and 2041. The grid mix – and subsequent grid carbon intensity – is not defined past 2041.

Between 2020 and 2050, the grid could potentially decarbonize further if there is political will, which would significantly impact Ontario Tech University's path to 100% GHG reduction from the 2022 level. Ontario's electricity generation is determined by the IESO as directed by the Ontario Ministry of Energy[6]. Currently, the grid has a low carbon intensity factor as the result of eliminating coal from the generation stack in 2013.

[6] *IESO: http://www.ieso.ca/Powering-Tomorrow/Data/The-IESOs-Annual-Planning-Outlook-in-Six-Graphs*

9. Supporting Sustainability Initiatives

Recommendations listed under the General Sustainability Initiatives in this section will reduce all three Scopes and continue to foster sustainable practices in the University. The Sustainability Policy Cycle will help garner support and spread awareness amongst the broader Ontario Tech University community.

9.1. Scope 3 Emissions

Scope 3 emissions are generated by both Ontario Tech University's operations and as a direct result of those that work and study at Ontario Tech University. It is vital to have sustainability policies that align with Ontario Tech University's climate action strategy and its GHG emissions reduction targets. Although not an exhaustive list, the strategies presented in the Enervolve should be considered for all facets of Ontario Tech University's operations.

One of the important Scope 3 categories is waste. Ontario Tech University recognizes the importance of waste reduction and waste diversion and has an ongoing culture of recycling and composting.

To achieve its carbon-neutral target, Ontario Tech University has contracted UPak to collect the university's waste to convert it into energy and prevents additional waste from being sent to landfills.

There are three waste diversion strategies that should be focused on: upstream, onsite, and downstream. Upstream is waste that is produced before a product reaches the University; onsite is produced on the University, and downstream is how a product is disposed of.

The following strategies can be implemented on Ontario Tech University to help achieve the goal of a zero-waste and zero emissions associated with waste:

Upstream

- Upstream waste reduction through sustainable material management.
- A stronger focus on waste reduction as it related to purchasing decisions. Look for products with less packaging; bring fewer single-use disposable items as much as possible to the University and reduce the amount of less non-recyclable and non-compostable materials being purchased.

Onsite

- Eliminate single-use products (i.e. disposable food service ware, disposable cups, straws, etc.).
- Require new buildings, expansions, or renovations to reuse or recycle at least 50% of the construction debris or dispose of no more than 2.5 lbs. per sq. ft.
- Replace plastic bags with reusable, compostable or paper bags labelled with 40% post-consumer recycled content.
- Encourage the employees to less use paper.

Downstream

- Create multiple locations in the University where employees can bring their hard-to-recycle materials (i.e. electronics, small appliances, books, textiles, etc.).
- Increase awareness around proper waste sorting to improve students and staff participation in composting and recycling programs (i.e. improved signage, more centralized waste bins, expand composting).

The reduction strategies focus on reducing the total amount of disposable products purchased by Ontario Tech University, while the diversion strategies focus on recycling and composting all waste.

9.1. Electric Vehicles (EV) Charging Stations Considerations

Blackstone recommends as part of Ontario Tech University's commitment to scope 3 emission reduction and innovation, that the University commence a process in spring of 2023 to complete a detailed analysis of an initial first phase of installation of EV chargers.

The roll out cycle of EV chargers (Specifications>Proposal>Procurement>Installation>Commmissioning>) can be completed turn-key by Blackstone, and the cycle does not have to be long. It can be as short as 3 to 4 months so EV Charger projects and rollouts can be completed and reassessed annually in phases. Note: Winter construction will be more expensive, and the ideal seasons for installation are spring and summer.

Generally, institutions are making chargers available to students and staff. How they charge for the use differs depending on the institution's preference, however the chargers generally work with a mobile app in which the user has already entered their credit card information and they use the app to reserve time, and to pay for use. The charging fees are sent to a University account. The app and chargers require very little, if any, maintenance. Blackstone can manage the chargers' operation if desired.

Some specific rule of thumb best practices and considerations are:

Policies: The University is advised to set up policies for use. What fee will the University charge EV drivers How long can a user charge their vehicle? What is the penalty if they do not unplug and move after their time is up? Blackstone can provide guidance.

Provision: How many chargers does the University reserve for staff use versus student use? Does the University wish to install fleet chargers at the maintenance or contractor entrance for University fleet vehicles only?

Security: Locate the chargers within visible site line of the campus.

Types of chargers: There are 3 levels of chargers that determine how quickly the user can charge their battery.

- Level 1: Uses a common 120-volt household outlet. This method works well for plug-in hybrid EVs, which have small batteries. However, depending on battery size, Level 1 chargers could take up to 100 hours to fully charge a battery-only EV.

- Level 2: Most commonly used method for EV daily charging. The charging equipment can be installed in your home. It can take up to 14 hours to fully charge a large, battery only EV with this method.
- Level 3: Also known as DC fast chargers. These can be found in charging stations on highways and, depending on charger power, can charge an EV from empty to 80 per cent in 30 to 45 minutes.

# of chargers: There is no mathematical rule of thumb for quantity of charger. The number can change depending on geography of the University, number of parking spaces, etc. However, Lakehead engaged Blackstone in 2022 to procure 4 dual port chargers allowing 8 vehicles to charge concurrently, while St. Lawrence University in Kingston engaged Blackstone in 2021 to install 11 dual port chargers allowing 22 vehicles to charge concurrently.

Location of chargers: It is recommended that chargers are installed as close to the electrical supply as possible. In some cases, this can be done by installing within the existing parking lot. In other cases, it might be more financially feasible to pave new spots in a location closer to the electrical supply. The further the EV chargers are located from the electrical supply, the more civil and/or work is involved to trench and run the service to the chargers. Blackstone will work with the University to examine the campus map and recommend ideal locations for the proposed EV chargers.

Electrical capacity: The electrical capacity required for EV chargers is one 40-amp breaker per charging port (or two 40-amp breakers per dual port charger).

Budget: As a conservative rule of thumb, EV chargers generally cost $15-20,000 per port (installed cost). Depending on the size of the installation, the NRCan ZEVIP program will fund roughly $5,000 per port (roughly $10,000 for a dual port charger).

9.2. The Sustainability Policy Cycle

Ontario Tech University does not have the same degree of control over its Scope 3 GHG emissions as it does over Scope 1 and 2 emissions. The implementation of the Sustainability Policy Cycle shown in Figure 36 can help maximize that control and reduce the overall impact of Scope 3 emissions. This section will provide a detailed analysis of each step in the Sustainability Policy Cycle. Each phase of the policy cycle is elaborated on below.

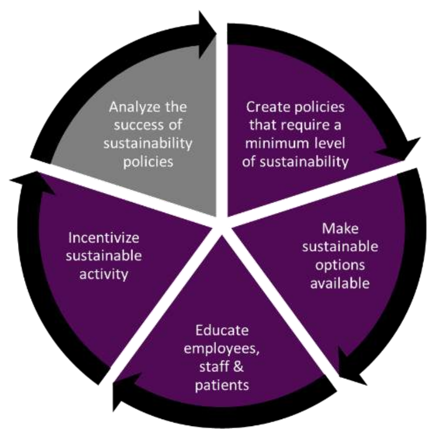


Figure 36. *The Sustainability Policy Cycle*

Polices that Require a Minimum Level of Sustainability

Ontario Tech University can develop policies that would foster environmental sustainability and GHG reduction practices in The University. Below is a list of policies that Ontario Tech University could implement to improve the University's sustainability and reduce GHG emissions from its operations.

Table 17. Operational Sustainability Policies

Category	Concept	Policy Description Summary
Air & Climate	Outdoor Air Quality	Create policies (e.g., anti-idling) that limit outdoor air pollutants from sources such as idling vehicles and fossil fuel-powered lawn care equipment
Buildings	Building Operations, Maintenance and Air Quality	Create a publicly available Indoor Air Quality (IAQ) management policy, green cleaning policy, energy and water management and benchmarking program
	Building Design and Construction	Create a policy that requires all new building construction to be either Net Zero Energy or Net Zero Carbon
	Appliances	Enforce policy to remove to remove small fridges, microwaves and coffee makers from areas that are not designated break areas
Energy	Building Energy Consumption	Continue making historical energy consumption data publicly available annually.
	Clean and Renewable Energy	Create a policy that requires a minimum amount of total annual energy consumption to come from renewable sources
Food & Dining	Food and Beverage Purchasing	Build on current plant-based food and container removal policy by requiring a minimum amount of food and beverages purchased to be locally sourced, Certified Organic or Certified Humane
Grounds	Landscape Management	Continue enforcing the policy that The University does not use fertilizer or pesticides
	Biodiversity	Create a policy that requires a minimum amount of vegetation on The University be a species native to its jurisdiction
Purchasing	Sustainable Procurement	Eliminate or reduce single-use disposable packaging and materials
	Electronics Purchasing	Create a policy that requires all electronics to be registered through the Electronic Product Environmental Assessment Tool (EPEAT) and/or to be Energy Star certified
	Cleaning and Janitorial Purchasing	Create a policy that requires onsite cleaning and janitorial supplies to be Green Seal certified, ECOLOGO certified, US EPA Safer Choice labelled (or a comparable local equivalent)
	Office Paper Purchasing	Create a policy that requires paper to be purchased with post-consumer recycled, agricultural residue, and/or Forest Stewardship Council (FSC) certified content
Rainwater	Rainwater Management	Create a comprehensive rainwater management policy and plan that incorporates green infrastructure and rainwater management, including using rainwater for irrigation purposes

Make Sustainable Options Available

Below is a list of policies that Ontario Tech University could implement to encourage sustainable practices among its larger community of employees and students. This would improve the University's sustainability, reducing Scope 3 GHG emissions from dining, and planning. As per Ontario Tech University's Sustainability Plan, many of these initiatives are underway or being planned.

Table 18. *Sustainable Lifestyle Policies*

Category	Description Summary
Sustainable Dining	• Host regular farmers' markets • Keep hosting low-impact or sustainably themed dining events such as Meatless Mondays • Provide locally sourced, Certified Organic and/or Certified Humane dining options • Encourage onsite food outlets to donate food that would otherwise go to waste like the "Too Good to Go" program that allows people to buy food at a discounted price that would otherwise be thrown away
Coordination & Planning	• Create a sustainability committee made up of faculty, staff, and students

Educate Employees and Students

Awareness around the environmental impacts associated with individuals' daily actions would help motivate more members of the Ontario Tech University community into the idea of creating a culture of sustainability in the University.

The following is a list of program examples designed to reduce employees and students' transportation:

- Experiment and adopt virtual platforms.
- Hold fewer conferences.
- Experiment with coordinating conference timing.
- Invite speakers to give talks remotely.
- Envision new ways to build a community online.
- Convene online reading or discussion groups.
- Plan longer or smarter meetings that occur less frequently.

Analyze the Success of Sustainability Policies

It is recommended that Ontario Tech University analyzes the success of each sustainability and GHG emission reduction policy annually. Success can be evaluated by looking at the uptake of each program and the reduction in each relevant Scope 3 category. Policies and programs can be revised over time to encourage more participation and improved uptake.

10. List of Recommended Measures

Table 19. *Proposed Project - Status Quo*

Measure Number	Measure	Annual GHG Reduction (tCO_2e)	Annual Savings ($)	Total Cost ($)*	Incentives ($)	Phase-in Through DM	Phase 1 target	Phase 2 target	Phase 3 target
ECM#1	LED Lighting Upgrade	45	$73,318	$451,000	$79,000	FY26 & FY27		45	
ECM#2	BAS Re-commissioning, Controls Upgrade	147	$74,725	$794,018	$145,000	FY28			147
ECM#3	Decouple Central Heating Plant from DHW System and Install Electric DHW Heaters	241	-$8,648	$350,000	$0	FY25 & FY26	241		
ECM#4	Electrification of Central Boiler Plant and High Temperature Heat Pump Installation- UB Building	246	-$12,237	$1,300,000	$0	FY25 & FY26	246		
ECM#5	Electrification of Boiler Plant - Sirc Building	70	-$524	$300,000	$0	FY30			70
ECM#6	Electrification of Boiler Plant - Charles Hall	78	-$2,692	$350,000	$0	FY29			78
ECM#7	Replace Existing AHUs with Heat Pump Units - CERL	94	-$4,797	$725,061	$0	FY29			94
ECM#8	Replace the Existing Boiler with Air Sourced Heat Pumps and Modify Existing AHU - CIC	114	-$1,788	$421,000	$0	FY27		114	
ECM#9	Replace the Existing Boiler with DHW Air Sourced Heat Pumps - CIC	100	-$14,744	$650,000	$0	FY28			100
ECM#10	Replace Existing Gas-Fired Desiccant Dehumidifier with High Efficiency Electric Desiccant Dehumidifier - CIC	122	-$4,103	$794,341	$0	FY27		122	
ECM#11	Installation of Heat Pump RTUs - Bordessa Hall	21	-$6,624	$511,000	$0	FY25& FY26	21		
ECM#12	Monitor and Control Plug Loads Across the Campus	36	$22,964	$167,153	$0	FY29			36
ECM#13	Install a 3.71 MW Ground Mount Solar PV System	257	$476,959	$7,226,100	$0	FY30			257
ECM#14	Integration of Airbound Sensor into BAS	62	$23,572	$146,625	$0	FY26	62		
ECM#15	Install Blackpack Metering System	42	$12,571	$104,591	$0	FY28			42
Total		**1,675**	**$627,952**	**$14,290,888**	**$224,000**		**570**	**280**	**824**

Table 20. Proposed Project - Energy Performance Contract

Measure Number	Measure	Annual GHG Reduction (tCO_2e)	Annual Savings ($)	Total Cost ($)*	Incentives ($)
ECM#1	LED Lighting Upgrade	21	$73,318	$599,830	$79,000
ECM#2	BAS Re-commissioning, Controls Upgrade	98	$74,725	$1,056,044	$145,000
ECM#3	Decouple Central Heating Plant from DHW System and Install Electric DHW Heaters	273	-$8,648	$465,500	$0
ECM#4	Electrification of Central Boiler Plant and High Temperature Heat Pump Installation- UB Building	287	-$12,237	$1,729,000	$0
ECM#5	Electrification of Boiler Plant - Sirc Building	74	-$524	$399,000	$0
ECM#6	Electrification of Boiler Plant - Charles Hall	85	-$2,692	$465,500	$0
ECM#7	Replace Existing AHUs with Heat Pump Units - CERL	106	-$4,797	$964,331	$0
ECM#8	Replace the Existing Boiler with Air Sourced Heat Pumps and Modify Existing AHU - CIC	124	-$1,788	$559,930	$0
ECM#9	Replace the Existing Boiler with DHW Air Sourced Heat Pumps - CIC	110	-$14,744	$864,500	$0
ECM#10	Replace Existing Gas-Fired Desiccant Dehumidifier with High Efficiency Electric Desiccant Dehumidifier - CIC	135	-$4,103	$1,056,473	$0
ECM#11	Installation of Heat Pump RTUs - Bordessa Hall	24	-$6,624	$679,630	$0
ECM#12	Monitor and Control Plug Loads Across the Campus	19	$22,964	$222,313	$0
ECM#13	Install a 3.71 MW Ground Mount Solar PV System	138	$476,959	$9,610,713	$0
ECM#14	Integration of Airbound Sensor into BAS	49	$23,572	$195,011	$0
ECM#15	Install BlackPAC Metering System	37	$12,571	$139,106	$0
Total		**1,580**	**$627,952**	**$19,006,881**	**$224,000**

**Table 19 and 20 presents costs estimated by ON Tech U and these costs are different from original estimates by Blackstone.*

The two tables above present costs provided by ON Tech University based on their experience on campus with past projects. Table 19 is the "Status Quo" scenario, which assesses measures using historically available financial mechanisms and scheduling parameters. Table 20 is the "Energy Performance Contract" scenario which assess all measures undertaken as a single project to expedite the resultant benefits.

Table 20 lists all recommended measures of the Proposed Project, their costs, cost savings, GHG reduction and incentives.

A full Measure Summary Report can be found below in *Appendix 1 – Measure Summary Report*.

Appendix 1: Measure Summary Report

1 Recommended Energy Efficiency & GHG Reduction Initiatives

As part of Enervolve Decarbonization Study, Blackstone has conducted several visits at Ontario Tech University in 2023 and 2024, with the aim of establishing a GHG reduction program which will help the University to reach their established greenhouse gas reduction targets. Our investigations have included review of the documentation provided by the University as well as conversations with knowledgeable personnel.

Based on these activities, Blackstone has come up with the following recommended energy efficiency and GHG reduction measures. Project costs are provided by ON Tech University based on their experience on campus with past projects and these costs are different from original estimates by Blackstone.

1.1 LED Upgrade

1.1.1 Existing Conditions and Assumptions

The illumination for the interior areas such as classrooms, offices, corridors, and common areas is mainly provided by the combination of the linear and compact fluorescent lamps and LEDs.

The intent of this measure is to upgrade existing fluorescent and other type of lamps with LEDs to improve efficiency of the lighting systems and the interior lighting levels, which includes the following six (6) buildings:

- ACE
- OPG
- UB (Business and IT Building)
- Science East and West
- Library
- ERC (Energy Research Centre)

The pictures and counts for existing indoor lighting fixtures were provided by the University. Blackstone worked closely with the University staff to organize and update the lighting audit summary. The rated power input for existing indoor fixtures were compiled based on the lighting drawings and lighting review comments provided by the University staff.

The approximate quantities of existing lighting to be replaced for each building are listed in the table below. Note that aside from stairways and corridors, the operating hours for the interior lights are estimated as 12 hours per day and 7 days per week, year around.

Table 1-1. Existing Lighting Fixture Quantity

	Existing Fixture Quantity	Operation Hours
ACE	1,346	4,368
OPG	328	4,368
UB	519	4,368
Science East and West	425	4,368
Library	413	4,368

ERC	647	4,368
Total	**3,678**	**-**

The lighting audit entails a room-by-room, fixture quantity, bulb per fixture and watts per bulb, to the best knowledge of the assisting University staff. Existing lighting pictures were also documented for UB & ERC, per Retrofit Incentive Program information request from IESO, per lighting type, to include a long-shot, a close-up and a nameplate photo, as shown below.

Figure 1-1 Existing Indoor Lighting: Lightolier - 71263242BG120 – 1 lamp 26W (C3)

Ontario Tech University identified preferred product list including LED lamps and fixtures that would replace the existing lamps. These LED products were used to estimate the annual energy and demand reduction savings. The room-by-room audit and selected LED products are provided in *Appendix 4 – Lighting Fixtures*.

The estimated measure implementation cost, annual energy and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-2. LED Upgrade Project Summary

Project Details	
Project Cost (Class D Estimate)	$599,830
Annual Electricity savings (kWh)	732,276
Annual Natural Gas savings (m3)	-3,661
Annual Cost Savings	$73,318
Simple Payback (yrs.)	8.2
Life Cycle of Measure (yrs.)	20
Annual GHG Reductions (tonnes of CO_2e)	44.7
Total Utility Cost Reduction (%)	2.9%
Total GHG Reduction (%)	1.2%

1.1.2 Proposed Scope of Work

It is recommended to replace linear and compact fluorescent lamps and other type of lamps used in the campus with LEDs. For the fixtures that are in good condition and areas where fixture replacement not required, re-lamp and re-ballast measures can be implemented on a wide variety of luminaire types and lamp/ballast combinations. Typical lamp lengths of 2’, 3’ and 4’ and existing ballasts are replaced with corresponding lower wattage T8 and T5HO LED lamps and high efficiency electronic ballasts. Likewise, recessed downlights throughout the facilities with existing compact fluorescent pin-type lamps will be replaced with corresponding lower wattage PL-LED lamps and electronic ballasts. Depending on the type and condition of the existing lighting fixtures and the University staff decision, installation of new LED fixtures might be required. LED fixtures are efficient luminaires with LEDs and electronic driver technology.

1.1.3 Impact on Current Operations and Maintenance

LED lamps have a longer life span compared to the fluorescent lamps. As such, significantly less maintenance will be required after implementation of this measure. In addition, electronic ballast will be replaced which will reduce future maintenance cost as the ballasts that’re at the end of their life cycle will be replaced with the new ones. This will reduce the expenditures due to emergency replacement.

1.1.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main electricity utility meters.

1.2 BAS Re-Commissioning, Controls Upgrade

1.2.1 Existing Conditions and Assumptions

Definition of Building Recommissioning

Building re-commissioning is a low-cost, low-risk energy management strategy. The benefits extend beyond operational efficiencies and energy cost savings. It improves equipment operations and extends equipment service life, hence reducing operating expenditures over time. The intent of this measure is to enhance the operations of the HVAC equipment and BAS by implementing recommissioning process that would lead to energy and cost savings as well as reduced greenhouse gas emissions.

HVAC and BAS recommissioning consists of three phases which are investigation phase, implementation phase and persistence phase. As a high-level summary for all phases, the process would include the following steps:

- Confirmation of the operations of sensors, control systems, actuators, programming & sequence of operation, and I/O devices (investigation phase)
- Verification of operational parameters such as set-point temperatures and schedules for HVAC equipment such as boilers, heat pumps, chillers, AHU, pumps and RTUs (investigation phase)
- Identification of EBCx measures based on the findings of the investigation phase

- Optimization, repairing, replacing and/or recalibrating HVAC equipment, sensors, and BAS systems to improve the efficiency of the systems and equipment (implementation phase)
- Implementation of measures identified during the confirmation and verification stage (implementation phase).

The Existing Building Commissioning (EBCx) Program

EBCx is an IESO incentive program designed to help owners, operators and managers of commercial and institutional buildings in Ontario to implement building management best practices, and through which reduce energy waste, enhance occupant comfort and increase profitability. Eligible buildings must meet a minimum annum consumption of 750,000 kWh of grid supplied electricity and have not taken building wide commissioning exercise in the last two years.

Accredited by IESO, Blackstone is a pre-qualified CP for the EBCx program and has setup a delivery procedure in compliance with IESO's EBCx Incentive Program timeline and requirements.

EBCx incentive program consists of three (3) sequenced phases: 1) Investigation; 2) Implementation; 3) Persistence or M&V. Blackstone is currently contracted to deliver EBCx Investigation phase, together with Enervolve Decarbonization Study.

EBCx Investigation – Planning

Working with Ontario Tech University, Blackstone reviewed the utility data (January 2016 to December 2022), identified a list of candidate buildings, prioritized eligible buildings, completed the EBCx Application online submission and approval. As shown in Table 1 below, it should be noted that the savings show a conservative estimate that 6.5% of electricity could be saved through the entire EBCx program based on industry standard for savings and costs for Building Automation System recommissioning projects. The savings estimates will be further calculated and confirmed through subsequent phase completion of Investigation, Implementation and Persistence.

Table 1-3. Building Screening & EBCx Investigation Planning

<table>
<tr><th colspan="3">Building Screening</th><th colspan="5">EBCx Incentive Program</th></tr>
<tr><th>Building Name</th><th>Building Address</th><th>Sq. ft.</th><th>Total Sq. Ft. per EBCx Application</th><th>Annum kWh (Jan-Dec 2022)</th><th>kWh Savings Estimates @6.5%</th><th>EBCx App. ID. (Online Submission Approved)</th><th>Phase 1 Investigation (kwh)</th></tr>
<tr><td>Business and IT Building</td><td>20 Founders</td><td>100,218</td><td rowspan="5">600,569</td><td rowspan="5">16,144,961</td><td rowspan="5">1,049,422</td><td rowspan="5">EA-0002654741</td><td rowspan="5">36,034</td></tr>
<tr><td>Energy Research Centre</td><td>30 Founders</td><td>105,889</td></tr>
<tr><td>Library</td><td>50 Founders</td><td>76,493</td></tr>
<tr><td>Science Building</td><td>31 Avenue of Champions</td><td>208,895</td></tr>
<tr><td>Shawenjigewining Hall (A5 Student Centre)</td><td>40 Founders</td><td>109,074</td></tr>
<tr><td>Ace</td><td>60 Founders</td><td>158,666</td><td>158,666</td><td>4,891,238</td><td>317,930</td><td>EA-0002729660</td><td>9,520</td></tr>
<tr><td>Software and Informatics Research Centre (SIRC)</td><td>40 Conlin Road W</td><td>82,260</td><td>82,260</td><td>970,245</td><td>63,066</td><td>EA-0002729659</td><td>4,936</td></tr>
</table>

Campus Ice	2200 Simcoe St N	82,540	82,540	950,373	61,774	EA-0002729704	4,952
		Totals	**924,035**	**22,956,817**	**1,492,193**	**-**	**55,442**

Existing BAS and Operations

Siemens Apogee™ Building Automation System (BAS) has been used to control and monitor the operations of central plant boilers, ground source heat pumps, chiller, AHUs, pumps, EFs and other HVAC equipment for the buildings located at the Simcoe Campus except Shawenjigewining Hall and Campus Ice Centre. Currently, Siemens Apogee BAS is being upgraded to Siemens Desigo Platform.

Johnson Controls Metasys™ BAS is used to control the AHUs, pumps, EF's and other HVAC equipment for Shawenjigewining Hall. CIMCO BAS is used to control the refrigeration system and HVAC equipment for Campus Ice Centre.

The Siemens Apogee™ BAS systems and Johnson Controls Metasys™ BAS are managed by Durham College Facility Management Team (DCFM). CIMCO BAS is managed by NuStadia supported by OCIS.

DCFM Team provided read only access to allow Blackstone Team to collect information on the operations of the HVAC and BAS equipment. As Blackstone Team was granted a limited access. A set of questions to gather information on the BAS sequences of operations and operating parameters were compiled and submitted to the Durham College DCFM Team with the collaboration of the Ontario Tech University Facility Management Team. Based on the correspondence with the Durhan College Management DCFM Team and review of the available information on the BAS graphics, following measures were identified.

- Revise time of day schedules for AHUs, MAUs and RTUs to match the space occupancy hours and reduce the operating hours of the equipment
- Implement or enable optimum start strategy and close the outdoor air dampers during warm up and after occupancy hours if AHUs, MAUs and RTUs are required to run to meet the space heating and cooling demand
- Implement summer and winter schedules and setpoint temperatures for HVAC equipment to match changing space occupancy throughout the year and reduce simultaneous heating and cooling
- Review and revise all heating and cooling temperature set points and dead-band between heating and cooling to reduce simultaneous heating and cooling for AHUs, RTUs
- Review and revise economizer control strategy to increase the mixed air temperature and reduce intake amount of outdoor air wherever possible
- Increase the mechanical cooling lockout temperature to reduce the mechanical cooling
- Recalibrate or replace OA, RA, MA, SA and space temperature and humidity sensors to optimize the operations of the HVAC equipment
- Recommission HRV/ERV units and all the AHUs and MAUs
- Review and revise sequences of operations for pumps
- Increase chilled water temperature set point to eliminate low delta T syndrome
- Install Demand Control Ventilation for Campus Ice Rink kitchen MAU
- Install VFDs on brine pump for Campus Ice Rink
- Optimize central boiler plant supply hot water temperatures after decoupling of the central boiler plant from DHW system and installation of electric DHW heating system.

Some of the control strategies identified above are relatively simple measures such as revising and reducing operating hours for AHUs, RTUs, EFs and installation of optimum start (or enable) and controlling OAD operations. These measures can be implemented immediately to optimize the equipment operations and reduce electricity and gas consumption of the HVAC equipment. Recommissioning of HVAC equipment such as the central heating plant boilers, ground source heat pumps, AHUs, MAUs, RTUs and VAVs, and re-calibration or replacement of sensors can be carried out during the implementation phase of building recommissioning.

1.2.2 Proposed Scope of Work

Estimated scope of work for the implementation of BAS re-commissioning is provided below.

- Confirmation of the operations of sensors, control systems, actuators, programming & sequence of operation and I/O devices.
- Verification of operational parameters such as setpoint temperatures and schedules for HVAC equipment such as boilers, heat pump chillers, chillers, AHU, pumps, RTUs and heat recovery units.
- Verification of controls and operations of VAV boxes.
- Optimization, repairing, replacing and/or recalibrating sensors .
- Installation of improved sequences of operation to monitor and control the operations of the equipment.
- Implementation of measures identified during the investigation phase.
- Accurate and detailed documentation of the measures implemented.

It is recommended to begin the installation of the simpler measures such as BAS programming changes identified in the section above, before the implementation of the EBCx process to optimize the building systems. Screenshots from the existing BAS graphics are shown below for reference.

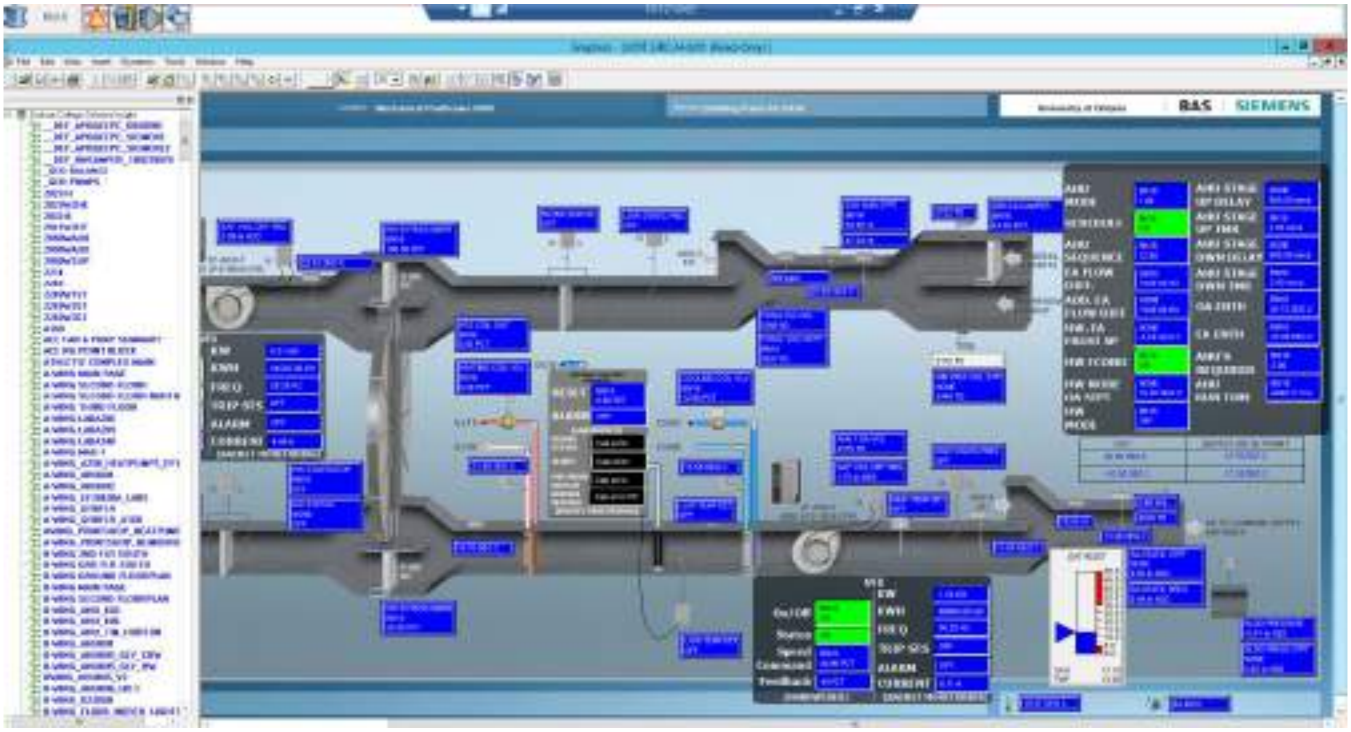


Figure 1-2. BAS Existing Graphics

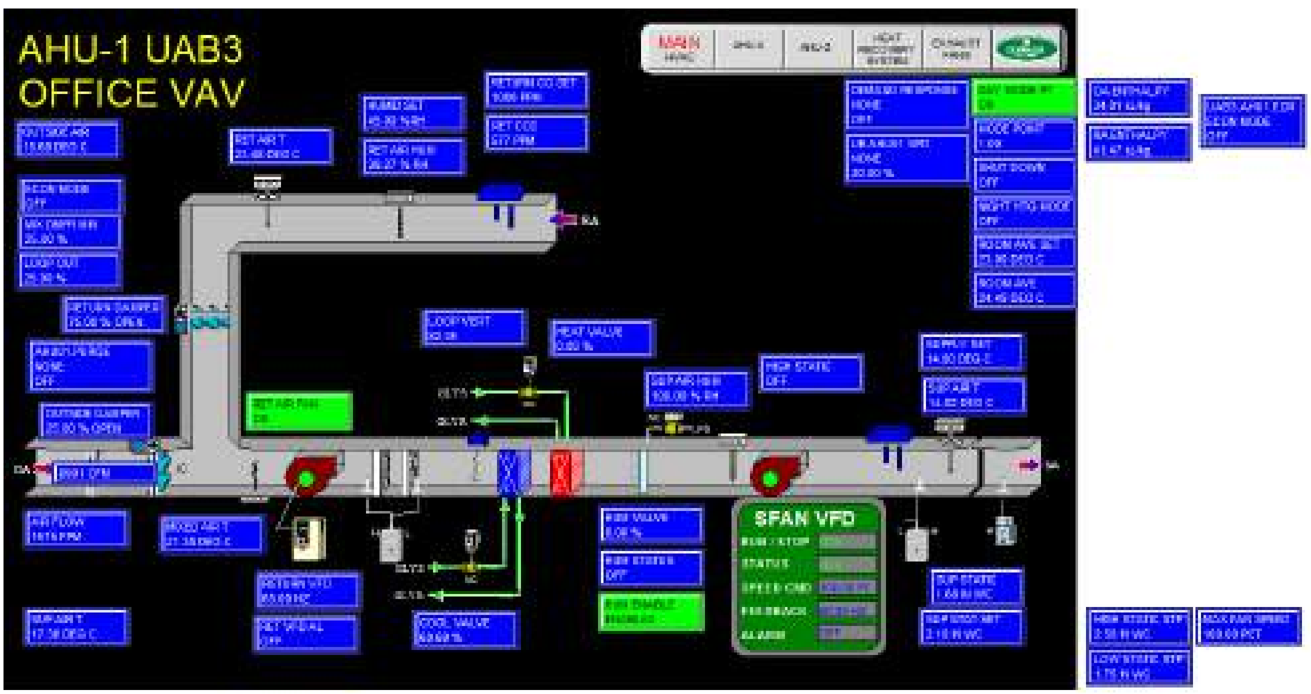


Figure 1-3. BAS Screen - Return Fan VFD

The return fan VFD speed on the BAS screen above is 65 hz which is higher than the highest set point of 60 hz. There must be an error on the VFD status or speed display or the control sequence. This will be investigated during the BAS recommissioning phase. The BAS screenshot for the central ground source heat pump loop and the chiller is shown below for reference.

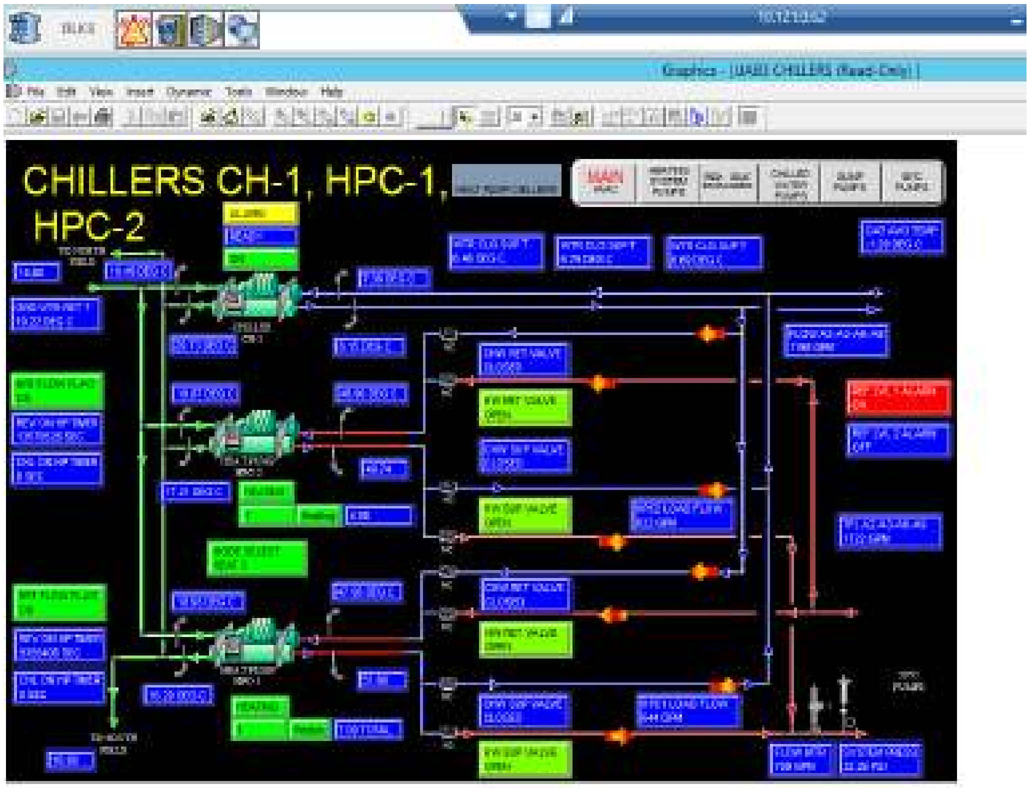


Figure 1-4. BAS Screen - Chiller Supply

The chiller supply temperature can be raised to increase the delta T across the chiller. The BAS screenshot for the boiler plant is shown below for reference.

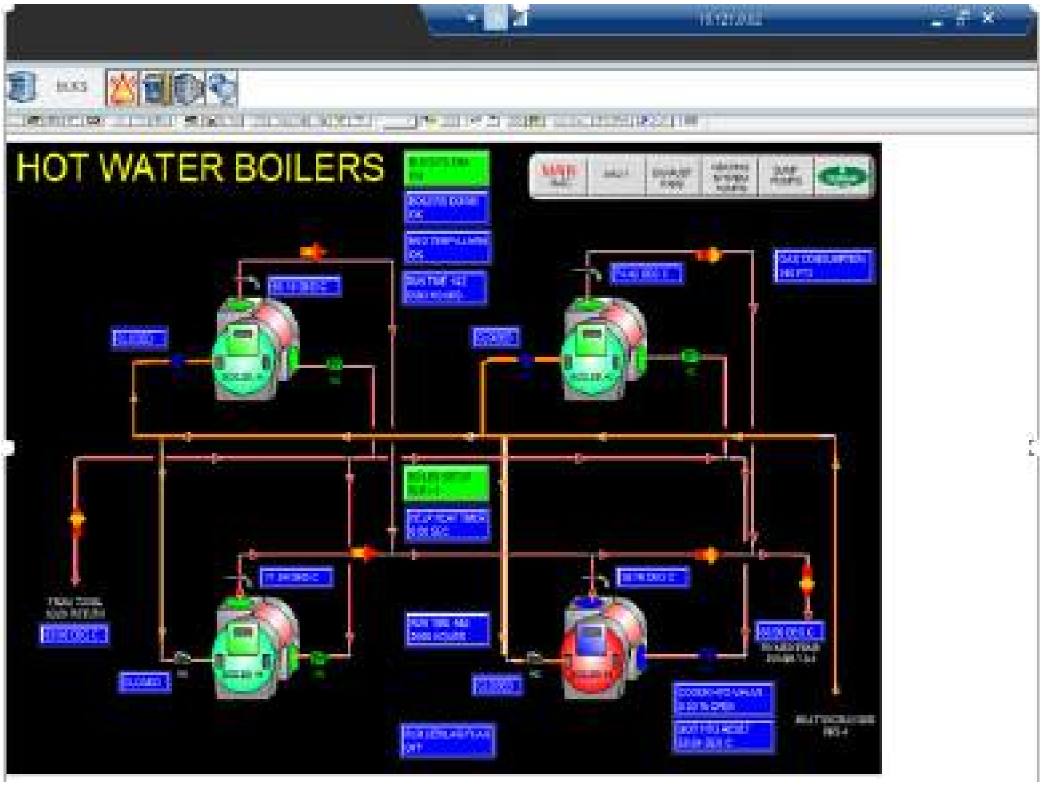


Figure 1-5. BAS Screen - Central Plant Sequences of Operations

Sequences of operations for the central plant boilers will be reviewed as part of recommissioning process to optimize the operations of the equipment.

The estimated measure implementation cost, annual energy and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-4. BAS Replacement Project Summary

Project Details	
Project Cost (Class D Estimate)	$1,056,044
Annual Electricity savings (kWh)	1,492,193
Annual Natural Gas savings (m3)	21,646
Annual Cost Savings	$74,725
Simple Payback (yrs.)	14.1
Life Cycle of Measure (yrs.)	20
Annual GHG Reductions (tonnes of CO_2e)	146.9
Total Utility Cost Reduction (%)	2.9%
Total GHG Reduction (%)	3.8%

1.2.3 Impact on Current Operations and Maintenance

BAS and HVAC recommissioning will improve the operations of the HVAC and BAS systems and equipment. Faulty and non-functional devices will be replaced due to the re-commissioning process. This will improve the performance of the equipment and optimize energy efficiency. The amount of emergency repairs will be reduced, resulting in lower the operating expenditures.

1.2.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.3 Decouple Central Heating Plant from DHW System and Install Electric DHW Heaters

1.3.1 Existing Conditions and Assumptions

The central heating plant located in the mechanical room under the Business and IT (UB) Building generates high temperature heating hot water (70 deg. C) used for the space heating and the DHW systems for the following buildings connected to the central plant:

- OPG
- UB (Business and IT Building)
- Science East and West
- Library
- ERC (Energy Research Centre)

Central heating plant consists of four Viesmann gas-fired boilers with a total heating capacity of 13,083 MBH (3x 3,361 MBH and 1 x 3,000 MBH input capacities). The high temperature hot water is distributed to the five buildings through the underground tunnel piping system. The circulation pumps located in the basement mechanical room of the UB building circulates the high temperature loop hot water through underground piping system to the five buildings. There is a dedicated heat exchanger separating (or isolating) the main distribution (high temperature) system from the building high temperature hot water loop in each building. Each heat exchanger is equipped with circulation pumps circulating the high temperature hot water through the radiant panels, unit heaters, forced flow heaters and DHW tank heater in the buildings.

DHW is generated using DHW tank located in the basement of each building. Heating hot water for the DHW tank is provided by the heat exchanger via circulation pumps. The central boiler plant is operational all year round to generate high temperature hot water for the DHW system. Building occupancy is lower in summer months compared to the winter occupancy rates. Running central boiler plant to meet low DHW demand reduces the efficiency of the boilers, thus increasing the gas consumption. In addition, the heating hot water is supplied through the underground piping system to the heat exchanger located in the basement mechanical room of each building. This results in distribution losses as 70 deg. C water is circulated in the main piping system and through the heat exchangers.

The purpose of this measure is to decouple central heating plant from the DHW system to increase the efficiency of the boiler plant, to reduce distribution losses and to enable boiler plant to operate under sequence of operations and controls based on the building heating demand instead of false load generated due to the inefficiencies of the existing distribution system generated particularly in summer since high temperature hot water is only used for DHW.

Consequently, the boiler supply water temperature can be reduced to optimize the central plant operations and reduce gas consumption. The boiler will run to meet the actual load requirements during shoulder season and non-peak periods. This will increase the efficiency of the main boiler plant. The boiler plant will be shut down in summer due to the implementation of this measure.

Blackstone put together the list of the DHW systems included in this measure. The list is provided below for reference.

Table 1-5. Heat Exchanger Schedule

Building	Equipment ID	Location	Area Served	Rated input Capacity (btu/hr)	storage capacity (U.S Gallons)	flow rate (usgpm)	EWT (deg.F)	LWT (deg.F)
UB	DHWT-1	Basement Mech. Room	Labs, washrooms	282,258	462	3.33	40	140
ERC	DHWT-1	Basement Mech. Room	Labs, washrooms	282,258	462	3.33	40	140
UA- East	DHWT-1	Basement Mech. Room	Labs, washrooms	230,000	220	3.33	40	140
UA- West	DHWT-1	Basement Mech. Room	Labs, washrooms	282,258	462	3.33	40	140
Library	DHWT-1	Basement Mech. Room	washrooms	250,000	330	3.67	50	140
OPG	DHWT-1	Basement Mech. Room	Labs, washrooms	282,258	462	3.33	40	140

One of the decoupling strategies is to install an electric DHW tank heater for each building to generate heating hot water for the DHW system. Since the mechanical rooms are located below the grade and the roof installation would require modifications to the DHW piping, installation of high temperature heat pump system to supply heating hot water for DHW system is not selected for these buildings.

The rated capacities for the proposed electric DHW heaters are shown below in the table below.

Table 1-6.Proposed Electric DHW Heater Schedule

Building	Equipment ID	Location	Area Served	Input kw
UB	DHWT-1	Basement Mech. Room	Labs, washrooms	83
ERC	DHWT-1	Basement Mech. Room	Labs, washrooms	83
UA- East	DHWT-1	Basement Mech. Room	Labs, washrooms	67
UA- West	DHWT-1	Basement Mech. Room	Labs, washrooms	83
Library	DHWT-1	Basement Mech. Room	Washrooms	33
OPG	DHWT-1	Basement Mech. Room	Labs, washrooms	83

The rated heating capacities (btu/hr) for existing DHW tanks were used to estimate the input capacities of the proposed electric DHW tanks except Library, since there're a few washroom faucets and no laboratories in the library building.

It is suggested to connect the proposed electric DHW heaters to the existing DHW tanks to increase the DHW storage capacity with the intent of reducing the electricity demand when there is need for the DHW during the peak occupancy hours at the buildings. The existing piping connection to the high temperature heat exchanger will be capped. Existing piping schematic for a similar system is provided below.

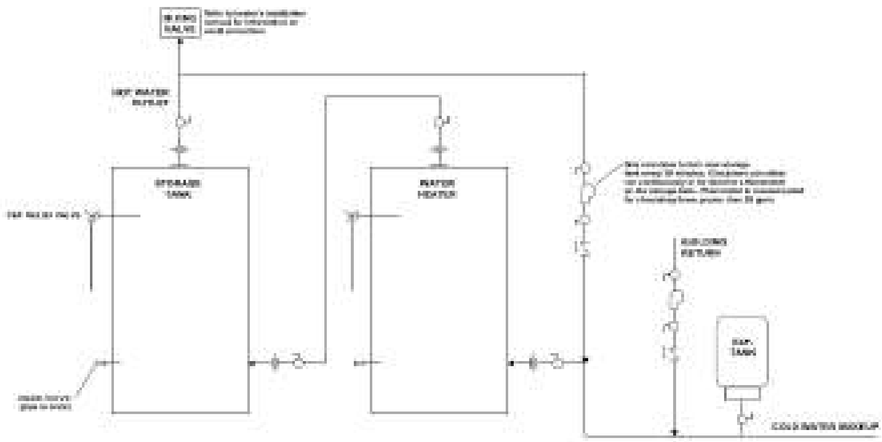


Figure 1-6. DHW Tank Schematic

Heating hot water piping schematic for the high temperature hot water and low temperature hot water for the UB Building is provided below for reference.

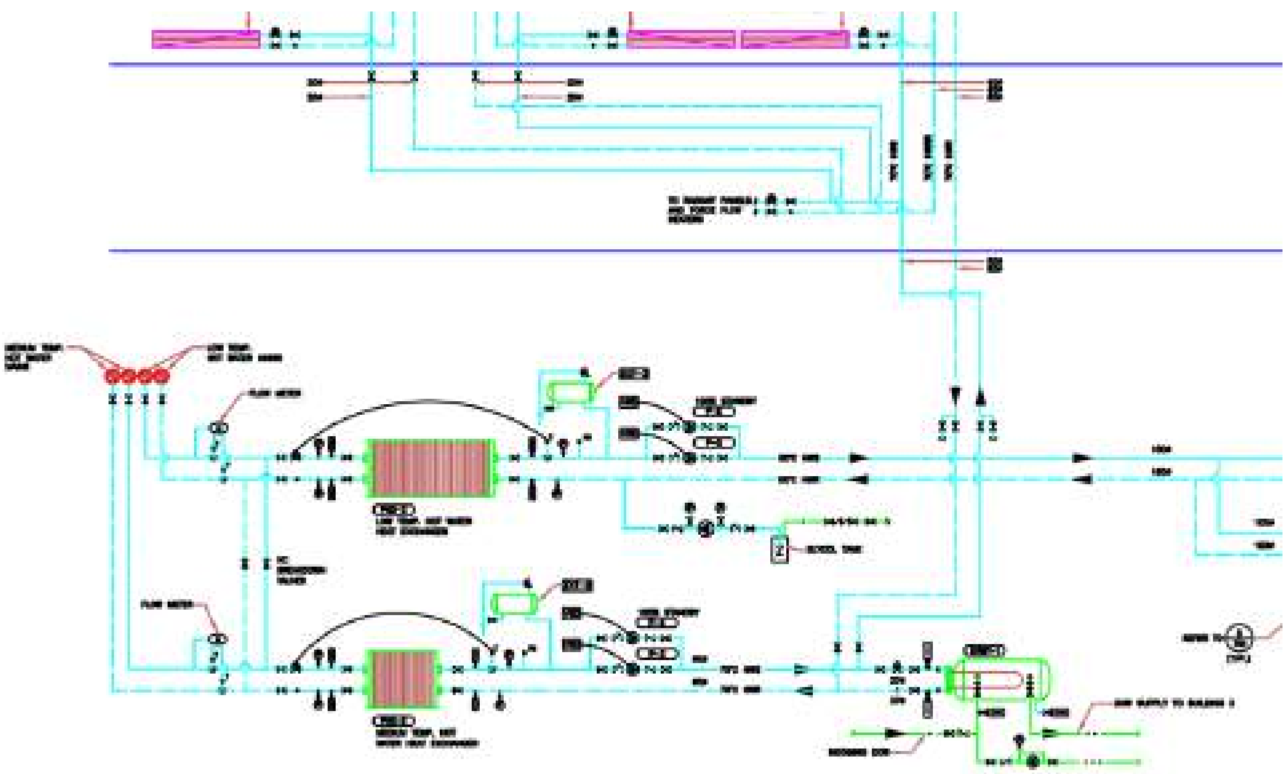


Figure 1-7. Existing Piping Heating Schematic

The estimated measure implementation cost, annual energy and cost savings GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-7. Decouple Central Heating Plant from DHW System and Install Electric DHW Heaters

Project Details	
Project Cost (Class D Estimate)	$465,500
Annual Electricity savings (kWh)	-966,133
Annual Natural Gas savings (m3)	161,026
Annual Cost Savings	-$8,648
Simple Payback (yrs.)	-
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	241.1
Total Utility Cost Reduction (%)	NA
Total GHG Reduction (%)	6.2%

1.3.2 Proposed Scope of Work

Proposed scope of work includes but not limited to the followings:

1. Installation of electric DHW Tank for each building
2. Installation of control panel for each boiler
3. Installation of all required piping, wiring, electrical connections
4. Integrating new system into BAS and programming
5. Caping off existing DHW tank piping connection to the high temperature heating loop
6. Commissioning and start-up

Blackstone reviewed the electrical single line diagrams and electrical drawings to assess the available power capacity to feed the DHW heaters. It is concluded that there is spare capacity to feed the DHW heaters.

1.3.3 Impact on Current Operations and Maintenance

The new electric DHW tanks will be integrated into the BAS to allow for monitoring and control of the system performance and operating parameters. The new DHW tanks will require maintenance, however the boilers will shut down in summer which will increase the overall efficiency of the boiler plant and reduce maintenance requirements.

1.3.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulting from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.4 Electrification of Central Boiler Plant and Heat Pump Installation- UB Building

1.4.1 Existing Conditions and Assumptions

The central ground source heat pump system generates low temperature heating hot water (50 deg. C) supplied to the buildings connected to the central plant through the underground distribution system. The low temperature heating water is used to heat glycol used for AHU hydronic coils via heat exchangers located in the basement mechanical room of each building.

The central boiler plant provides high temperature hot water (70 deg. C) for the radiant panels, unit heaters, forced flow heaters and DHW tank heater for the building connected to the central plant. Currently, the boiler plant is operational all year round since it supplies the heating hot water for the DHW system.

The intent of this measure is to reduce the heating load on the gas-fired boilers by installation of heat pump equipment to generate high temperature hot water serving radiant panels, unit heaters, forced flow heaters for the buildings connected to the central boiler plant and the UA West building AHUs.

It is recommended to install this measure after implementation of decoupling the Central Boiler Plant from the DHW systems (ECM #3) due to the following reasons:

- To enable seasonal shut down of the boiler plant in summer
- To optimize the operations of the central boiler plant by incorporating control strategies such as reducing supply water temperature to 60 deg.C (decreasing from 70 deg. C) and outdoor reset temperatures
- To assess the building heating load and equipment operations under set of supply hot water heating temperatures before the final selection of the heat pump equipment

A preliminary analysis was performed to select the heat pump equipment that will generate high temperature heating water based on the information collected on the operating parameters for the chiller, ground source heat pump system and central heating plant. The heat pump system can be connected to the chilled water loop or the ground source heat pump loop to generate heat for the central plant. The intent of this measure is to present possible heat pump solution to supply heating hot water to reduce the heating load on the central boiler plant.

As per the preliminary analysis, WaterFurnace TruClimate 700 heat pumps which is a modular heat pump system with a VFD was selected. This heat pump system can be connected to the chilled water loop generating chilled water for the cooling loop while supplying the heating hot water for the central plant.
The equipment selection must be revisited after the implementation of the ECM #3 and implementation of central plant boiler control strategies to analyze the heat load of the central plant and to select the equipment most applicable to the building loads and systems.

The cut sheets for the preliminary selection are provided in *Appendix 5 – CutSheets*. The central plant schematic is provided below for reference.

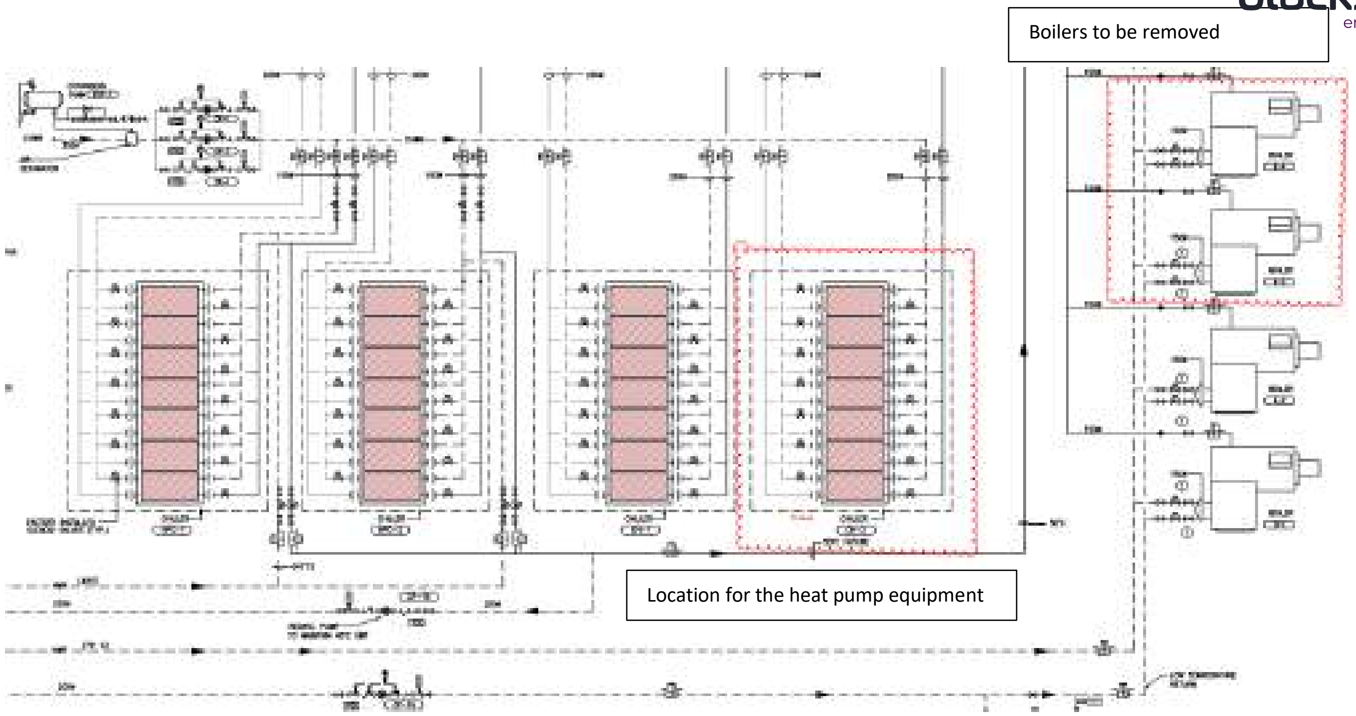


Figure 1-8. Existing Heating Piping Schematic

Proposed equipment make and model number is provided below for reference. Equipment performance and selection parameters are provided in the *Appendix 5 – Cutsheets*.

Table 1-8. Proposed Heat Pump Equipment

Location	Make	Model	Nominal Tonnage (tons)	Quantity	Voltage	Installation Date
UB Building Basement Mechanical Room	Water Furnace – Commercial Solutions	TruClimate 700 (WCH 140)	140	3	460/60/3	2020

The estimated measure implementation cost, annual energy, and cost savings GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-9.Electrification of Central Boiler Plant and Heat Pump Installation - UB Building

Project Details	
Project Cost (Class D Estimate)	$1,729,000
Annual Electricity savings (kWh)	-1,251,180
Annual Natural Gas savings (m3)	173,989
Annual Cost Savings	-$12,237
Simple Payback (yrs.)	-
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	245.9
Total Utility Cost Reduction (%)	NA
Total GHG Reduction (%)	6.3%

1.4.2 Proposed Scope of Work

The heat pumps will require new control panels and electrical wiring from the main power supply to control panel and from control panels to the heat pumps. Step down transformer may be required to reduce the incoming voltage to provide 460 Volts if required.

Proposed scope of work will require removal of the existing boilers and installation of the air sourced heat pumps. Existing piping will be modified, and new piping will be required to connect the heat pumps to the existing heating hot water system and the chilled water loop in the underground mechanical rooms. Circulation pumps will be required to pump the heating hot water to the main heating distribution loop. New system will be connected to the BAS.

1.4.3 Impact on Current Operations and Maintenance

The new heat pumps will be integrated into the new BAS to allow for control and monitoring of the system performance and operating parameters. The heat pumps will require regular maintenance to ensure proper operations of the systems. Since the existing boiler will be removed, it is estimated that overall annual maintenance expenditures will remain same.

1.4.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.5 Electrification of Boiler Plant - SIRC Building

1.5.1 Existing Conditions and Assumptions

Heating hot water for the fan coils unit heaters and AHUs hydronic heating coils is provided by three Raypak gas fired boilers located in the penthouse mechanical room. Each boiler has a rated input capacity of 850 MBH. The heating hot water is circulated through the building via circulation pumps with VFDs located in the penthouse boiler room. The boilers and pumps were installed in 2016.

The intent of this measure is to replace one of the boilers with air sourced heat pumps and keep other two boilers as a back-up. Gas fired boilers have lower thermal efficiency compared to heat pumps. Average COP (coefficient of performance) of a gas fired boiler is around .88, whereas COP of a heat pump may vary between 1.5 and 4 depending on the outdoor air temperature. In comparison to electrical boilers, air sourced heat pump technology is still being developed for colder climate applications, however heat pumps are more efficient and consume less electricity. This measure is considered as an alternative option to further achieve desired GHG reduction goals.

The heating schematic for SIRC Building is provided below.

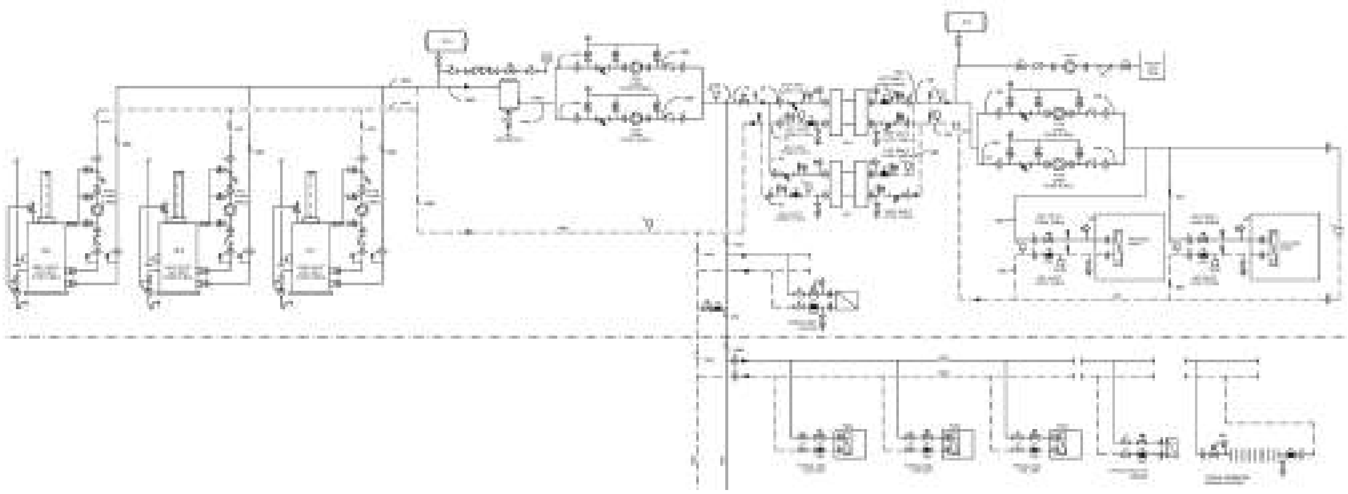


Figure 1-9. Existing Heating Piping Schematic

As per the preliminary selection, it is proposed to replace the boiler # 3 with the cascading water-sourced heat pump with outdoor VRF condensing modules. The product data for the proposed system is provided in *Appendix 5 – Cutsheets*. The list of the existing gas fired boilers is shown in the Table below.

Table 1-10. Existing Boilers Capacities

Building	Existing Boiler Make	Existing Boiler Model	Existing Boiler Capacity (MBH)	Quantity	Installation Date
SIRC	Raypak	H7-0850A	850	3	2016

The estimated measure implementation cost, annual energy and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-11. Electrification of Boiler Plant – SIRC Building

Project Details	
Project Cost (Class D Estimate)	$399,000
Annual Electricity savings (kWh)	-173,856
Annual Natural Gas savings (m3)	41,122
Annual Cost Savings	-$524
Simple Payback (yrs.)	-
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	70.4
Total Utility Cost Reduction (%)	NA%
Total GHG Reduction (%)	1.8%

The scheduled implementation for this measure will be based on equipment lifecycle. The targeted date for doing this is 2035.

1.5.2 Proposed Scope of Work

The heat pump system will require new control panels and electrical wiring from the main power supply to control panel and from control panels to the heat pumps, booster module and outdoor VRF condensers. Step down transformer may be required to reduce the incoming voltage to provide 600 Volts to the control panel.

Proposed scope of work will require removal of one of the boilers and installation of the heat pump system. Existing piping will be modified, and new piping will be required to connect the heat pumps to the existing heating hot water system and the chilled water loop. New system will be connected to the BAS.

1.5.3 Impact on Current Operations and Maintenance

The new heat pumps will be integrated into the new BAS to allow for control and monitoring of the system performance and operating parameters. The heat pumps will require regular maintenance to ensure proper operations of the systems. One of the boilers will be removed, it is estimated that the overall annual maintenance expenditures may increase slightly.

1.5.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.6 Electrification of Boiler Plant – Charles Hall

1.6.1 Existing Conditions and Assumptions

Heating hot water for the space heating and AHUs hydronic heating coils is provided by two Thermal Solutions gas fired boilers located in the main floor mechanical room. The boilers were installed in 2010, and each boiler has a rated input capacity of 2,000 MBH. The heating hot water is circulated through the building via circulation pumps located in the penthouse boiler room. The pumps are equipped with the VFDs.

The intent of this measure is to replace one of the boilers with air sourced heat pumps and leave the second boiler as a back-up. Gas fired boilers have lower thermal efficiency compared to heat pumps. Average COP (coefficient of performance) of a gas fired boiler is around .88, whereas COP of a heat pump may vary between 1.5 and 4 depending on the outdoor air temperature. In comparison to electrical boilers, air sourced heat pump technology is still being developed for colder climate applications, however heat pumps are more efficient and consume less electricity. This measure is considered as an alternative option to further achieve desired GHG reduction goals.

The heating schematic for Charles Hall is provided below.

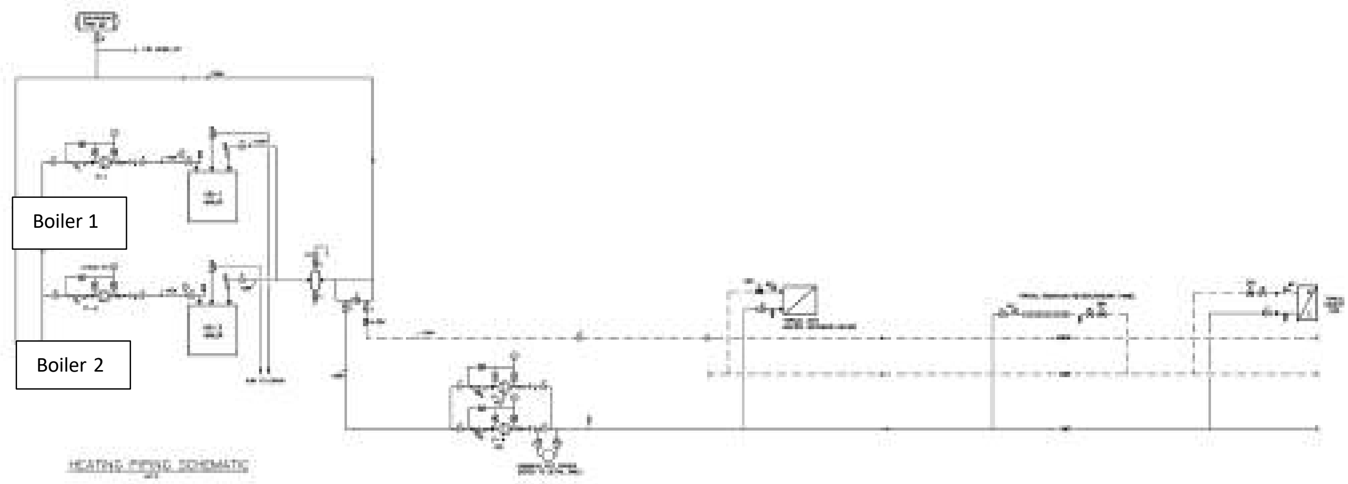


Figure 1-10. Existing Heating Piping Schematic

Error! Reference source not found. below shows the list of existing boilers.

Table 1-12. Existing Boilers Capacities

Building	Make	Model	Capacity (MBH)	Quantity	Installation Date
Charles Hall	Thermall Solutions	EVA2000	2000	2	2010

The estimated measure implementation cost, annual energy and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-13. Electrification of Boiler Plant – Charles Hall Building

Project Details	
Project Cost (Class D Estimate)	$465,500
Annual Electricity savings (kWh)	-202,073
Annual Natural Gas savings (m3)	48,822
Annual Cost Savings	-$2,692
Simple Payback (yrs.)	NA
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	77.6
Total Utility Cost Reduction (%)	NA%
Total GHG Reduction (%)	2.0%

The scheduled implementation for this measure will be based on equipment lifecycle. The targeted date for doing this is 2030.

1.6.2 Proposed Scope of Work

The heat pump system will require new control panels and electrical wiring from the main power supply to control panel and from control panels to the heat pumps, booster module and outdoor VRF condensers. Step down transformer may be required to reduce the incoming voltage to provide 600 Volts to the control panel.

Proposed scope of work will require removal of the existing boiler and installation of the air sourced heat pumps. Existing piping will be modified, and new piping will be required to connect the heat pumps to the existing heating hot water system in the buildings. New system will be connected to the BAS.

1.6.3 Impact on Current Operations and Maintenance

The new heat pumps will be integrated into the new BAS to allow for control and monitoring of the system performance and operating parameters. The heat pumps will require regular maintenance to ensure proper operations of the systems. The existing boiler will be removed. It is estimated that overall annual maintenance expenditures will increase slightly.

1.6.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.7 Replace Existing AHUs with Heat Pump Units - CERL

1.7.1 Existing Conditions and Assumptions

The heating, cooling and ventilation for the CERL building is provided by two gas fired AHUs (AHU 1 & AHU 2) equipped with the DX cooling system. AHU 1, a mixed air unit, serves the offices. AHU 2, 100% outdoor air MAU, serves the labs. The rated cooling capacities of the AHU 1 and AHU 2 are 15-ton and 30-ton, respectively.

The intent of this measure is to replace the existing AHUs with the heat pump AHUs with back-up electric heat to further reduce the green house gas emissions for the Campus. New AHUs would have higher cooling efficiencies (EER/SEER numbers). They are equipped with more efficient fan motors such as electronically commutated (EC) motors which will reduce the annual fan electricity consumption.

Cross section of the building and equipment layout is shown below for reference.

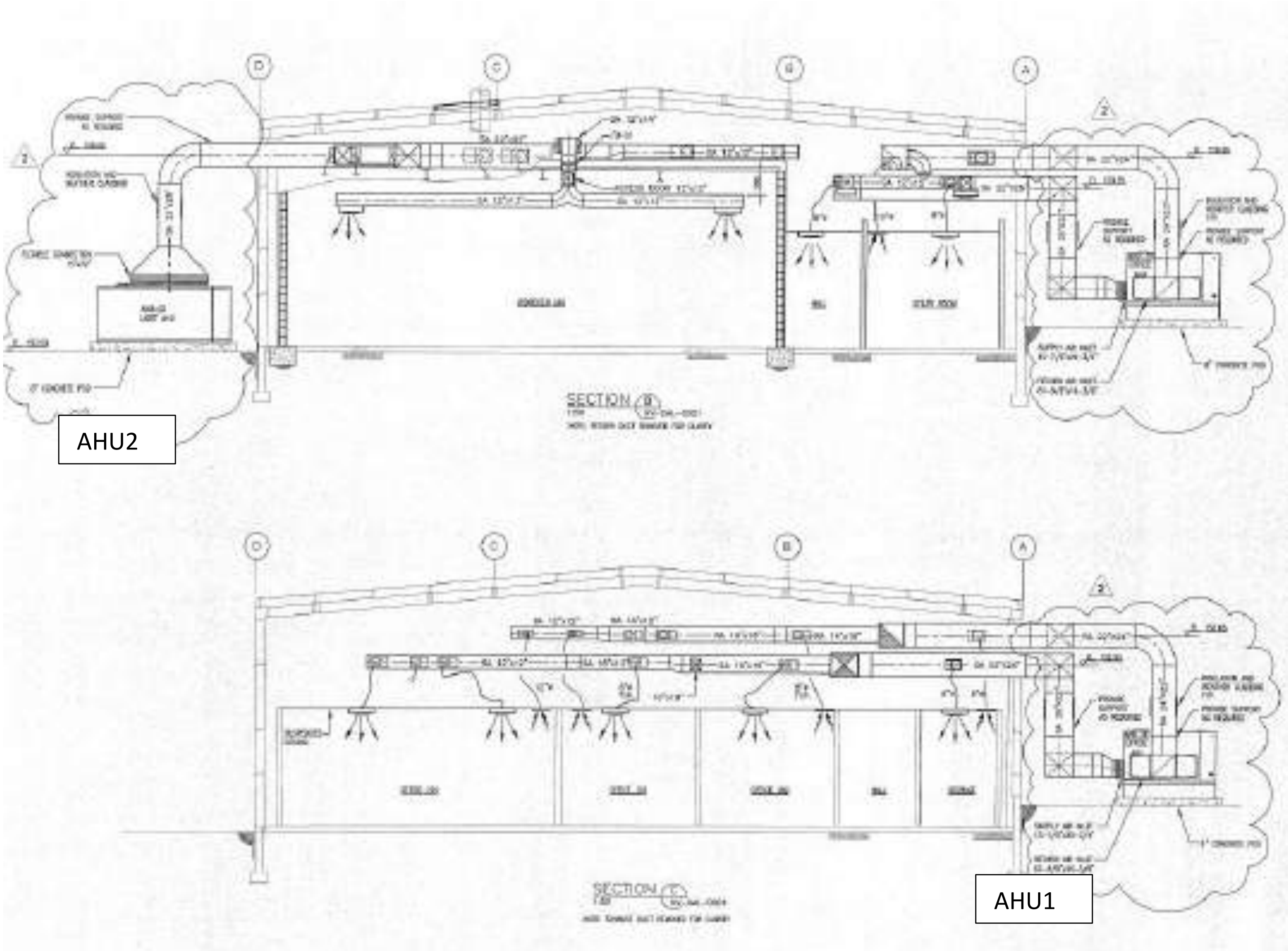


Figure 1-11. Existing Duct Work and Cross Section of the Building

The table below shows the list of existing AHUs.

Table 1-14.Existing AHU Heating and Cooling Capacities

Item #	Building	Tag	Equipment Description	Location	Area Served	VFD	Supply Fan (HP)	Supply Air Flow Rate	Return Air Flow Rate	Cooling Capacity (tons)	Heating Capacity (btu/hr)
1	CERL	AH U-1	RTU- mixed air	Outside Storage Area	Offices	No	5	5,000	3,750	15	177,970
2	CERL	AH U-2	MAU- 100% outdoor air	Outside Hydrolysis Area	Labs	No	10	6,670	-	30	566,733

The cut sheets for the proposed heat pump AHUs are provided in *Appendix 5 – Cutsheets*.

The estimated measure implementation cost, annual energy, and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-15. Replace Existing AHUs with Heat Pump Units - CERL

Project Details	
Project Cost (Class D Estimate)	$964,331
Annual Electricity savings (kWh)	-357,110
Annual Natural Gas savings (m3)	62,106
Annual Cost Savings	-$4,797
Simple Payback (yrs.)	NA
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	94.1
Total Utility Cost Reduction (%)	NA%
Total GHG Reduction (%)	2.4 %

The scheduled implementation for this measure will be based on equipment lifecycle. The targeted date for replacement of existing RTUs and MAUs are 2026 and 2040, respectively.

1.7.2 Proposed Scope of Work

Proposed scope requires the followings:

- Removal of the old AHUs
- New AHUs to be connected to the existing gas piping
- New AHUs to be connected to the existing duct work
- Electrical wiring to be provided to power the new unit
- Integration of new AHUs to the existing BAS
- New AHUs to be commissioned

1.7.3 Impact on Current Operations and Maintenance

The new heat pump AHUs will be integrated into the new BAS to allow for control and monitoring of the system performance and operating parameters. The heat pump AHUs will require regular maintenance to ensure proper operations of the systems. Since the existing AHUs will be removed, it is estimated the overall annual maintenance expenditures will remain same.

1.7.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.8 Replace the Existing Boiler with Air Sourced Heat Pumps and Modify Existing AHU -CIC

1.8.1 Existing Conditions and Assumptions

The heating hot water for the fan coil units and DHW system for Campus Ice Centre is generated by two gas fired Viessmann Vitorond 200 boilers installed in 2004. The rated input capacity of each boiler is 1,544 MBH.

The intent of this measure is to replace the one of the boilers with the air sourced heat pumps and to separate space heating (fan coils) loop from the DHW system. This measure includes modifications to the existing AHU to convert the gas fired burner to hydronic heating coils. The heating hot water to the hydronic coils will be provided by the air sourced heat pump system.

Air sourced heat pumps can be used an alternative to electrical boilers to generate hot water to be used for space heating. The main purpose of this measure is to reduce the gas consumption of the Campus to reach their greenhouse gas reduction targets.

This is a more energy efficient approach compared to electric boilers as an average COP of air sourced heat pump system can be around 3 whereas COP of electric heating is 1.

The boilers heating schematic and DHW tanks are shown in the figure below.

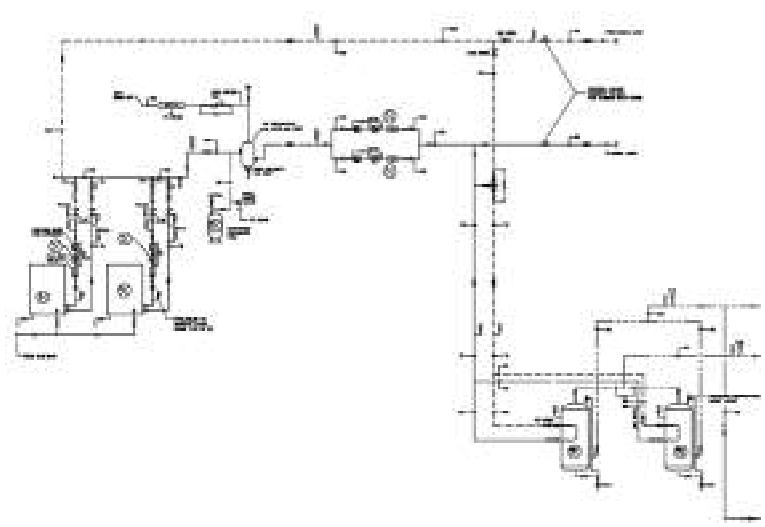


Figure 1-12. Existing Boilers Heating Schematic and DHW Tanks

The preliminary selection of equipment consists of ARK Heat heat pumps, booster modules and Daikin VRF condensing units. The cut sheets for the equipment are provided in *Appendix 5 – Cutsheets*. It is recommended to revisit the equipment selection as this is a preliminary selection.

The estimated measure implementation cost, annual energy and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-16. Replace Existing Boiler with Air Sourced Heat Pumps and Modify Existing AHU - CIC.

Project Details	
Project Cost (Class D Estimate)	$559,930
Annual Electricity savings (kWh)	-332,026
Annual Natural Gas savings (m3)	71,317
Annual Cost Savings	-$1,788
Simple Payback (yrs.)	NA
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	113.6
Total Utility Cost Reduction (%)	NA%
Total GHG Reduction (%)	2.9%

The scheduled implementation for this measure will be based on equipment lifecycle. The targeted date for doing this is 2025.

1.8.2 Proposed Scope of Work

Proposed scope of work includes removal of the one of the existing gas fired boiler and installation of booster modules and VRF condensing units. New equipment will require electrical wiring from the control panel. Wiring should be enclosed in conduit to provide protection from physical harm and electrical shock. Electrical panels may require upgrades depending on the available power supply from the panel to the electric boiler.

It is recommended to integrate the new equipment into the BAS to enable the system to monitor and control the operations of the equipment.

1.8.3 Impact on Current Operations and Maintenance

This measure may result in increased operational expenditures.

1.8.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.9 Replace the Existing Boiler with DHW Air Sourced Heat Pumps -CIC

1.9.1 Existing Conditions and Assumptions

The heating hot water for the fan coil units and DHW system for Campus Ice Centre is generated by two gas fired Viessmann Vitorond 200 boilers, installed in 2004. The rated input capacity of each boiler is 1,544 MBH.

The intent of this measure is to replace the one of the boilers with the air sourced heat pumps to provide heating hot water for the DHW system. DHW system supplies heating hot water used for the showers, faucets, kitchen, and ice-resurfacing used by Zambonis.

The Campus Ice Centre is operational all year round as the ice-rinks are rented throughout the year including summer. There is a heat recovery system recovering the waste heat from the compressor loop and using it to heat the domestic cold water. Tempered water is mixed with DHW through the mixing station.

Air sourced heat pump systems can be used an alternative to electrical boilers to generate hot water to be used for space heating. The main purpose of this measure is to reduce the gas consumption of the Campus to reach their greenhouse gas reduction targets.

This is a more energy efficient approach compared to electric boilers as an average COP of air sourced heat pump system can be around 3 whereas COP of electric heating is 1.

The piping schematic for the DHW system is shown in the figure below.

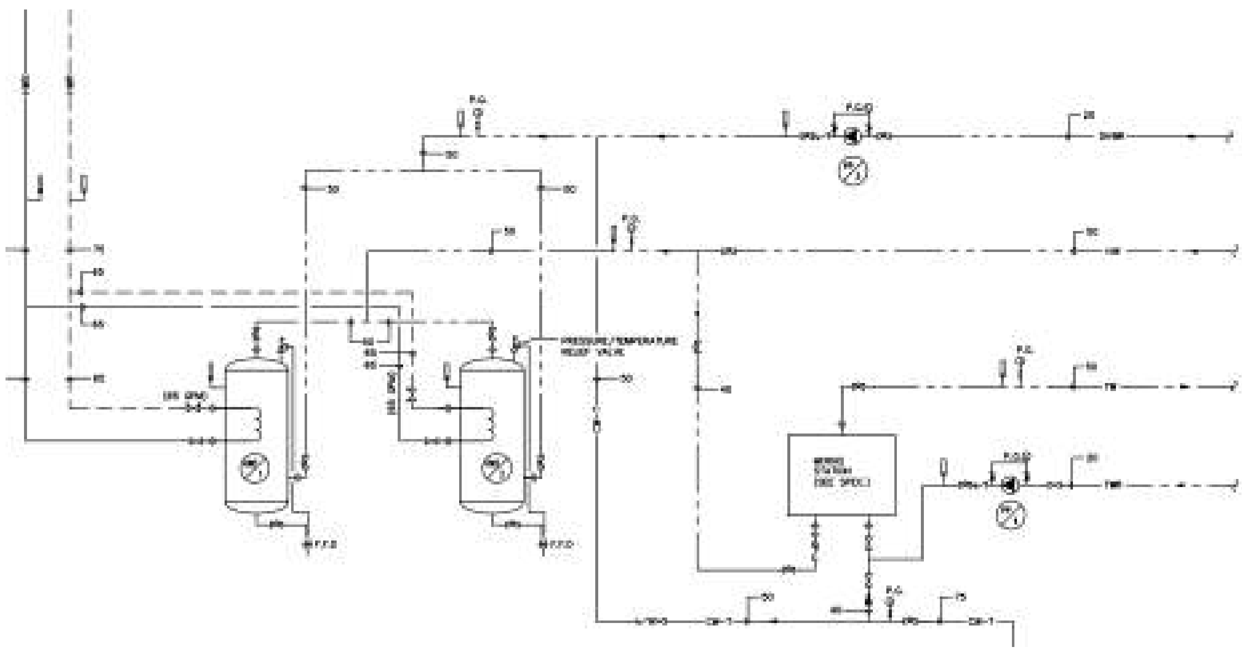


Figure 1-13. Existing DHW Tanks and Piping

The preliminary selection of equipment includes Lync high temperature heat pumps that will work with the existing DHW storage tanks. It is suggested to maximize the DHW storage capacity to reduce the load on the heat pumps and increase the capability to keep up with the DHW demand. The cut sheets for the equipment are provided in *Appendix 5 – Cutsheets*. It is recommended to revisit the equipment selection at the design stage as this is a preliminary selection.

The estimated measure implementation cost, annual energy and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-17. Replace the Existing Boiler with DHW Air Sourced Heat Pumps - CIC

Project Details	
Project Cost (Class D Estimate)	$864,500
Annual Electricity savings (kWh)	-293,384
Annual Natural Gas savings (m3)	63,017
Annual Cost Savings	-$14,744
Simple Payback (yrs.)	NA
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	100.3
Total Utility Cost Reduction (%)	NA%
Total GHG Reduction (%)	2.6%

The scheduled implementation for this measure will be based on equipment lifecycle. The targeted date for doing this is 2025.

1.9.2 Proposed Scope of Work

Proposed scope of work includes removal of the existing gas fired boiler and installation of heat pumps. New heat pumps will require electrical wiring from the control panel. Wiring should be enclosed in conduit to provide protection from physical harm and electrical shock. Electrical panels may require upgrades depending on the available power supply from the panel to the electric boiler.

Heat pumps will be connected to the existing DHW tanks. Piping in the boiler room will require modifications.

It is recommended to integrate the new equipment into the BAS to control and monitor the operations of the systems.

1.9.3 Impact on Current Operations and Maintenance

This measure may result in increased operational expenditures.

1.9.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.10 Replace Existing Gas-Fired Desiccant Dehumidifier with High Efficiency Electric Desiccant Dehumidifier - CIC

1.10.1 Existing Conditions and Assumptions

Gas-fired desiccant dehumidifier is used to remove the humidity from two ice rinks. The dehumidifier is operational 8760 hours per year as the ice rinks are operational all year-round including summer. It is suggested to replace the existing desiccant dehumidifier with the Novel-Ice desiccant dehumidifier to reduce the gas consumption of the Campus.

Novel-Ice, Energy Efficient Ice Rink dehumidification innovatively uses waste condenser heat from a high efficiency refrigeration cycle to regenerate a desiccant wheel, eliminating fossil fuel regeneration heat. As per the manufacturer data, the proposed system is 30% more efficient than typical gas fired desiccant dehumidifier. The data sheet for the proposed equipment is provided in *Appendix 5 – Cutsheets*.

The estimated measure implementation cost, annual energy and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-18. Replace the Existing Gas-fired Desiccant Dehumidifier with High Efficiency Electric Desiccant Dehumidifier - CIC

Project Details	
Project Cost (Class D Estimate)	$1,056,473
Annual Electricity savings (kWh)	-392,305
Annual Natural Gas savings (m3)	77,978
Annual Cost Savings	-$4,103
Simple Payback (yrs.)	NA
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	122.1
Total Utility Cost Reduction (%)	NA%
Total GHG Reduction (%)	3.1%

The scheduled implementation for this measure will be based on equipment lifecycle. The targeted date for doing this is 2027.

1.10.2 Proposed Scope of Work

Proposed scope of work includes removal of the gas fired dehumidifier and installation of the new equipment. New equipment will require electrical wiring from the control panel. Wiring should be enclosed in conduit to provide protection from physical harm and electrical shock. Electrical panels may require upgrades depending on the available power supply from the panel to the electric boiler. It is recommended to integrate the new equipment into the BAS.

1.10.3 Impact on Current Operations and Maintenance

This measure may reduce the operational expense as the existing equipment is old and may require repairs.

1.10.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.11 Installation of Heat Pump RTUs

1.11.1 Existing Conditions and Assumptions

This measure proposes upgrading existing three RTUs for Bordessa Hall with the heat pump RTUs with electric heat.

New RTUs will have higher cooling efficiencies (EER and SEER values) and will be equipped with more efficient electronically commutated (EC) motors and VFDs. This will reduce electricity consumption and demand during cooling season and improve the overall efficiency of operations.

The list of the existing RTUs is provided in the table below.

Table 1-19. List of RTUs

Unit	Air Flow Rate (cfm)	Heating Capacity (MBH)	Cooling Capacity (MBH)	Fan Power (hp)	Cooling Capacity (tons)
HVAC-1	15,000	350	477	15	40
HVAC-2	15,000	350	408	15	40
HVAC-3	4,000	120	113.9	3	10

The cut sheet for the proposed equipment is provided in *Appendix 5 – Cutsheets*. The proposed heat pump RTUs will be equipped with enVerid Sorbent Ventilation technology that reduces the outdoor air requirements.

As per the manufacturer, enVerid SVT is a non-toxic sorbent-based air cleaning technology designed to capture carbon dioxide, ozone, and a wide range of volatile organic compounds (VOCs) including formaldehyde. When applied in combination with the ASHRAE 62.1 Indoor Air Quality Procedure (IAQP), SVT not only safely cleans indoor air but also reduces outside air requirements by as much as 80 percent. As a result, annual HVAC energy costs can be reduced by up to 40%, substantially lowering a building's energy intensity and carbon emissions.

The estimated measure implementation cost, annual energy, and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-20. Installation of Heat Pump RTUs

Project Details	
Project Cost (Class D Estimate)	$679,630
Annual Electricity savings (kWh)	-70,761
Annual Natural Gas savings (m3)	13,674
Annual Cost Savings	-$6.624
Simple Payback (yrs.)	NA
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	21.3
Total Utility Cost Reduction (%)	NA%
Total GHG Reduction (%)	0.5%

The scheduled implementation for this measure will be based on equipment lifecycle. However, structural modifications are required to support added load. The targeted date for planned modifications is 2025. The targeted date for replacement of RTUs is 2026.

1.11.2 Proposed Scope of Work

Proposed scope requires the followings:

- Removal of the old RTUs
- Installation of new heat pump RTUs
- New RTUs to be connected to the existing duct work
- New RTUs to be connected to the roof curb
- All required electrical wiring to be provided to power the new unit
- Power panels to be supplied for the new units
- Integration of new RTUs to the existing BAS
- New RTUs to be commissioned

1.11.3 Impact on Current Operations and Maintenance

This measure may reduce the operational expenses as the existing equipment are at the end of their life span and may require repairs.

1.11.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.12 Monitor and Control Plug Loads Across the Campus (Main Campus)

1.12.1 Existing Conditions and Assumptions

Phantom loads or plug loads can make up to 15 to 20% of the building electricity load. The electrical equipment such as computers, laptops, monitors and smart phones can consume significant amount energy when they’re turned off but still plugged into the grid. One of the ways to identify and reduce the electricity consumption related to plug loads is submetering as it would provide information to analyze the plug load energy consumption with respect to time of use.

Estimated total GHG emission reduction for this measure can be low compared to other measures, however, it would decrease the electricity consumption of the building and operating expenditures. Through implementing energy conservation measures, the facility electricity consumption can be reduced and used as a step towards electrification.

The estimated measure implementation cost, annual energy and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-21. Monitor and Control Plug Loads Across the Campus

Project Details	
Project Cost (Class D Estimate)	$222,313
Annual Electricity savings (kWh)	510,309
Annual Natural Gas savings (m3)	NA
Annual Cost Savings	$22,964
Simple Payback (yrs.)	9.7
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	36
Total Utility Cost Reduction (%)	0.9%
Total GHG Reduction (%)	0.9%

1.12.2 Proposed Scope of Work

Proposed scope of work includes installation of current transducers and integration to the BAS to monitor and control the energy consumption of plug loads. Sub-meters can be installed at the electrical panels that serves the loads connected to the computer labs, offices and other areas. Time of day schedules can be implemented to shut down the plug loads when systems not in use apart from servers that need to be on 24/7.

1.12.3 Impact on Current Operations and Maintenance

The impact on the current operations will be minimal.

1.12.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.13 Install a 3.71 MW Ground Mount Solar PV System (Main Campus)

1.13.1 Existing Conditions and Assumptions

It is recommended to install ground mount solar (PV) panels to generate electricity onsite to reduce the electricity consumption and GHG emissions of the Campus. Onsite energy generation will impact (decrease) peak demand and reduce GA charges accordingly.

Helioscope simulation program was used to model the electricity generation for the ground mount PV panels. The locations for the solar PV panels are marked on the detailed layout from the Helioscope Annual Production Report. The Helioscope models are attached in *Appendix 3 – Helioscope Models*.

As part of the modelling of this measure, the following equipment has been considered:

- Panel type and size: Longi Solar, LR5-72HPH-540M (540W)
- Inverter type: CSI-30KTL-GS-FL

A proposed layout of the ground mount solar PV rooftop locations is shown in the following picture:

Figure 1-14. Proposed Ground Mount Solar Locations

The estimated measure implementation cost, annual energy and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-22. Install a 3.71 MW Ground Mount Solar PV System (Main Campus)

Project Details	
Project Cost (Class D Estimate)	$9,610,713
Annual Electricity savings (kWh)	3,638,157
Annual Natural Gas savings (m3)	NA
Annual Cost Savings	$476,959
Simple Payback (yrs.)	20.1
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	256.9
Total Utility Cost Reduction (%)	18.6%
Total GHG Reduction (%)	6.6%

1.13.2 Proposed Scope of Work

Structural analysis of the selected areas may be required as well as the Connection Impact Assessment (CIA) with local utility company to confirm connection availability will need to be carried during detailed engineering design. Civil engineering work may be required as some of the selected location close to green areas surrounding the campus and they weren't developed previously.

Cutsheets for proposed equipment are shown in *Appendix 5 – Cutsheets*.

1.13.3 Impact on Current Operations and Maintenance

Solar panels require minimal maintenance to ensure that they operate properly and generate energy output. Annual maintenance cost will be confirmed during the design stage. Annual snow removal costs because of the proposed system installation will be determined during design stage, once further details about panels incline, spacing and possible sun tracker installation are developed. The effect of snow soiling is included in the projected solar PV system annual electricity production. Please note that the indicated annual maintenance costs are for the period after extended warranties are expired.

1.13.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters. Additionally, the ground mount solar PV (power generation) system will be sub-metered.

1.14 Integration of Abound Sensor into BAS

1.14.1 Existing Conditions and Assumptions

Ontario Tech University installed 185 indoor air quality Abound sensors amongst all buildings to monitor the indoor air quality including parameters such as temperature, relative humidity, CO2, TVOCs, PM 2.5, Rodon. Abound is a digital platform that provides a single, integrated view of data across building portfolio to inform facility management team about the indoor air quality standards.

The intent of this measure is to integrate existing Abound Sensors and Platform into the BAS to control the operations of the outdoor air dampers based on the feedback from Abound Sensors on the indoor air quality indicators such as humidity, C02 levels, TVOCs and other contaminants.

Implementation of this measure will result in gas and electricity savings, as well as the green house gas reductions. The estimated measure implementation cost, annual energy and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Figure 1-15. Abound Sensors Digital Platform

Table 1-23. Integration of Abound Sensors into the BAS

Project Details	
Project Cost (Class D Estimate)	$195,011
Annual Electricity savings (kWh)	382,731
Annual Natural Gas savings (m3)	18,139
Annual Cost Savings	$23,572
Simple Payback (yrs.)	8.3
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	61.9
Total Utility Cost Reduction (%)	0.9%
Total GHG Reduction (%)	1.6%

1.14.2 Proposed Scope of Work

The proposed scope of work includes programming required for BAS integration. The commissioning of the system integration is recommended to ensure that all systems work accordingly.

1.14.3 Impact on Current Operations and Maintenance

There is no anticipated changes to the current operations and maintenance expenditures apart from the energy and cost savings.

1.14.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

1.15 Install blackPAC Metering System

1.15.1 Existing Conditions and Assumptions

Installation of blackPAC metering system is proposed to monitor the gas consumption for the boiler plants for the UB Building central boiler plant, Campus Ice Centre (CIC) and ACE buildings.

blackPAC can produce consumption, GHG and M&V reports for real time monitoring of any systems and provides real time utility data monitoring and graphics that can be used for presentation and integrated into the existing BAS. It creates Dashboards that can be used for educational purposes about existing systems and GHG emissions.

Screen shots from blackPAC is provided below for information.

Figure 1-16. blackPAC Metering System Dashboards

The estimated measure implementation cost, annual energy and cost savings, GHG reductions, simple payback and other details are tabulated in the table below.

Table 1-24. Install blackPAC Metering System

Project Details	
Project Cost (Class D Estimate)	$139,106
Annual Electricity savings (kWh)	153,093
Annual Natural Gas savings (m3)	16,235
Annual Cost Savings	$12,571
Simple Payback (yrs.)	11.1
Life Cycle of Measure (yrs.)	25
Annual GHG Reductions (tonnes of CO_2e)	42.0
Total Utility Cost Reduction (%)	0.5%
Total GHG Reduction (%)	1.1%

1.15.2 Proposed Scope of Work

The proposed scope of work includes installation of ultrasonic meters, temperature sensors, controllers and programming.

1.15.3 Impact on Current Operations and Maintenance

There is no anticipated changes to the current operations and maintenance expenditures apart from the energy and cost savings.

1.15.4 Proposed Measurement & Verification (M&V) Method

IPMVP Option C: Whole Facility is recommended. Total energy savings resulted from the implementation of all the measures will be quantified by using whole building analysis on the main gas and electricity utility meters.

Appendix 2: GHG Emissions Factors

Year	Emission Factor (gCO_2e/kWh)	Year	Emission Factor (gCO_2e/kWh)
2005	232.9	**2028**	75.4
2006	207.1	**2029**	69.3
2007	230	**2030**	48.1
2008	190.1	**2031**	24.7
2009	112.5	**2032**	20.7
2010	143.5	**2033**	13.9
2011	96.5	**2034**	6.6
2012	97.5	**2035**	0.9
2013	64	**2036**	0.5
2014	35.3	**2037**	0.2
2015	41.6	**2038**	0.2
2016	35.9	**2039**	0.2
2017	16.4	**2040**	0.2
2018	25.6	**2041**	0.2
2019	25	**2042**	0.2
2020	25.8	**2043**	0.2
2021	26.2	**2044**	0.2
2022	70.6	**2045**	0.2
2023	82.8	**2046**	0.2
2024	65.5	**2047**	0.2
2025	87.8	**2048**	0.2
2026	76.7	**2049**	0.2
2027	87.1	**2050**	0.3

Appendix 3: Helioscope Models

Ground Mount Solar Panels Ontario Tech Univeristy, ontariotechu.ca University Of Ontario Institute Of Technology 2000 Simcoe St N, Oshawa ON L1G0C5

Report

Project Name	Ontario Tech Univeristy
Project Address	ontariotechu.ca University Of Ontario Institute Of Technology 2000 Simcoe St N, Oshawa ON L1G0C5
Prepared By	Ian Sinclair isinclair@blackstoneenergy.com

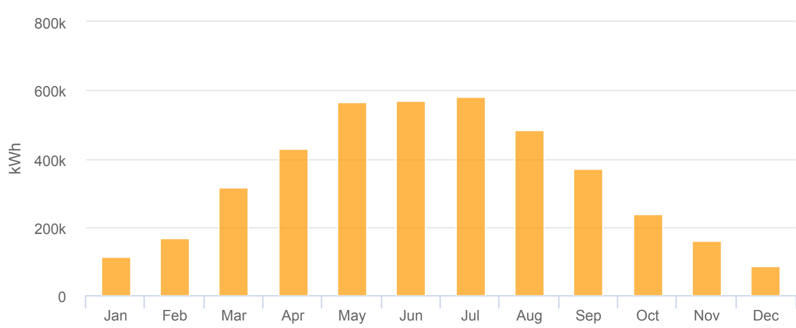
blackstone energy services

System Metrics

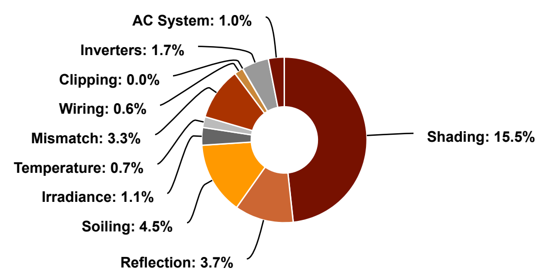
Design	Ground Mount Solar Panels
Module DC Nameplate	3.71 MW
Inverter AC Nameplate	2.97 MW Load Ratio: 1.25
Annual Production	4.085 GWh
Performance Ratio	71.8%
kWh/kWp	1,102.3
Weather Dataset	TMY, 0.04° Grid (43.93,-78.9), NREL (psm3)
Simulator Version	4961bffae4-37759b62a3-bf9d38e791-ad379a4e98

Project Location

Monthly Production



Sources of System Loss



HelioScope

blackstone energy services

Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,426.2	
	POA Irradiance	1,535.8	7.7%
	Shaded Irradiance	1,297.7	-15.5%
	Irradiance after Reflection	1,249.7	-3.7%
	Irradiance after Soiling	1,192.8	-4.5%
	Total Collector Irradiance	**1,192.8**	**0.0%**
Energy (kWh)	Nameplate	4,444,469.5	
	Output at Irradiance Levels	4,395,027.6	-1.1%
	Output at Cell Temperature Derate	4,365,346.4	-0.7%
	Output After Mismatch	4,221,199.3	-3.3%
	Optimal DC Output	4,197,660.4	-0.6%
	Constrained DC Output	4,197,127.6	0.0%
	Inverter Output	4,125,768.0	-1.7%
	Energy to Grid	**4,084,510.5**	**-1.0%**
Temperature Metrics			
	Avg. Operating Ambient Temp		10.9 °C
	Avg. Operating Cell Temp		17.8 °C
Simulation Metrics			
		Operating Hours	4315
		Solved Hours	4315

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, 0.04° Grid (43.93,-78.9), NREL (psm3)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C
East-West	-3.56	-0.075	3°C
Carport	-3.56	-0.075	3°C

Soiling (%)

J	F	M	A	M	J	J	A	S	O	N	D
25	25	15	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5	25

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	0% to 1.03%
AC System Derate	1.00%

Module Characterizations

Module	Uploaded By	Characterization
LR5-72HPH-540M (Longi Solar)	HelioScope	Spec Sheet Characterization, PAN

Component Characterizations

Device	Uploaded By	Characterization
CSI-30KTL-GS-FL (Canadian Solar)	HelioScope	Spec Sheet

Components

Component	Name	Count
Inverters	CSI-30KTL-GS-FL (Canadian Solar)	99 (2.97 MW)
Strings	10 AWG (Copper)	495 (41,997.1 m)
Module	Longi Solar, LR5-72HPH-540M (540W)	6,862 (3.71 MW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	11-17	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 4 (copy 5)	Fixed Tilt	Landscape (Horizontal)	Module: 10°	Module: 163.5°	0.0 m	1x1	6,862	6,862	3.71 MW

Detailed Layout

Ground Mount Solar Panels Ontario Tech Univeristy, ontariotechu.ca University Of Ontario Institute Of Technology 2000 Simcoe St N, Oshawa ON L1G0C5

Report

Project Name	Ontario Tech Univeristy
Project Address	ontariotechu.ca University Of Ontario Institute Of Technology 2000 Simcoe St N, Oshawa ON L1G0C5
Prepared By	Ian Sinclair isinclair@blackstoneenergy.com

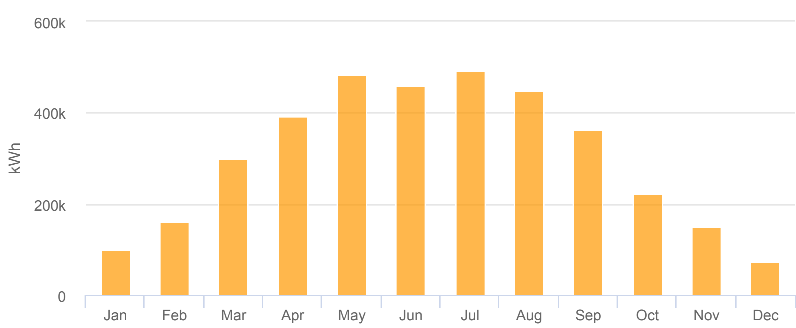
blackstone energy services

System Metrics

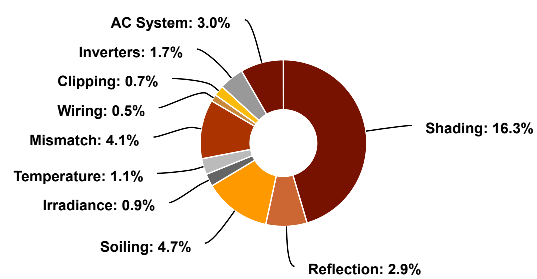
Design	Ground Mount Solar Panels
Module DC Nameplate	3.19 MW
Inverter AC Nameplate	2.59 MW Load Ratio: 1.23
Annual Production	3.638 GWh
Performance Ratio	69.0%
kWh/kWp	1,141.9
Weather Dataset	TMY, 0.04° Grid (43.93,-78.9), NREL (psm3)
Simulator Version	8088d0a5b8-5488d6ea9a-91df99285c-045e20fc21

Project Location

Monthly Production



Sources of System Loss



Annual Production

	Description	Output	% Delta
Irradiance (kWh/m²)	Annual Global Horizontal Irradiance	1,426.2	
	POA Irradiance	1,655.3	16.1%
	Shaded Irradiance	1,385.7	-16.3%
	Irradiance after Reflection	1,346.0	-2.9%
	Irradiance after Soiling	1,283.3	-4.7%
	Total Collector Irradiance	**1,283.3**	**0.0%**
Energy (kWh)	Nameplate	4,110,135.8	
	Output at Irradiance Levels	4,073,964.6	-0.9%
	Output at Cell Temperature Derate	4,028,545.9	-1.1%
	Output After Mismatch	3,862,668.5	-4.1%
	Optimal DC Output	3,844,278.3	-0.5%
	Constrained DC Output	3,816,030.3	-0.7%
	Inverter Output	3,750,677.8	-1.7%
	Energy to Grid	**3,638,157.3**	**-3.0%**
Temperature Metrics			
	Avg. Operating Ambient Temp	10.9 °C	
	Avg. Operating Cell Temp	18.4 °C	
Simulation Metrics			
	Operating Hours		4315
	Solved Hours		4315

Condition Set

Description	Condition Set 1
Weather Dataset	TMY, 0.04° Grid (43.93,-78.9), NREL (psm3)
Solar Angle Location	Meteo Lat/Lng
Transposition Model	Perez Model
Temperature Model	Sandia Model

Temperature Model Parameters

Rack Type	a	b	Temperature Delta
Fixed Tilt	-3.56	-0.075	3°C
Flush Mount	-2.81	-0.0455	0°C
East-West	-3.56	-0.075	3°C
Carport	-3.56	-0.075	3°C

Soiling (%)

J	F	M	A	M	J	J	A	S	O	N	D
25	25	15	0.5	0.5	0.5	0.5	0.5	0.5	0.5	5	25

Irradiation Variance	5%
Cell Temperature Spread	4° C
Module Binning Range	0% to 1.03%
AC System Derate	3.00%

Module Characterizations

Module	Uploaded By	Characterization
LR7-72HGD-600M (Longi)	HelioScope	Spec Sheet Characterization, PAN

Component Characterizations

Device	Uploaded By	Characterization
CSI-185K-T600GL03-U (Canadian Solar)	HelioScope	Spec Sheet

Components

Component	Name	Count
Inverters	CSI-185K-T600GL03-U (Canadian Solar)	14 (2.59 MW)
Strings	10 AWG (Copper)	220 (20,955.0 m)
Module	Longi, LR7-72HGD-600M (600W)	5,310 (3.19 MW)

Wiring Zones

Description	Combiner Poles	String Size	Stringing Strategy
Wiring Zone	-	12-26	Along Racking

Field Segments

Description	Racking	Orientation	Tilt	Azimuth	Intrarow Spacing	Frame Size	Frames	Modules	Power
Field Segment 4 (copy 5)	Fixed Tilt	Landscape (Horizontal)	Module: 35°	Module: 163.5°	0.5 m	1x1	5,310	5,310	3.19 MW

Detailed Layout

Appendix 4: Lighting Fixtures

Provided as a separate document

Appendix 5: Cut Sheets

Provided as a separate document