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The Regional Municipality of Durham Report

From:	Commissioner of Works
Report:	#2024-INFO-34
Date:	May 17, 2024

Subject:

Water and Wastewater Greenhouse Gas Emissions Management Strategy Overview

Recommendation:

Receive for information.

Report:

1. Purpose

1.1 This report provides an overview of the Water and Wastewater Greenhouse Gas Emissions Management Strategy, completed in March 2024.

2. Background

2.1 The Regional Municipality of Durham (Region) has shown a strong commitment by declaring a climate emergency in January 2020[1], and directing staff to work towards establishing the Region as a corporate leader in the communitywide transition to net zero greenhouse gas (GHG) emissions by 2050.

1 Minutes of Durham Regional Council Meeting, 29 January 2020.

2.2 In March 2021, this commitment was further solidified by Durham Regional Councils approval of the adoption of a Corporate Climate Action Plan (CCAP) 2021-A-3[2], which set the following GHG reduction goals for the Region's corporate operations:

- 20 percent below 2019 levels by 2025
- 40 percent below 2019 levels by 2030
- 100 percent below 2019 levels by 2045

2.3 The CCAP recognized that the reported emissions associated with water and wastewater operations are subject to a higher degree of uncertainty than those solely from the consumption of energy, and further efforts were necessary to develop a comprehensive road map for GHG emissions management for the Region's water and wastewater systems.

2.4 The Region initiated the Water and Wastewater (W&WW) Greenhouse Gas (GHG) Emissions Management Strategy project in September 2022 to develop a long-term GHG Management Strategy for all Regional W&WW facilities over the next 20 years. This project was completed in March 2024, and the summary document for the strategy is included with this report (Attachment #1). The key elements of the project are as follows:

a. Developing a framework for quantifying and reporting GHG emissions from the Region's W&WW facilities, building upon the best practices of comparable utilities.

b. Establishing the baseline GHG emissions for tracking progress, including a comprehensive analysis of the significant process-related fugitive emissions resulting from wastewater treatment.

c. Establishing GHG reduction targets specific to the W&WW sector and identifying the limitations and gaps in meeting the CCAP reduction targets.

d. Identifying the appropriate key performance indicators for each system, as applicable.

e. Identifying the priority focus areas within existing operations and facilities to achieve the short-, medium-, and long-term GHG reduction targets.

2 Minutes of Durham Regional Council Meeting, 24 March 2021.

f. Developing an action plan for GHG reduction and mitigation for the Region's W&WW facilities.

g. Identifying areas for future improvement and road map to achieve the 2045 net-zero target.

3. Relationship to Strategic Plan

3.1 This report aligns with the following strategic goals and priorities in the Durham Region Strategic Plan:

a. Environmental Sustainability 1.1: accelerate the adoption of green technologies and clean energy solutions through strategic partnerships and investment.

b. Environmental Sustainability 1.4: demonstrate leadership in sustainability and addressing climate change.

4. Conclusion

4.1 The Water and Wastewater Greenhouse Gas Emissions Management Strategy is the first project of its kind in Ontario to establish Greenhouse Gas reduction targets specific to the water and wastewater sector, considering the 'possibility' and 'reality' of Greenhouse Gas mitigation in Ontario.

4.2 The project established a transparent framework that clearly defines the scope of Greenhouse Gas emissions included in the inventory, the methodologies used to quantify these emissions, the associated limitations and opportunities for improvement, and changes from the previous methodologies – allowing the Regional Municipality of Durham to re-baseline the Greenhouse Gas emissions to include additional emission sources and refine the reduction targets as the quantification methodologies continue to evolve and improve.

4.3 A road map was developed for the Regional Municipality of Durham's Water and Wastewater systems to 2045, consistent with the Corporate Climate Action Plan, including an action plan with key Greenhouse Gas mitigation opportunities in the short- (2025), medium- (2030), and long-term (2045). Meaningful Greenhouse Gas reduction commitments were established based on comprehensive assessments of net-zero solutions that considered the technical feasibility and operational and financial impacts to the Regional Municipality of Durham.

4.4 The strategy acknowledges significant gaps in achieving cost-effective net-zero emissions based on technologies available today and that an ambitious implementation plan is necessary to expedite some projects and to adopt other innovative net-zero solutions as they become more established. The Region is committed to continuing efforts in Greenhouse Gas mitigation through collaboration with academic researchers, consultants, and technology vendors, with a goal to adapt to future changes and technology developments to progress towards its net-zero commitment in the long term.

4.5 Many of the recommended Greenhouse Gas mitigation opportunities also offer co-benefits with respect to process performance, stability, resiliency, or capacity. Recognizing the synergies, the recommendations from this study will inform the development of the upcoming biosolids master plan study, and other future planning and design projects as appropriate.

4.6 The plan for the Water and Wastewater Greenhouse Gas Emissions Strategy is to update the study every five years to reflect the latest developments in quantification methods and refine the Greenhouse Gas reduction targets based on Regional Municipality of Durham's mitigation progress and available decarbonization technologies.

4.7 For additional information, contact: Joe Green, Manager, Infrastructure Analytics, at 289-928-4578.

5. Attachments

Attachment #1: Durham Water and Wastewater Greenhouse Gas Emissions Management Strategy Consolidated Report (April 2024)

Respectfully submitted,

Original signed by:

Ramesh Jagannathan, MBA, M.Eng., P.Eng., PTOE
Commissioner of Works

Water and Wastewater Greenhouse Gas Emissions Management Strategy

Regional Municipality of Durham

May 2024

Version 3

DURHAM REGION

Jacobs

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Courtice WPCP

1. Introduction

1.1 Durham Region Corporate Climate Action Plan

The Regional Municipality of Durham (Region) declared a climate emergency in January 2020, and directed staff to work towards establishing the Region as a corporate leader in the community-wide transition to net zero greenhouse gas (GHG) emissions by 2050. In March 2021, the Durham Regional Council approved the adoption of a Corporate Climate Action Plan (CCAP), which set the following GHG reduction goals for the Region's corporate operations (Durham Region, 2021):

- 20 percent below 2019 levels by 2025
- 40 percent below 2019 levels by 2030
- 100 percent below 2019 levels by 2045

The CCAP recognized that the reported emissions associated with water and wastewater operations are subject to a higher degree of uncertainty than those solely from the consumption of energy, and further efforts are necessary to develop a more comprehensive road map for GHG emissions management for the Region's water and wastewater (W&WW) systems.

Newtonville Standpipe

Sources of Region's GHG Inventory for Corporate Operations

- Durham York Energy Centre
- Region-owned Closed Landfills
- Vehicle Fleets
- Water Supply and Sanitary Sewerage
- Facilities and Traffic Signals

Nonquon WPCP

1.2 Water and Wastewater Greenhouse Gas Emissions Management Strategy

The Region initiated the *Water and Wastewater Greenhouse Gas Emissions Management Strategy* project in September 2022 to develop a long-term GHG Management Strategy for all Regional W&WW facilities over the next 20 years. Key elements of the project include the following:

- Developing a framework for quantifying and reporting GHG emissions from the Region's W&WW facilities, building upon the best practices of comparable utilities.
- Establishing the baseline GHG emissions for tracking progress.
- Establishing GHG reduction targets specific to the W&WW sector, and identify the limitations and gaps in meeting CCAP reduction targets.
- Identifying the appropriate key performance indicators for each system, as applicable.
- Identifying the priority areas of focus within existing operations and facilities to achieve the short-, medium-, and long-term GHG reduction targets.
- Developing an action plan for GHG reduction and mitigation for the Region's W&WW facilities.
- Identifying areas for future improvement and road map to achieve the 2045 net-zero target.

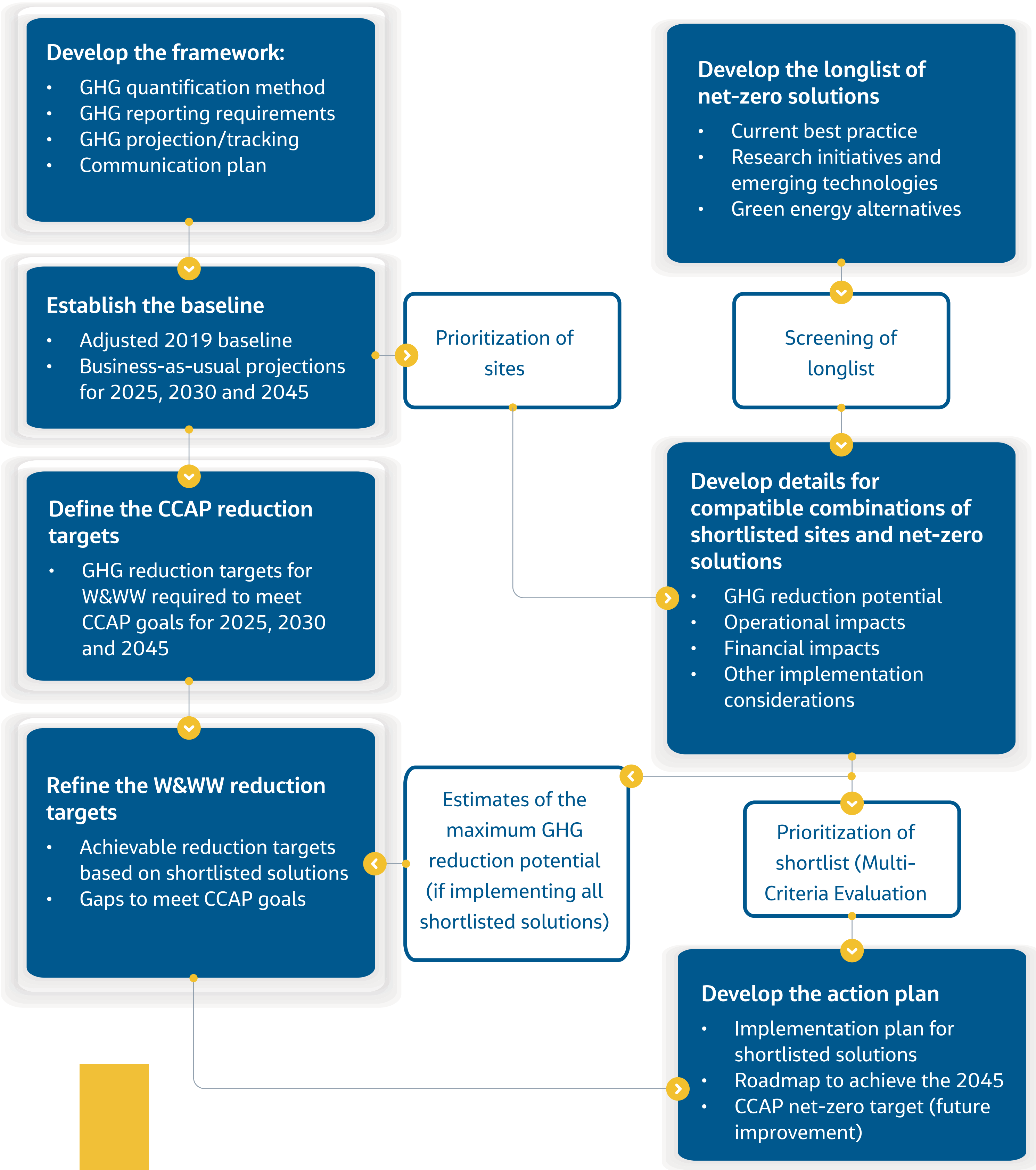


Figure 1. Overall Approach for Developing the Water and Wastewater GHG Emissions Management Strategy

2. Durham Region's Water and Wastewater Systems*

The Region operates and maintains its water and wastewater infrastructure, supplying safe drinking water to customers across the Region, and overseeing the collection and treatment of municipal wastewater to protect the environment and human health.

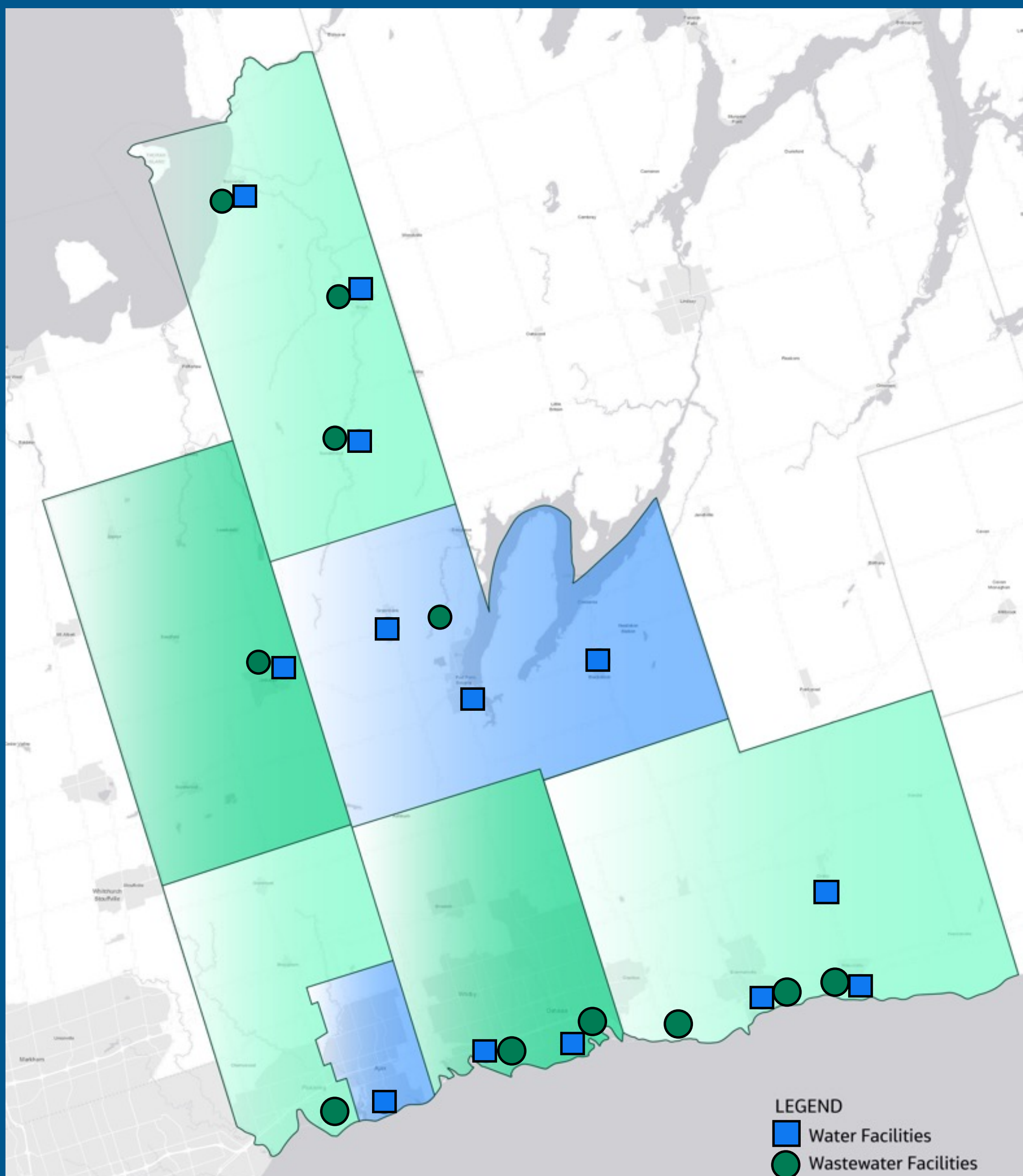


Figure 2. Water and Wastewater Treatment Facilities in Durham Region
(excluding pumping and/or storage facilities)

*All of the stated information (number and capacity of facilities/systems) herein represents the current status as of the time of this report (2024).

2.1 Water Treatment and Distribution

The Region owns and operates 14 drinking water systems across its eight area municipalities, including 6 surface water supply plants (WSPs) and 8 groundwater well systems with a total treatment capacity of 500 million litres per day (ML/d).

- The WSPs in Ajax, Whitby, Oshawa, Bowmanville and Newcastle take water from two surface water sources – Lake Ontario and Lake Simcoe; about 95 percent of the Region's drinking water comes from Lake Ontario. The lake water has gone through a series of physical and chemical treatment processes to remove any biological, organic, or inorganic matter, generally including screening, coagulation and flocculation, filtration, disinfection, and fluoridation.
- The groundwater well systems employ simpler treatment processes, including small amount of chemical addition to control minerals (such as iron) and to maintain disinfection residual in the distribution system.
- The treated water is tested daily to make sure it meets all regulatory requirements before going out to the customers.

The drinking water is supplied to residents, institutions and businesses in Durham Region through a complicated distribution system consisting of 10 water pumping stations, 13 water storage facilities, 8 combined water pumping/storage facilities, and 2,615 kilometres (km) of water mains.

Bowmanville Elevated Tank

2.2 Wastewater Collection and Treatment

The wastewater collection system collects and moves wastewater from homes, businesses, and institutions to the downstream water pollution control plants (WPCPs) for treatment. The Region owns and operates 11 WPCPs with a total treatment capacity of 865 ML/d, 51 sanitary pumping stations, and more than 2,000 km of sewers to service residents and businesses of both Durham Region and York Region (the latter served by the York-Durham Sewage System [YDSS]).

- The 6 largest WPCPs treat more than 90 percent of the Region's wastewater, including Duffin Creek, Corbett Creek, Courtice, Harmony Creek, Port Darlington, and Newcastle. Common treatment processes include screening, grit removal, conventional primary treatment and activated sludge secondary treatment, phosphorus removal via chemical addition (iron or alum salts), and disinfection.
- The remaining wastewater is treated in 5 smaller facilities, including 3 extended aeration plants with tertiary treatment (Lake Simcoe, Nonquon, and Uxbridge Brook) and 2 lagoon treatment facilities (Cannington and Sunderland).
- The solids removed during wastewater treatment are further processed to generate biosolids, a nutrient-rich organic matter. The biosolids are either incinerated at the Duffin Creek WPCP (with the residual ash being recycled in a cement manufacturing process) or applied to farms. The majority of the Region's solids are treated using anaerobic digestion, a process that also generates biogas, which is a renewable energy source typically used in boilers to provide process and building heating onsite, with excess biogas flared.
- The treated wastewater is monitored and tested daily to ensure it meets all regulatory requirements before releasing into the environment.

Courtice WPCP

2.2.1 Duffin Creek Water Pollution and Control Plant

The Duffin Creek WPCP, located in Pickering on the shores of Lake Ontario, is one of the largest wastewater treatment facilities in Canada. It has a total treatment capacity of 630 ML/d, and serves communities from Durham Region and York Region. The Duffin Creek WPCP provides centralized management of the Region's biosolids through dewatering and incineration, including solids generated onsite, and anaerobically or aerobically digested biosolids from Durham Region's other WPCPs.


Duffin Creek WPCP

In this study, GHG emissions associated with Duffin Creek WPCP only represent the net Durham share (that is, 20 percent of the total emissions at Duffin Creek WPCP based on historical split of flows and loads between Durham and York Regions).

3. Water and Wastewater GHG Reduction Objectives

3.1 Sources of GHG Emissions

GHG emissions can be quantified and reported by scope. The most commonly accepted definitions were introduced by the GHG Protocol to categorize emissions by ownership levels, including direct (Scope 1) and indirect (Scopes 2 and 3) emissions (Greenhouse Gas Protocol, 2013). Traditionally, emission reduction efforts have been largely focused on sources associated with energy consumption, such as the consumption of fossil fuels (Scope 1) and purchased electricity (Scope 2). However, the wastewater sector faces a unique challenge due to the Scope 1 process emissions generated during the treatment of wastewater and biosolids (Figure 3), such as fugitive methane (CH_4) and nitrous oxide (N_2O) emissions, biosolids incineration, and biogas flaring. In addition, there are Scope 3 emissions applicable to the water and wastewater sector, such as chemicals, biosolids management offsite (e.g., haulage, land application), and "embodied" carbon in existing and new infrastructure, among others.

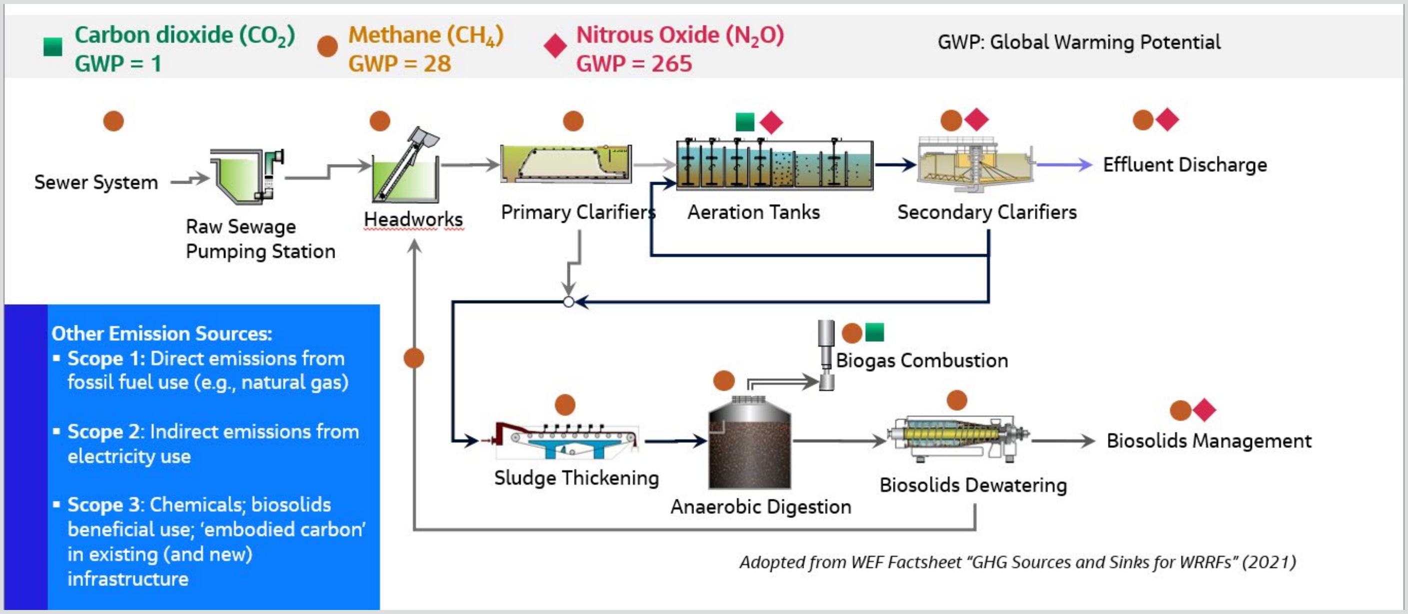


Figure 3. GHG Sources from Typical Water Resource Recovery Facilities

3.2 Considerations for GHG Inventory and Objective Setting

Recognizing that it is not practical to include all applicable Scope 1, 2, and 3 emissions, development of the GHG inventory considered the industry best practice, applicable local and federal GHG reporting requirements, the availability and accuracy of quantification methodologies for each source, the level of complexity and difficulty in quantifying these emissions, and whether mitigation measures are available (such that the contribution to GHG reduction goals can be reasonably quantified). Table 1 summarizes the Scope 1, 2, and 3 emissions recommended to be included in the Region's inventory, generally consistent with the current best practice established in the 2019 Intergovernmental Panel on Climate Change (IPCC) Refinement to the 2006 IPCC Guidelines *(IPCC, 2019).*

Table 1. GHG Emission Sources Included in Inventory and for Objective Setting

Scope	Emission Source	Applicability	Included for Objective Setting
Scope 1	N_2O from wastewater treatment	WW	Yes
Scope 1	N_2O from wastewater effluent	WW	Yes
Scope 1	CH_4 from wastewater treatment	WW	Yes
Scope 1	CH_4 from wastewater effluent	WW	Yes
Scope 1	CH_4 from sludge treatment	WW	Yes
Scope 1	Fossil fuel combustion	W&WW	Yes
Scope 1	Biogas combustion (boilers)	WW	Yes
Scope 1	Biogas flaring	WW	Yes
Scope 1	Biomass incineration	WW	Yes
Scope 2	Electricity consumption	W&WW	Yes
Scope 3	Chemicals	W&WW	No
Scope 3	Offsite biosolids and residuals (ash) management	WW	No

The recommended inventory captures significant emission sources from the Region's W&WW facilities. However, setting GHG reduction objectives for all emissions sources is currently not practical, given the difficulty and uncertainty associated with the quantification methods.

Therefore, only Scope 1&2 emissions from the inventory are considered for GHG reduction objectives in this project (consistent with the CCAP). It is recommended that Scope 3 emissions should be quantified and tracked to assist decision making, and target setting can be considered in the future as improved methodologies and data sources become available.

3.3 GHG Reduction Objectives

Figure 4 presents the projected GHG reduction progress for the Region's water and wastewater operations (Scope 1&2 only) relative to the business-as-usual projection and the CCAP targets. The **achievable reduction potential** was established based on detailed analyses of GHG mitigation opportunities with information available to reasonably quantify the GHG reduction potential and estimate the operational and financial impacts to the Region (details in Section 6).

The Region can achieve substantial GHG reduction by adopting current best practices and well-established net-zero solutions (about 66% reduction by 2045 compared with business-as-usual, or 40% reduction from the 2019 baseline). However, achieving net-zero in a cost-effective manner is still challenging based on the net-zero solutions currently available in the market. To move towards the CCAP targets, the Region will need to be proactive in expediting some projects and adopting other innovative net-zero solutions as they become more established in the long term (examples in Section 7).

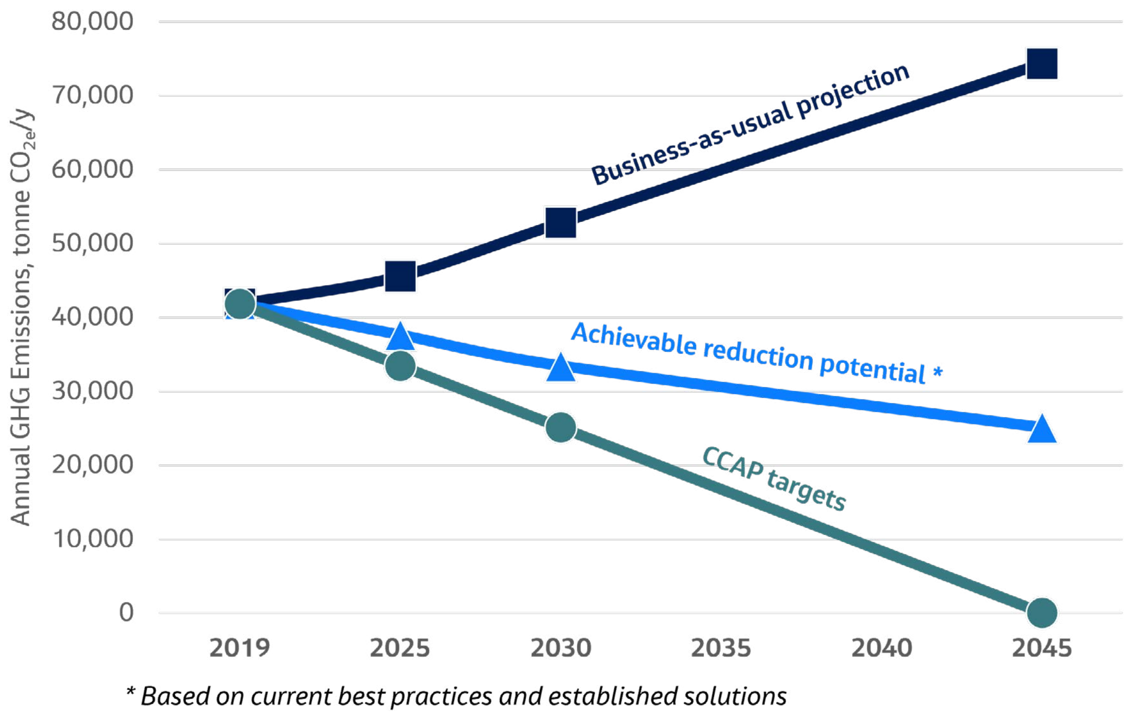


Figure 4. Projected Reduction Progress for Durham Region's Water and Wastewater GHG Emissions (Scope 1&2)

4. GHG Emissions for Durham Region's Water and Wastewater Systems

4.1 Re-baselining 2019 GHG Emissions

The original 2019 baseline reported in the CCAP is subject to change with improvements in data collected and updates to the quantification methodologies. The inventory used in the CCAP includes emissions associated with energy consumption and limited process emissions. A more comprehensive GHG inventory was established for this project, which resulted in an approximately 50 percent increase in the 2019 baseline emission (Scope 1&2 only) compared with the CCAP baseline, as compared in Figure 5. Specifically, the CCAP inventory was expanded to include additional Scope 1 process emissions (CH_4 and N_2O) consistent with the 2019 IPCC Refinement, along with some improvements on the quantification methodologies.

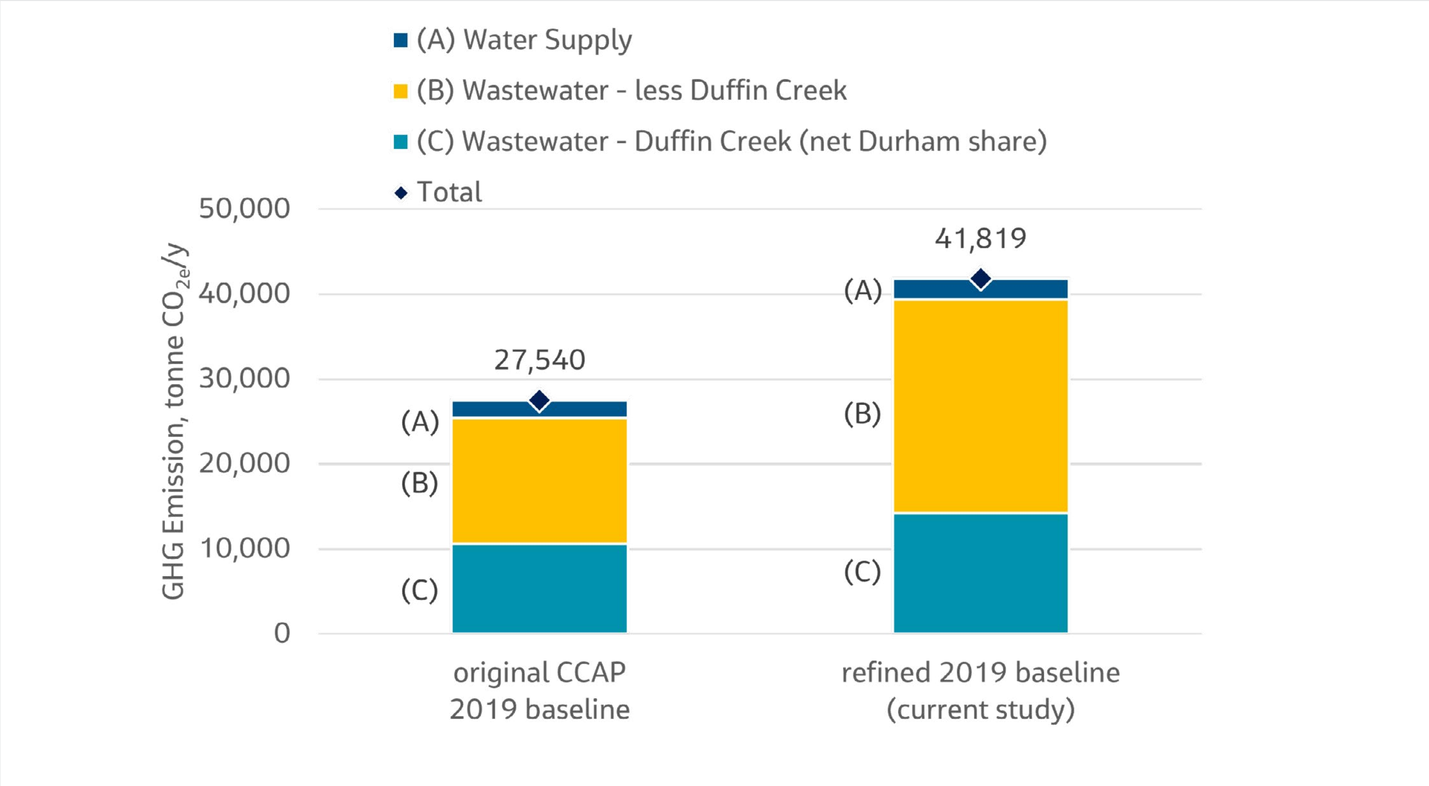


Figure 5. Re-baseline of 2019 Scope 1&2 GHG Emissions (CCAP Base Year)

4.2 2019 Baseline Inventory (Scope 1, 2 & 3)

Although only Scope 1&2 emissions are included in target setting, Scope 3 emissions from the inventory were quantified for the 2019 base year, as summarized in Figure 6. The water systems only accounted for 8 percent of the total emissions, with approximately equal contributions from Scope 1, 2, and 3. The wastewater systems accounted for 92 percent of the total emissions, where Scope 1 process emissions contributed to more than three-quarters of the wastewater emissions.

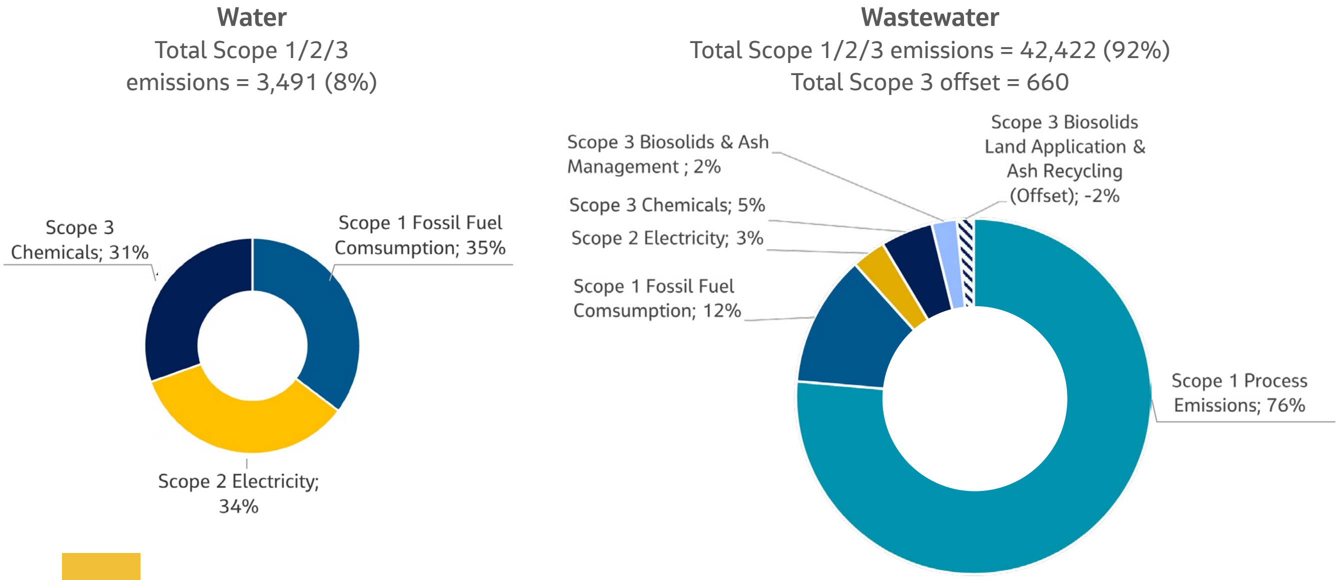


Figure 6. 2019 Baseline GHG Emissions by Scope: Water and Wastewater

4.3 Scope 1&2 Business-as-Usual GHG Emission Projections

The business-as-usual projections were developed for Scope 1&2 operations GHG emissions in 2025, 2030, and 2045, as summarized in Table 2; the projections included ongoing and planned capital works that could affect future GHG emissions. The Scope 1 N_2O emission from wastewater treatment represents the single largest GHG source from Region's water and wastewater operations.

Table 2. Business-as-usual GHG Projections for Region's Water and Wastewater Operations

Emission Source	2019 (base year)	2025	2030	2045
Scope 1: N_2O – wastewater treatment	21,289	24,377	27,592	37,286
Scope 1: N_2O – wastewater effluent	3,294	3,863	4,361	5,864
Scope 1: CH_4 – wastewater treatment	3,402	2,995	3,289	4,289
Scope 1: CH_4 – wastewater effluent	285	284	322	435
Scope 1: CH_4 – sludge treatment	989	1,193	1,451	1,801
Scope 1: Biosolids incineration	3,360	3,038	3,242	4,737
Scope 1: Biogas combustion and flaring	280	313	343	440
Scope 1: Fossil fuel – wastewater	5,164	4,250	4,250	4,250
Scope 1: Fossil fuel – water	1,232	921	921	921
Scope 2: Electricity – wastewater	1,328	2,295	3,731	7,630
Scope 2: Electricity – water	1,197	2,034	3,297	6,707
Total Scope 1&2 Emissions, tonne CO_{2e}/y	**41,819**	**45,563**	**52,801**	**74,360**

5. Challenges and Opportunities of Decarbonization in Water and Wastewater

The primary mandate for the Region's water and wastewater facilities is to meet service and performance objectives to serve the growing populations while complying with regulatory requirements for water quality, wastewater effluent and air quality, as well as health and safety. Every day, the Region delivers more than 200 million litres of safe drinking water to customers across Durham Region and treats more than 450 million litres of wastewater from residents and businesses across Durham and York Regions. Moving and treating water and wastewater will require energy and resources, leading to GHG emissions each year.

As one of the fastest-growing regions in the world, Durham Region's population is projected to double over the coming decades, leading to increased demand for services and supporting infrastructure, and associated GHG emissions. To respond to the Region's emissions reduction targets, a paradigm shift in management focus is required through operating efficiency and low-carbon–aligned investment across the organization. Table 3 presents examples of current best practices for GHG management and their applicability to Region's water and wastewater sectors.

Table 3. Examples of Current Best Practices for GHG Management and Applicability

Best Practice	Strategies	Applicability
Reduce Scope 2 emission from electricity consumption	• Energy optimization • Demand management	Water and wastewater
Reduce Scope 1 emission from fossil fuel consumption	• Process optimization • Alternative fuels	Water and wastewater
Mitigate Scope 1 process emissions	• Monitor and mitigate CH_4 and N_2O emissions	Wastewater
Maximize energy and resource recovery	• Biogas energy recovery • Biosolids beneficial use • Waste heat recovery • Sewer thermal recovery	Wastewater
Life-cycle carbon management	• Embodied carbon calculation for capital projects • Materials management • Chemical use optimization	Water and wastewater
Leverage synergies with energy sector transition	• Renewable energy generation • Energy storage • Green hydrogen economy	Water and wastewater
Improve water efficiency	• Water conservation • Leakage reductions	Water

Traditionally, emission reduction efforts have largely focused on sources associated with energy consumption, such as electricity and natural gas. The Region has been continuously implementing a multitude of measures to improve energy efficiencies for corporate operations over the years, as established in its Energy Conservation and Demand Management Plan (Durham Region, 2019). However, indirect emissions from electricity currently only account for less than 10 percent of the total GHG footprint for the Region's W&WW sector, thanks to the low-emission intensity of Ontario's power grid, while fugitive process emissions (N_2O and CH_4) are expected to account for the majority of GHG emissions for wastewater utilities in Ontario.

Reducing energy consumption would have a measurable financial impact on reducing operating cost but less impact on the GHG reduction goals, whereas reducing process fugitive emissions would have a more substantial impact on achieving the net-zero target but currently does not have a measurable financial impact. When developing the GHG management plan, the systems involved in the W&WW facilities should not be looked at in isolation, and the potential trade-offs between energy efficiency and process emission reductions need to be considered carefully.

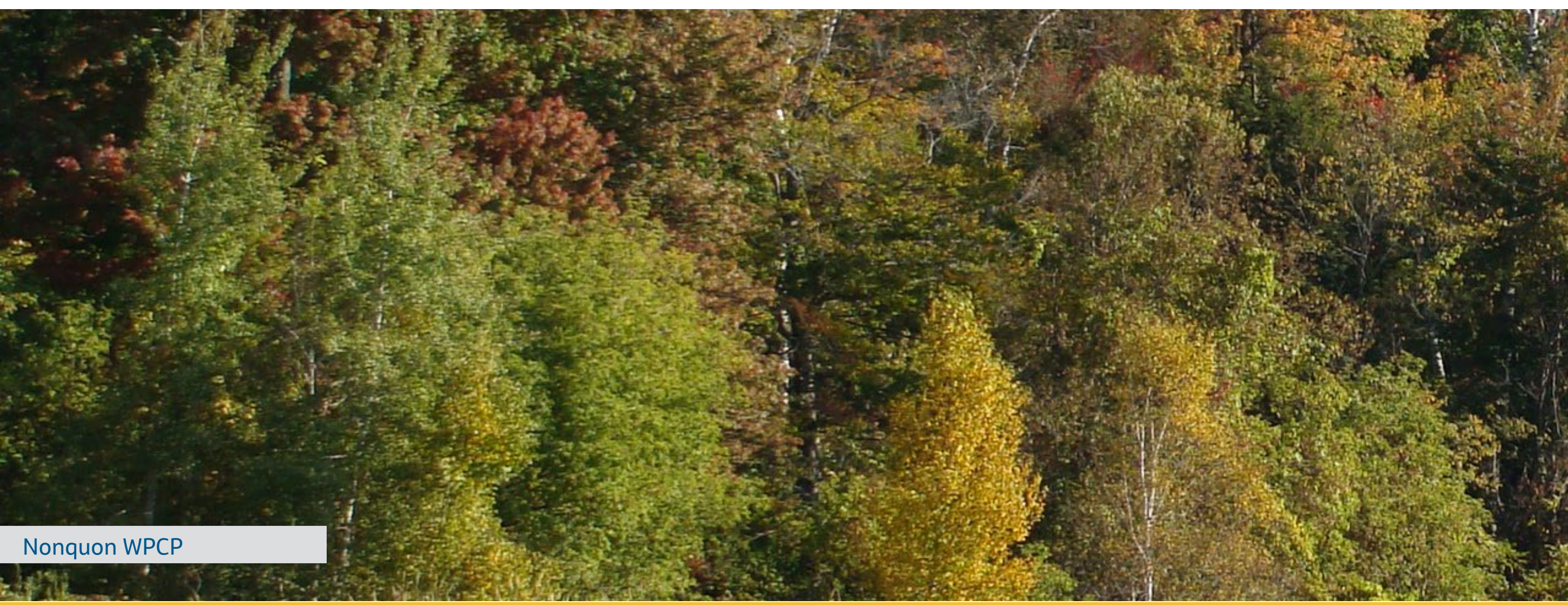
Tackling process emissions is critical for the wastewater sector to achieve its net-zero target. Quantifying these process emissions from the treatment of wastewater, sludge, and biosolids is not as straightforward as GHG emissions from energy consumption, because these biological processes are highly complex, and emissions depend on environmental and operational conditions, as well as the wastewater characteristics. The current methodology applies emission factors to estimate the potential for generating N_2O and CH_4 emissions based on influent contaminant loads. These generic emission factors were recommended by IPCC based on best available science to represent a global average; however, they do not depict the variability of emission patterns against time, location, process configurations, and operating conditions.

Nonquon WPCP

Facility-level monitoring remains the only effective strategy to accurately quantify and understand process emissions and their variations and triggers, and to allow for mitigation interventions to be designed, implemented, and quantified. This remains an emerging area with research and field work underway globally.

Facility-level monitoring remains the only effective strategy to accurately quantify and understand process emissions and their variations and triggers, and to allow for mitigation interventions to be designed, implemented, and quantified. This remains an emerging area with research and field work underway globally.

However, there are “win-win” opportunities. Many of the decarbonization solutions offer co-benefits, such as improved energy efficiency (and associated cost saving), enhanced process performance, stability and/or resiliency (e.g., reduced process upsets or equipment downtime, leading to reduced maintenance cost), or process intensification (e.g., deferring capital spending for major capacity expansion). These opportunities can be incorporated into the capital planning and delivery process (that traditionally prioritizes capacity, performance, and infrastructure renewal) to identify potential synergies while leveraging other Regional initiatives. For example, the new *Durham Standard* (version 1.0, 2023) will facilitate the implementation of low-carbon technologies by including energy and carbon performance requirements for new construction and major retrofits of existing facilities. As the Region continues to develop guidelines and standards for sustainable infrastructure, there will be more opportunities to promote decarbonization solutions within the organization.



Nonquon WPCP

Table 4. Key Challenges and Opportunities for GHG Management at Durham Region's Water and Wastewater Systems

Challenges	Opportunities
Expanding service area and growth (Durham and York) – lead to increased demand for service and supporting infrastructure, and associated GHG emissions	• Shift management focus through operating efficiency and low-carbon–aligned investment • Use per capita-based metrics to track and communicate the GHG reduction progress
Capital planning and competing priorities – prioritizing major capital works over projects solely for GHG reduction	• Leverage 'co-benefits' of decarbonization solutions • Incorporate GHG management into annual business planning and budget process
Aging infrastructure – leads to reduced energy efficiency and/ or increased process emissions	• Proactively maintain and upgrade aging system components to improve energy efficiencies and reduce fugitive leaks
Regulatory limitations – more stringent regulatory standards related to water quality, effluent and air quality, and health and safety may result in the need for more energy- or carbon-intensive operations	• Implement low-carbon technologies for new constructions or retrofits that can meet regulatory requirements • Document regulatory context to justify the associated increase in GHG emissions
Operations and maintenance – existing practices may not be compatible with GHG reduction goals; limited staff resources to accommodate new technologies	• Include operations and maintenance staff in developing GHG management strategies and implementation plan • Leverage innovative digital solutions to address operational challenges caused by poor equipment efficiency, lack of instrumentation, controls, and automation, or improving control for optimized operations
Market volatility – rapid changes in Ontario's energy and carbon market make it challenging to assess the long-term impacts of GHG reduction projects	• Monitor changes in policies and regulations to take advantage of the associated incentives and funding opportunities

Challenges	Opportunities
Low-emission power grid in Ontario – need to shift focus to tackle process emissions and onsite fossil fuel combustion	• Implement facility-level monitoring and mitigation campaigns at wastewater facilities to reduce process emissions (N_2O and CH_4) • Explore alternative low-carbon fuel sources (e.g., offsetting natural gas use through biogas upgrade to renewable natural gas or sewer thermal recovery) • Consider the trade-offs between energy efficiency (measurable financial impact from energy saving) and process emissions reduction (substantial impact on achieving net-zero target) in developing GHG management strategies for wastewater
Uncertainties associated with quantification methodologies – methods for process emissions subject to high uncertainties and do not offer opportunities to reduce reportable emissions; changes/improvements in methodologies resulting in inconsistencies with the base year emission	• Implement continuous monitoring to develop facility-level emission factors and mitigation strategies for process emissions – improving the accuracy of quantification and allowing for measurement of mitigation results • Document changes/improvements in methodologies, and apply the recommended adjustments/improvements to historical inventory to re-baseline GHG emissions and refine reduction targets
Lack of explicit policies for GHG reduction or offset credits – ambiguities around the allocation of environmental attributes for sewer thermal recovery, renewable natural gas generation, biosolids application on agricultural fields, and incineration ash recycling	• Develop standard policies to allow for the assessment and implementation of sewer thermal recovery projects • Leverage Region's existing consultation experience with Enbridge to understand the connection requirements, responsibilities, cost-sharing, and allocation of environmental attributes for RNG projects • Collaborate with academic and research partners to develop science-based methods for quantifying carbon offset credits associated with biosolids management

Newcastle WPCP

6. Progressing Toward the Objective

Detailed evaluation was completed in this study to project what the Region's progress may look like in achieving the proposed Baseline Objectives in the short-, medium-, and long-term. The projection was developed based on historical operational emissions data, considered ongoing and planned capital works and initiatives that could affect future GHG emissions, and included detailed analysis of GHG reduction potential by implementing a series of best mitigation practices, as illustrated in Figure 7.

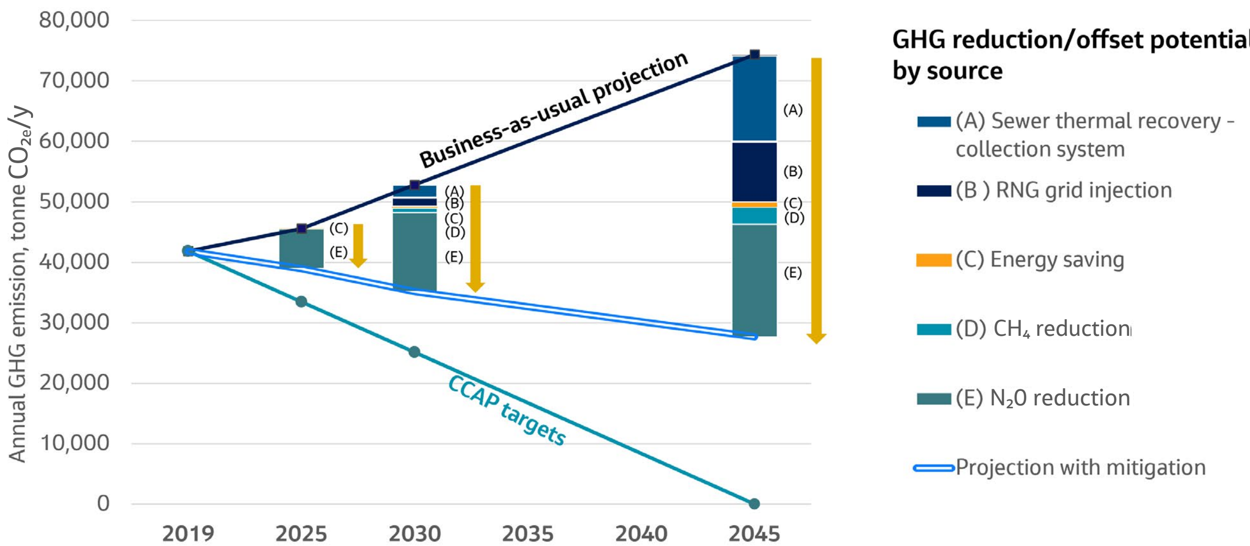


Figure 7. Water and Wastewater GHG Projections with Recommended Mitigation Projects

6.1 Key Opportunities

Table 5 summarizes the key projects identified and the recommended approximate implementation timeline. A few examples are highlighted in this section. The top three opportunities account for more than 90 percent of the overall GHG reduction potential, including (1) reducing process N_2O emissions from wastewater treatment, (2) sewer thermal recovery from the collection system, and (3) biogas upgrade to renewable natural gas (RNG) for grid injection.

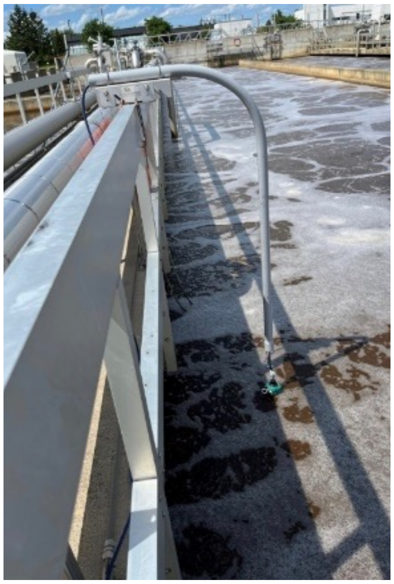
Table 5. Implementation Plan for Recommended Projects

Project(s)	Facility/System	GHG Reduction Potential	Capital Cost	Equivalent Life-cycle Cost per Tonne of CO_{2e} Reduced	Implementation Timeline
N_2O monitoring and mitigation at WPCPs – permanent installation	Duffin Creek Courtice	> 10,000 tonne CO_{2e}/y	< $1 million	$$ < $100	2024 to 2025
	Corbett Creek Harmony Creek Port Darlington	5,000 – 10,000 tonne CO_{2e}/y	< $1 million	$$ < $100	2026 to 2030
Sewer thermal recovery in the collection systems	Collection system	> 10,000 tonne CO_{2e}/y	Project-specific	Project-specific	2026 to 2030 (selected projects) 2031 to 2045 (Region-wide)
Biogas upgrade to renewable natural gas (RNG) at anaerobic digestion facilities	Duffin Creek	500 – 2,000 tonne CO_{2e}/y	$10 to $50 million	$ net cost saving	2026 to 2030
	Courtice Corbett Creek Harmony Creek Port Darlington	2,000 – 5,000 tonne CO_{2e}/y	$10 to $50 million	$$$ $100 to $500	2031 to 2040
Thermal hydrolysis pre-treatment (THP) with post-aerobic digestion (PAD), and RNG expansion	Duffin Creek	2,000 – 5,000 tonne CO_{2e}/y	$50 to $100 million*	$$$$ $500 to $1,000*	2036 to 2040
	Corbett Creek Courtice	2,000 – 5,000 tonne CO_{2e}/y	> $100 million*	$$$$ $500 to $1,000*	2036 to 2045
Sewer thermal recovery at WPCPs	Harmony Creek Port Darlington	2,000 – 5,000 tonne CO_{2e}/y	$1 to $10 million	$$$ $100 to $500	2041 to 2045
Converting sludge storage lagoon to gravity thickening	Nonquon WPCP	500 – 2,000 tonne CO_{2e}/y	$1 to $10 million	$$$$ $500 to $1,000	2031 to 2035

* Although with high capital costs, these projects can also defer significant capital spending for major process expansions (incinerators and digesters) to beyond the 2045 horizon.

Project(s)	Facility/System	GHG Reduction Potential	Capital Cost	Equivalent Life-cycle Cost per Tonne of CO_{2e} Reduced	Implementation Timeline
N_2O monitoring and mitigation at WPCPs – temporary installation	Nonquon Lake Simcoe Uxbridge Brook Newcastle Cannington and Sunderland (lagoon facilities to be converted to mechanical plants)	500 – 2,000 tonne CO_{2e}/y	< $1 million	$$ < $100	2031 to 2040
CH_4 leak detection and mitigation at anaerobic digestion facilities	Duffin Creek Courtice Corbett Creek Harmony Creek Port Darlington	500 – 2,000 tonne CO_{2e}/y	< $1 million to $1 to $10 million	Site-specific	2026 to 2030
Ammonia-based aeration control (ABAC) at large WPCPs	Duffin Creek Courtice Corbett Creek Harmony Creek Port Darlington	500 – 2,000 tonne CO_{2e}/y	$1 to $10 million	$ net cost saving	2026 to 2035
Water efficiency optimization at WSPs	Ajax Whitby Oshawa Bowmanville	< 500 tonne CO_{2e}/y	< $1 million	$$$$$ > $1,000	2026 to 2045 (opportunistically)
Solar PV generation at selected water facilities	5 largest WSPs 9 pumping station sites with rooftop area > 100 m²	< 500 tonne CO_{2e}/y	$1 to $10 million	$$$ $100 to $500	2026 to 2045 (opportunistically)

Tackling process emissions at water pollution control plants



Unisense Liquid Phase N_2O Probe (left) and Controller (right) Installed at Duffin Creek WPCP Aeration Tank 9

Process N_2O emissions from wastewater treatment represents more than 50 percent of the total Scope 1&2 emissions.

Although it represents the most significant opportunity, there is high uncertainty associated with the quantification of N_2O emissions using a generic emission factor (current method). It is therefore critical to prioritize facility-level N_2O monitoring at the Region's facilities to establish the baseline, and to identify potential mitigation strategies through operational adjustment. With a relatively low capital investment (additional instrumentation), facility-level N_2O monitoring and mitigation represent the low-hanging fruit with significant potential to reduce GHG emissions for existing assets in the short term.

A two-year continuous measurement program is currently underway at the Duffin Creek WPCP, with two liquid-phase N_2O probes installed in one of the aeration trains in Stage 3 – this was the second installation of this new technology in Ontario, demonstrating Durham Region's leadership in furthering N_2O research. Lessons learned from this program will be applied for N_2O monitoring (and potentially mitigation) at other Region facilities.

The Region is also actively exploring options for measuring and mitigating fugitive CH_4 emissions. A Region-wide leak detection and repair program has been recommended for the five WPCPs with anaerobic digesters; thermal infrared (IR) or optical gas imaging (OGI) cameras can be used to identify the sources of leakages from distance (non-intrusive) – information can be used to inform operations and maintenance for immediate mitigation actions (such as fixing digester roof leaks or replacing leaking pressure and vacuum relief valves). Reducing fugitive CH_4 leaks would reduce the associated GHG emission but also maximize the CH_4 capture for beneficial use. If substantial leaks are detected, a follow-up site-wide survey can be considered to quantify the CH_4 emissions using remote sensing methods or emerging drone flux method (these methods also allow site-wide quantification of N_2O).

Upgrading biogas to RNG

Anaerobic digestion of the residual solids is practiced at the Region's five largest WPCPs. Biogas, a byproduct generated from the anaerobic digestion process, is primarily used in hot water boilers to provide onsite heating with excess flared in waste gas burners. The biogas can be further upgraded to a high-grade fuel with comparable heating value to natural gas, referred to as RNG, which can be injected to the grid. The five WPCPs generate more than adequate RNG to satisfy the onsite heating demands, allowing excess RNG to be injected into the grid to offset natural gas consumption at other Region-owned facilities. A Region-wide RNG program can result in more than 6,000 tonnes of CO_{2e} reduction for corporate operations by 2045. There are opportunities to further increase the RNG output and associated GHG reduction potential, for example, implementing thermal hydrolysis pre-treatment (THP) or onsite sewer thermal recovery.

Biogas Upgrade Facility at Woodward Avenue WWTP (source: City of Hamilton, Ontario)

Promoting sewer thermal recovery in the collection system

False Creek Neighborhood District Energy System, Vancouver, BC (source: SHARC)

Wastewater contains recoverable heat and cooling potential compared with ambient water sources, providing a reliable and low-carbon alternative for heating and cooling processes and buildings, and offsetting natural gas use and the associated GHG emission. It is a well-established practice in Europe and Asia, and more recently, in British Columbia, Canada. The world's largest sewer thermal district energy system project is currently under construction at the Toronto Western Hospital (City of Toronto, Ontario). Preliminary assessment indicates immense thermal capacity available within the Region's collection system (more than 40 MW today, and potentially doubling by 2045), offering substantial opportunities to reduce GHG emissions at the community level. For example, harvesting 10 percent of the sewer thermal capacity (based on Durham share of the YDSS) can potentially result in more than 14,000 tonnes of CO_{2e} reduction by 2045. It is critical that the Region develop a sewer thermal policy and establish a standard approach for implementing sewer thermal recovery projects. Successful projects will require coordination with the planning department and local municipalities, developers, and end users.

Leveraging best practices in energy optimization and generation

Due to the low-intensity electricity grid in Ontario, energy optimization and renewable electricity generation are not expected to result in substantial GHG reduction, but they offer additional benefits such as reduced cost (from reduced grid purchase and demand cost) or improved site resiliency, and can be implemented opportunistically as practical (e.g., along with other planned facility upgrades).

The best practices in energy and demand management are expected to become 'business-as-usual' for future upgrades and new capital projects, driven by Region's policies and standards for sustainable infrastructure. Examples include implementing energy-efficient aeration technologies at WPCPs (such as ultra-fine bubble diffusers, high-speed turbo blowers, or ammonia-based aeration control [ABAC]), pumping optimization (e.g., fitting with high-efficiency motors), improving water efficiency (e.g., leak detection and demand management), improving building energy efficiency (e.g., lighting; heating, ventilation and air conditioning (HVAC) systems; and building envelopes), and solar photovoltaic (PV) generation.

Example rooftop solar PV installation

6.2 Key Performance Indicators

A series of key performance indicators (KPIs) were recommended to track the GHG emissions and progress of mitigation for the Region's water and wastewater systems.

The total (net) GHG emissions (offsets) will be used to track and communicate the progress toward the established reduction targets, with breakdown of water and wastewater systems as shown in Figure 8.

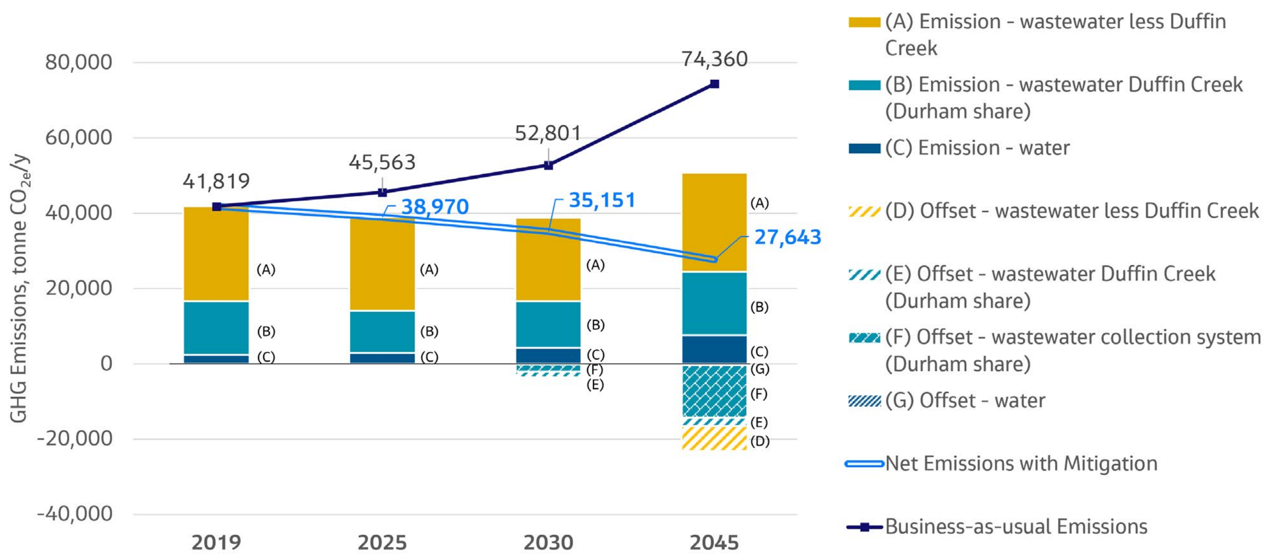


Figure 8. Total (Net) GHG Emission Projection (Scope 1&2)

The per capita GHG emissions will be calculated to reflect population growth and increased demand for services. For example, implementing the recommended projects identified in this strategy could result in more than 60 percent reduction in per capita GHG emission by 2045, as shown in Figure 9.

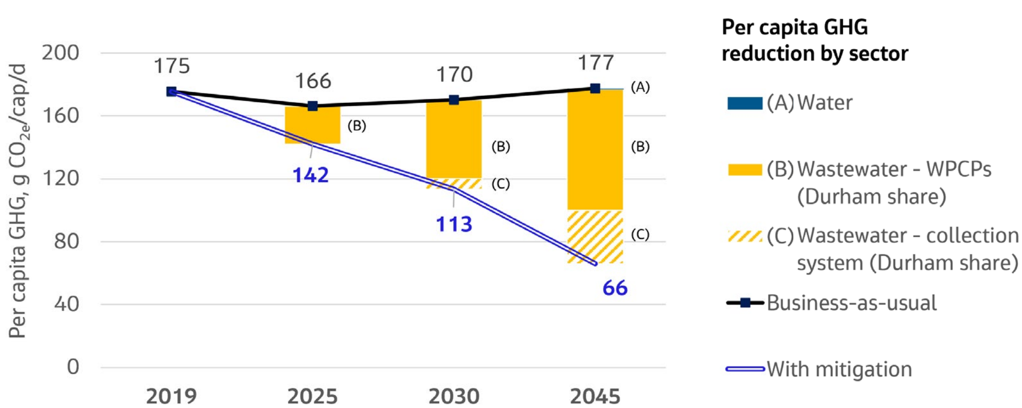


Figure 9. Per Capita Per Day GHG Emission Projection (Scope 1&2)

The energy emissions will be tracked separately, because reduction in energy use would also have a cost impact, and there is greater certainty in the methodology for quantifying the energy emissions. Implementing the recommended projects identified in this strategy could result in more than 50 percent reduction in energy emissions by 2045; the substantial reduction for wastewater shown in Figure 10 is mainly driven by the RNG generation which minimizes the need for natural gas at the WPCPs. Additional reduction is expected as the *Durham Standard* will drive the implementation of other energy efficiency measures for future projects within the Region.

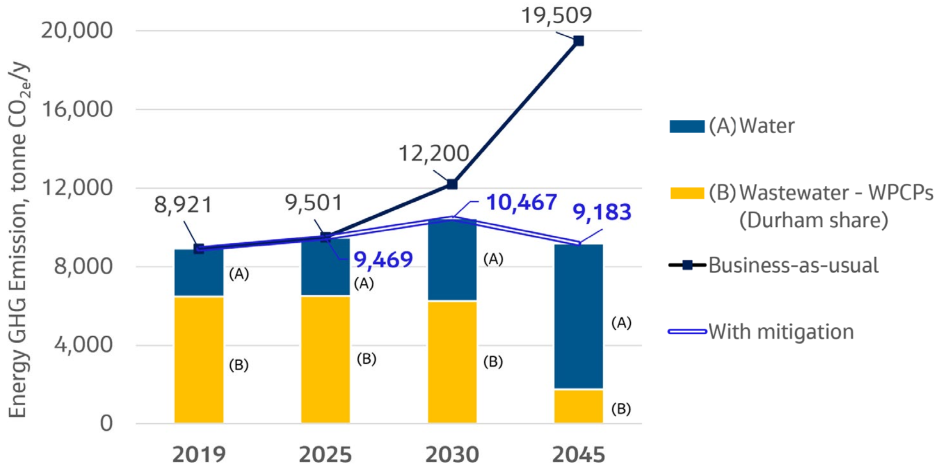


Figure 10. Energy GHG Emission Projection

Other recommended KPIs include the following:

- GHG emissions associated with biogas generation and utilization onsite (at WPCPs)
- GHG offset from RNG grid injection for corporate operations (equivalent natural gas offset for the portion of RNG injected to the grid for use at other Region facilities)
- GHG offset from collection system sewer thermal recovery (equivalent natural gas offset for the portion of sewer thermal energy recovered at community level)
- GHG reduction from renewable electricity generation onsite (e.g., solar PV)

6.3 Limitations in Methodology

It is important to acknowledge the significant uncertainties associated with the top two GHG reduction opportunities.

- There is high uncertainty in quantifying the process N_2O emission and the reduction potential through mitigation. The recommended facility-level measurement programs will be critical to establishing the baseline process emissions at the Region's WPCPs, to inform if or what mitigation measures are necessary, and to quantify the reduction. Experiences in Europe have demonstrated that sustained N_2O reduction is possible through simple operational adjustment (for example, adjusting set points for dissolved oxygen, increasing solids retention time) and, where required, minor works (for example, to redistribute loads). It is expected that a stepwise approach would be taken by the Region. Operational adjustment should be prioritized with the support of continuous N_2O monitoring to determine the level of N_2O reduction that can be reliably achieved at each facility. If further reduction is deemed necessary to achieve the long-term reduction target, alternative solutions that may require capital upgrades can be considered (examples in Section 7).
- The projected GHG offset from sewer thermal recovery in the collection system represents a high-level assessment for illustrative purposes only (for example, based on a target to harvest 2 percent of the sewer thermal capacity by 2030 and 10 percent of sewer thermal capacity by 2045). The actual GHG offset potential will be project-specific. It is critical that the Region prioritize the development of sewer thermal policies to facilitate the deployment of sewer thermal recovery projects.

Nonquon WPCP

Some of the regulations and policies are expected to drive initiatives that will further reduce GHG emissions.

- Although not captured in the projection, additional GHG reductions can be expected for future projects, as the new Durham Standard (and other Regional policies and initiatives for sustainable infrastructure) will drive the incorporation of best practices in energy and carbon efficiency during future asset renewals and/or expansions.
- Current projection for electricity GHG emissions is based on the most conservative forecast for the grid emission factor in Ontario. It is anticipated that the grid emission factor would be lower than what was used in this study, considering the potential impact of the Federal Clean Electricity standard on the Ontario grid (which is beyond the Region's control).
- Natural gas-related emissions are based on the current grid emission factor for Ontario; any changes made to increase renewable content shares for the natural gas grid may result in lower net natural gas emissions (for example, as Enbridge procures more RNG).

There are other potentially significant GHG emission sources not currently included in the inventory or target setting, due to difficulties in quantifying these emissions.

- Collection system/sewer CH_4 production can contribute to significant GHG emissions; however, due to the complex and dynamic nature of the sewer system, a standard quantification methodology is not available, and continuous system- wide measurement is impractical and cost prohibitive. The latest development involves the combination of measurements in selected hot spots with mathematical modelling to estimate CH4 production and emissions from the sewer systems. This topic remains an emerging area.


Courtice WPCP

- Although the majority of CO_2 emissions from the municipal wastewater treatment process are biogenic (therefore excluded from reporting), there are potential non-biogenic CO_2 emissions; for example, from industrial discharge that includes fossil carbon derived from cosmetics, pharmaceuticals and personal care products, and other organic chemicals. Practical methodologies for estimating these non-biogenic CO_2 emissions are currently not available (e.g., specialized techniques are required, such as isotope tracing).
- This study has identified a list of relevant Scope 3 emissions to be included in the Region's inventory, considering that the Region will be able to influence these Scope 3 emissions through operational adjustment, including chemicals, haulage of biosolids and residuals (incineration ash) within the Region, and biosolids land application offsite. Quantification methodologies were recommended, and the associated limitations and opportunities for improvement were identified. These Scope 3 emissions are currently not included in target setting, but they will be quantified and tracked to assist decision making.
- Quantification of embodied carbon (also referred to as "capital carbon") in buildings and construction is a growing space. Embodied carbon could include emissions from the manufacture and distribution of construction materials (e.g., concrete and steel), the operation of construction equipment (e.g., energy used to run the construction equipment), and other emissions associated with temporary works, construction waste management, etc. More utilities in Ontario are now requiring embodied carbon assessment for new capital projects to assist decision making. Similar requirements are included in the latest Durham Standard, although currently only applicable to admin areas, building envelopes, and lab space within the water and wastewater sites. Although the quantification methods are well established, data are very limited across the industry to quantify the embodied carbon associated with process components and equipment for water and wastewater facilities. It remains an emerging area with a lot of ongoing developments.

Changes in GHG calculation methodologies or improvements in the accuracy of emission factors or activity data may result in inconsistencies with the base year emissions or GHG quantification for other sectors. It is important to be transparent and properly document the quantification methodologies, including the scope of emissions, the source and quality of emission factors and activity data, and any changes from previous methodologies. As the methodology continues to evolve and improve, the Region needs to re-baseline the GHG emissions to include additional emission sources and refine the reduction targets.

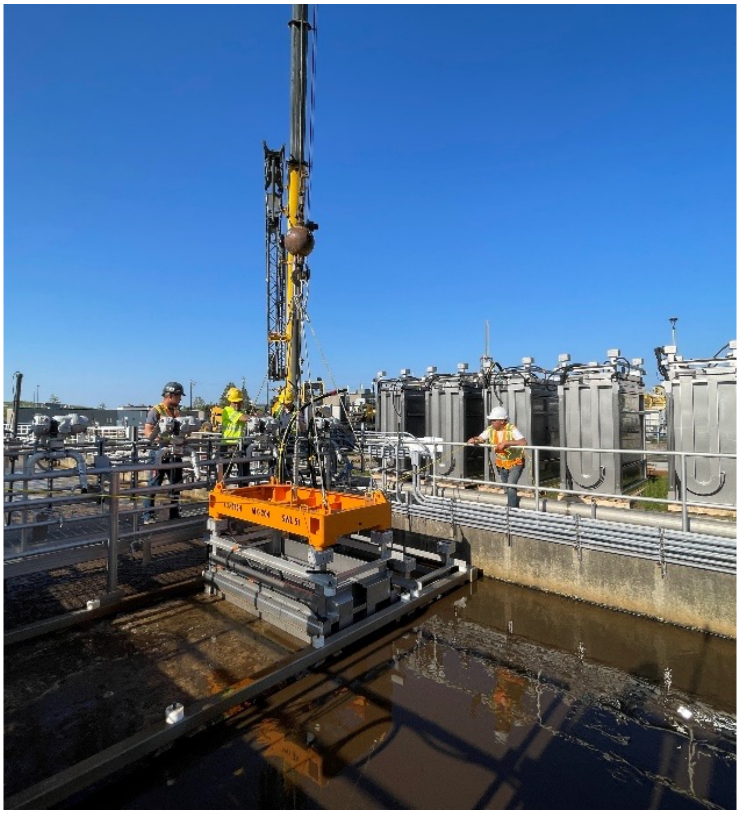
7. Road Map to Net-Zero Emission

Analysis in this study identified significant gaps in achieving the 2045 net-zero target for the water and wastewater systems. The Region needs to continue monitoring and adopting other innovative net-zero solutions as they become more established in the long term. This section highlights some of the promising technologies and strategies that Region should continue to monitor for future consideration.

Membrane aerated biofilm reactor (MABR)

MABR is a breakthrough technology for wastewater treatment that can provide enhanced nutrient removal with significantly improved aeration energy efficiency compared with traditional treatment processes.

Most recently, there has been increasing evidence of low N_2O emissions from MABR processes based on global case studies, though a consensus around the degree of N_2O reduction compared with other conventional treatment processes has not been established, which remains the focus of many ongoing works globally. In Ontario, a full-year continuous N_2O monitoring program is currently underway at the Region of Waterloo's Elmira Wastewater Treatment Plant.



Installation of MABR Modules at the Elmira Wastewater Treatment Plant, Region of Waterloo

The Region should continue to monitor the development of MABR and consider it in future facility upgrades or expansion projects, because the membrane modules can be easily retrofitted into existing aeration tanks to expand capacity and/or improve nutrient removal performance; the capital savings from avoided tankages and additional energy saving for aeration could make MABR cost competitive.

It is a promising decarbonization solution that can offer multiple benefits, including nutrient removal, energy efficiency, process N_2O mitigation, and process intensification.

Capture of process emissions for reuse/treatment

Mitigating process emissions is an emerging research topic in the wastewater sector globally. It is expected that the science will continue to advance, allowing the Region to incorporate the best practice into the design of future upgrades and expansions that can promote low-energy and low-carbon operations, including lessons learned from Region's own monitoring and mitigation programs.

Other innovative technologies are available that can capture the process emissions for reuse and/or treatment, such as vacuum CH_4 extraction from digested biosolids (to minimize CH_4 emissions from the downstream dewatering stage and increase CH_4 recovery from biogas), or catalytic treatment of N_2O from covered process tanks. These technologies are still in early market demonstration phase but can be considered in the long term as they become more established, especially if continuous monitoring indicates that further mitigation is not possible with operational adjustment alone.

ELOVAC® Vacuum CH_4 Extraction Unit Installed at the Ejby Mølle Water Resource Recovery Facility, Odense, Denmark (credit: VCS)

Thermal conversion of biosolids

It is very unlikely that the wastewater sector can eliminate process emissions, and the mitigation strategies need to be supplemented by adopting innovative resource recovery solutions to offset process emissions.

Thermal conversion of biosolids is one of the innovative resource recovery processes that has gained growing interests in recent years, with considerations of sustainability and circular economy (as these processes convert sludge or biosolids into low-carbon intensity products), and most recently the concern over per- and polyfluorinated substances (PFAS) in wastewater and biosolids – these high temperature processes can potentially destroy PFAS.

Pyrolysis Process Installed at the Morrisville Municipal Authority Facility, PA, USA (credit: Ecoremedy)

Several technologies are available in different stages of technological development and maturity. Pyrolysis and gasification are among the most developed thermal conversion technologies, with increasing number of full-scale demonstrations or installations globally.

Compared with the current practice (primarily through incineration, supplemented by seasonal land application), thermal conversion can offer potential GHG reduction opportunities by diverting sludge away from incineration and reducing the associated Scope 1 emissions.

In addition, the final product (e.g., biochar or other low-carbon fuels) offers high-carbon sequestration potential when applied on land or can be used as alternative fuels to replace fossil fuel. However, the overall GHG impacts from these technologies have not been well established, as the overall energy and carbon balances are quite complex, and limited information is available to conduct comprehensive assessment. Nevertheless, thermal conversion remains a promising decarbonization solution and an emerging research area in the industry.

8. Conclusions

The *Water and Wastewater Greenhouse Gas Emissions Management Strategy* is the first project of its kind in Ontario to establish GHG reduction targets specific to the water and wastewater sector, considering the 'possibility' and 'reality' of GHG mitigation in Ontario.

The project established a transparent framework that clearly defines the scope of GHG emissions included in the inventory, the methodologies used to quantify these emissions, the associated limitations and opportunities for improvement, and changes from the previous methodologies – allowing the Region to re-baseline the GHG emissions to include additional emission sources and refine the reduction targets as the quantification methodologies continue to evolve and improve.

A road map was developed for the Region's water and wastewater systems to 2045 (consistent with the CCAP), including an action plan with key GHG mitigation opportunities in the short- (2025), medium (2030), and long-term (2045). Meaningful GHG reduction commitments were established based on comprehensive assessments of net-zero solutions that considered the technical feasibility and operational and financial impacts to the Region.

Table 6. Projected Achievable GHG Reduction for Durham Region's Water and Wastewater Systems (Scope 1&2)

Timeline	GHG Reduction Potential (tonne CO_{2e}/y)	% Reduction from 2019 Baseline	% Reduction from Business-as-usual Projection
2025	4,200	10%	17%
2030	8,400	20%	37%
2045	16,700	40%	66%

The top three GHG reduction opportunities account for more than 90% of the long-term GHG reduction potential; it is therefore critical to identify challenges and develop strategies accordingly to allow the Region to prioritize implementation of these top opportunities. Key recommendations were identified as follows:

1. **Reducing process N_2O emissions from wastewater treatment.** Recognizing the high uncertainty in quantifying process N_2O emissions, facility-level measurement programs will be critical to establish the baseline emission and to inform if/what mitigation measures are necessary, and to quantify the reduction. The Region has already deployed two liquid-phase N_2O sensors at the Duffin Creek WPCP since summer of 2023 (the second installation in Ontario). This two-year monitoring campaign will capture the seasonal variances and different air control strategies (including the combination of N_2O measurement with ABAC operation), positioning the Region to better understand the quantities and factors affecting the N_2O emissions at the plant and prepare for monitoring at other Region facilities.

2. **Sewer thermal recovery from the collection system.** This represents a significant opportunity for the wastewater sector to make meaningful GHG reductions at community level. The actual GHG offset potential will be project-specific – mainly driven by the customer demand. It is critical that the Region develop a sewer thermal recovery policy and establish a standard approach for implementing sewer thermal recovery projects, including clear definition of responsibilities, cost sharing, and allocation of environmental attributes among different stakeholders (e.g., Durham and York Regions, local municipalities, developers, and end users).

3. **Biogas upgrade to RNG for grid injection.** The Region's WPCPs generate enough biogas that can be purified to RNG to offset natural gas use at the WPCPs, with excess RNG available for grid injection to be used by other Region facilities to offset the natural gas use (and associated displacement of GHG emissions) by corporate operations. The Region has been actively seeking RNG development opportunities in recent years with Enbridge (current natural gas provider) and other third-party entities including corporations and utilities, among others. It is important to understand the technical requirements for grid injection, and the associated responsibilities, cost sharing, and allocation of environmental attributes.

Many of the recommended GHG mitigation opportunities also offer co-benefits with respect to process performance, stability, resiliency, or capacity. Recognizing the synergies, the recommendations from this study will inform the development of the upcoming biosolids master plan study, and other future planning and design projects as appropriate.

The Region acknowledges significant gaps in achieving net-zero emissions in a cost-effective manner based on technologies available today, and the need to be proactive in expediting some projects and adopting other innovative net-zero solutions as they become more established. The Region is committed to continuing efforts in GHG mitigation through collaboration with academic researchers, consultants, and technology vendors, with a goal to adapt to future changes and technology developments to progress towards its net-zero commitment in the long term.

Moving forward, this study will be updated every five years to reflect the latest development in quantification methods, and to refine the GHG reduction targets based on the Region's mitigation progress and available decarbonization technologies at that time.

Courtice WPCP

9. References

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