Achieving Net Zero in the Water Sector

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Introduction

The Great Lakes and St. Lawrence Cities Initiative (Cities Initiative) aims to establish a program that would support water utilities along the Great Lakes in working towards net zero greenhouse gas (GHG) emissions. Under the guidance and direction of Professor Melissa Scanlan, graduate students at the University of Wisconsin-Milwaukee's School of Freshwater Sciences have produced this report recommending strategies to support water utilities in achieving net zero emissions. It's important to note that while this report covers drinking water, stormwater, and wastewater, most emission reduction efforts stem from wastewater treatment. The advancement and efficiency in one sector can positively impact the others as these three sectors of water are interconnected through the water-energy nexus (Zib, 2021).

We start this assessment with an overview of greenhouse gas emissions in the water industry in Section 1. Section 2 provides a comprehensive review of methods and technologies used within the water sector, and possibilities to reduce emissions. Section 3 explores the pathways to net zero through a review of case studies, highlighting the leading municipalities driving emission reduction projects. Section 4 delves into the challenges and opportunities the water sector faces in reducing emissions. This section addresses the barriers hindering projects across the Great Lakes and discusses the policies supporting water utilities. Section 5 considers funding resources available in Canada and the U.S. This section underscores historical funding roadblocks and provides an overview of available grants and loans utilities can utilize.

We conclude this assessment offering recommendations to the Cities Initiative based on our comprehensive research. These recommendations aim to equip the Cities Initiative with a toolkit of strategies to support water utilities in their transition to net zero.

Section 1: Greenhouse Gas Emissions in the Water Industry

1.1 Emissions Data

Climate disruption is driven by increases in global emissions of GHGs. In this section we explain the three major GHGs and how water utilities are contributing to national GHG emissions in the U.S. and Canada. The three major GHGs that occur naturally in nature but have had their atmospheric concentrations increased due to anthropogenic sources are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). GHG emissions are typically reported in metric tons of CO_2 – equivalent (MT CO_2 eq). This value accounts for the global warming potentials (GWP), which is a "concept to compare the ability of a greenhouse gas to trap heat in the atmosphere relative to another gas", in this case carbon dioxide (U.S. EPA 2024).

Global GHG emission data related to water treatment is limited, and when data is available, drinking water and wastewater treatment are often combined into one value or reported as emissions from just wastewater. Another issue with GHG emission data is unit consistency. While a unit conversion can be applied to switch between tons, metric tons, and megatonnes, some databases report emission data in total GHGs while others use the CO_2 – equivalent, which limits the ability for a direct comparison of values. Emissions data in this report will clearly state the units for numerical values. In the U.S., drinking water and wastewater treatment facilities produced over 40.8 million metric tons of GHGs in 2023 (U.S. EPA 2023), accounting for approximately 0.6% of total GHG emissions produced (U.S. EPA 2024). In Canada, wastewater treatment accounts for about 570 thousand metric tons of CO_2 eq., or 0.2% of total reported GHG emissions (Government of Canada 2023).

While this data suggests water utilities are a relatively small piece of the GHG puzzle, when we evaluate methane and nitrous oxide, the wastewater utility sector's significance is more pronounced. The "Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2022" goes over trends of several greenhouse gases over the past three decades, as well as breaking down the industry sources that are the largest contributors of CO_2, CH_4, and N_2O. Wastewater treatment was the eighth largest source of CH_4 emissions in 2022, with a little over 20 million MT CO_2 eq. Wastewater treatment, both domestic and industrial, was the second largest source of N_2O, accounting for 21.9 million MT CO_2 eq in 2022.

1.2 Energy Consumption

Regarding these two industries, energy consumption is the leading cause of GHGs, with "energy use by water and wastewater activities [accounting] for about 4% of international electricity consumption" (Kerres, et al. 2020), and 2% of energy consumption in the U.S (U.S. EPA 2024). We note that there is a difference between energy and electricity, energy being a broader concept referring to the ability to do work, whereas electricity is a specific form of energy involving charged particles (BKV Energy 2023). Numerical data involving these concepts will use the language of the source material. When we change our focus from national GHG inventories to the scale of municipalities, we see water utilities emerging as a top user of energy. In the United States, 30-40% of energy used by municipalities are used for drinking water and wastewater treatment facilities (U.S. EPA 2023). Of this, electricity consumed for water treatments is divided with "around 40% used to extract water, 25% for wastewater treatment and 20% for water distribution" (Kerres, et al. 2020). In Canada, municipal water and wastewater treatment consumes about 38% of energy usage of municipalities (Environmental Commisioner of Ontario 2017).

Due to growing demand, energy consumption in the water treatment sector is projected to double by 2040 (Kerres, et al. 2020). Growing populations, climate change, and aging infrastructure will all impact the quantity and quality of water treatment (Zhang, et al. 2024) (US Water Alliance 2022). Thus, it will be essential for municipalities to understand the role water utilities play in their GHG emissions and energy demands, and the opportunities for greater efficiency.

Section 2: Technology Review

In this section we will review the technology involved in drinking, wastewater, and stormwater treatment. While most technology to decrease GHG emissions in the water sector stems from wastewater treatment, it is crucial to understand that these three forms of water are interconnected. Improvement to one sector of treatment has the potential to benefit another.

2.1 Typical Drinking Water Treatment

Drinking water treatment varies slightly depending on the source of water. Surface water from lakes often requires additional treatment and filtration due to containing "more sediment, germs, chemicals, and toxins" as opposed to groundwater (Center for Disease Control and Prevention 2022). However, the same six steps are used in all forms of drinking water treatment: coagulation, flocculation, sedimentation, filtration, disinfection, and corrosion control (Zac 2023) (Denver Water n.d.). While many utilities use chlorine for disinfection, some drinking water treatment facilities utilize additional forms of disinfection such as UV light or bubbling in ozone gas (Center for Disease Control and Prevention 2022) (City of Milwaukee n.d.).

One practice that is gaining in popularity to decrease GHG emissions in drinking water treatment is reusing the sludge created in the drinking water treatment process after the sedimentation step. This sludge can be co-processed with the biosolids produced from wastewater treatment. Integrated treatment process management such as co-processing biosolids has a variety of potential advantages including energy and cost savings. With using biosolids and biogas from the wastewater treatment plants being one solution to reduce GHG emissions in the water sector, this would not only supply more fuel for potential energy, but also save energy that was being used to properly dispose of the waste or separate processing. This idea will be explored in depth later in this report.

2.2 Typical Wastewater Treatment

The wastewater treatment process can be broken down into four major treatments: preliminary/primary treatment, secondary treatment, disinfection, and biosolid management.

Preliminary treatment involves removing any large items by screening and then grit removal to remove any sand or gravel in the water. This then moves into primary treatment where the water is clarified for the first time. This produces primary sludge, and the water that moves on to secondary treatment.

Secondary treatment can be broken down into two processes, biological treatment and secondary clarification. Biological treatment typically involves aeration to stimulate bacteria which helps breakdown organic material. The wastewater is then clarified for a second time to settle any remaining organic sludge material.

The effluent is then disinfected to kill off any residual bacteria from the aeration and secondary clarification. Chlorination is the most commonly used method of disinfection; however, this requires testing before discharging the effluent into the environment to ensure chlorine levels are within acceptable levels. Other methods of disinfection are gaining in popularity such as ozone and UV as mentioned above for drinking water treatment (Cole-Parmer 2022).

The last portion of wastewater treatment is biosolids management. This is the step of wastewater treatment that holds the most possibilities of decreasing GHG emissions in the water industry. The primary and secondary sludges are combined and thickened through gravitational forces. There are several possibilities for this sludge including landfill disposal, incineration, or anaerobic digestion. This anaerobic digestion process produces biosolids and biogases which have the ability to reduce GHG emissions. This method will be explained more in depth below and seen in many examples of this report. (Greater Lawrence Sanitary District n.d.) (Cole-Parmer 2022) (Riffat and Husnain 2022) (Karia, Christian and Jariwala 2023).

2.3 Anaerobic Digestion

Sludge production is a part of the wastewater treatment process, with the U.S and Canada producing about 7.2 million and 0.6 million dry metric tons of sludge per year respectively (Mohammad, et al. 2021) (Nabaterega, et al. 2021). Handling this sludge is estimated to be between 50-70% of a treatment plant's operating costs, making it one of the most expensive tasks in the wastewater treatment process (Mohammad, et al. 2021). One technology being utilized to help offset the costs of sludge handling is anaerobic digestion, which is defined as "a biochemical process that employs various microorganisms to convert the degradable organic matter such as municipal sludge into biogas, digestate, and new bacterial cells in the absence of oxygen" (Nabaterega, et al. 2021). The biogas produced is roughly 50-75% methane, which can be captured and used similar to natural gas for energy. The digestate, also called biosolids, can be sold to farmers as a fertilizer (U.S. EPA 2024).

Anaerobic digestion involves four steps: hydrolysis, acidogenesis, acetogenesis, and methanogenesis (Ruffino, et al. 2015). These four steps can be performed in a single or two-stage approach. The two-stage approach starts with an Acid Phase, which includes hydrolysis and acidogenesis, and a Gas Phase, which is acetogenesis and methanogenesis (U.S. EPA n.d.). There are several conditions that impact the effectiveness of anaerobic digestion, including pH, temperature, and hydraulic retention time. Each step of the process has an ideal set of conditions that would maximize methane gas production and cost effectiveness, but many municipalities use a single-stage approach. This is because while the two-stage approach enhances pathogen destruction, which would improve the quality of the biosolids produced, it is not as widely utilized due to the sophistication, "little information on process stability" and the "higher operation/maintenance expenses" (Nabaterega, et al. 2021).

The hydrolysis step of anaerobic digestion is the rate-limiting step, requiring large amounts of time and energy as insoluble, high molecular weight compounds are broken down into smaller soluble compounds (Mohammad, et al. 2021). Due to this, a thermal hydrolysis process has been implemented in many water treatment facilities that utilize anaerobic digestion. Studies on the issue compare a variety of low and high temperatures for various lengths of time, seeking to find the optimal conditions for energy production and cost effectiveness. Low temperatures at 90 °C for optional pre-treatments and/or during the hydrolysis process have proven successful, increasing methane production between 31-56% compared to control conditions (Ruffino, et al. 2015) (Mohammad, et al. 2021).

As of 2020 only about 1,300 of the over 14,000 municipal wastewater treatment plants in the United States have anaerobic digesters that produce biogas. Of those 1,300 only 184 utilize the biogas for combined heat and power, with "one-third of the facilities utilizing their gas for electricity, while the rest use their biogas to heat the digester tanks" (Gursel, et al. 2020). By utilizing the products of anaerobic digestion in the wastewater treatment process, municipalities could not only reduce their greenhouse gas emissions, but also could save on operational costs. Capturing methane gas would decrease the amount of natural gas needed to power treatment operations and the facility infrastructure. Selling the biosolids would decrease the costs otherwise used to properly dispose of the material and make a profit which can then be put back into the wastewater treatment process.

2.4 Sewers

There are two classes of sewer systems, combined sewer systems and separate sewer systems. Separate sewer systems separate wastewater and stormwater, sending only the wastewater to the treatment facility. Combined sewer systems in contrast combine these sources of water in the sewers, thus increasing the amount of water needing to be processed at treatment facilities. This adds more burden to the system, requires more resources to work harder and longer, and releases more GHGs if the system is powered by fossil fuels. It is important to distinguish these two systems to understand the cause for concern and the need for intervention to achieve net zero GHG emissions.

Combined Sewer Systems

Combined sewer systems are designed to traffic wastewater and stormwater simultaneously in the same piping and pose as a source for water pollution and public health concern (U.S. EPA 2023). According to the US EPA, "there are approximately 700 communities in the United States that have combined sewer systems and experience combined sewer overflow (CSO) [events]" many of which are in the Northeast and Great Lakes regions (U.S. EPA 2023). These systems are often accompanied by an overflow program. As a storm event occurs, the combined sewer system must maintain the proper amount of wastewater flow while taking on the added responsibility of the stormwater surge increase. Often this results in an overburden on the system, and the excess combination of stormwater and wastewater is pumped to overflow points throughout local waters, an event called a combined sewer overflow event (U.S. EPA 2023).

With ever growing populations in cities and climate change, the demand for larger flow capacity tunnels and ways to slow stormwater runoff into combined sewer systems has increased. Several cities that have combined sewer systems will be discussed later in the report, highlighting the possibilities for infrastructure to decrease the number of CSO events annually.

Separate Sewer Systems

Separate sewer systems are more of a modernized sewer system, separating stormwater from wastewater. Here there are two different sets of piping run underground, mitigating cross contamination and the overburden that a combined system would experience. If there is an overburden on the system, the overflow procedure releases less contaminated stormwater into the waterways to reduce pollution locally. (U.S. EPA 2023). With this modernized system, some places across the world have begun to upgrade older combined sewer systems to separate systems which not only decreases pollution but also GHG emissions from less water being treated at wastewater facilities.

2.5 Green and Gray Infrastructure

As mentioned above, combined sewer systems merge both wastewater and stormwater and have the potential to experience a combined sewer overflow event after heavy rain events. Due to this, stormwater management practices are utilizing green infrastructure to alleviate the amount of stormwater entering the combined sewer systems.

Green infrastructure includes "natural vegetation, landscape design, and engineered techniques that retain, absorb, and often cleanse stormwater runoff" (U.S. EPA 2016). Several examples include storage ponds, permeable pavements, bio retention swales, and rain gardens (Hettiarachchi, Wasko and Sharma 2022). Regarding stormwater management, gray infrastructure includes storm drains and sewer systems. Aging infrastructure, the cost of replacing engineered systems, and the negative impacts to the environment demonstrate the need to supplement with green alternatives such as the examples mentioned above when replacement is not an option (Vorosmarty, et al. 2021).

In one study performed by Hettiarachchi, green infrastructure was shown to remain "effective during more frequent storms (~ 80th percentile) that can occur in warmer climatic conditions" and that "retrofitting or converting a smaller than expected percentage of the urban landscape (up to 5 %) can yield appreciable benefits" in stormwater management (Hettiarachchi, Wasko and Sharma 2022).

Similarly, a case study in Detroit, Michigan looked at the role of green stormwater infrastructure in flood mitigation. Catch basin blockages were shown to eliminate backflows and high flow rates during a 2 year, 24-hour storm. While there was surficial flooding due to these blockages, there was a decrease in elevation of water and water returned to base elevation at a faster rate than if there was no catch basin (Thorsby, Miller and Treemore-Spears 2020). These two cases show that even small increases in green infrastructure in urban areas can have a large impact on stormwater management and sewer overflows.

With green infrastructure, less stormwater makes its way into combined sewer systems which is crucial in preventing overflow events during periods of heavy rain. During rain events where an overflow isn't triggered, the decreased amount of stormwater means that there is less water to be treated at the wastewater treatment plant which in turn means less required energy to treat said water. This decrease in energy consumption will help water utilities in their goal towards net zero GHG emissions.

2.6 Renewable Energy

Renewable energy describes naturally replenished and unlimited sources of energy such as solar, hydro, and wind. There are several uses for renewable energy including electricity production, heating and cooling, and transportation (Energy.gov n.d.). In the United States, renewable energy makes up approximately 20% of the energy consumed (Energy.gov n.d.).

Utilizing and creating renewable energy is one way that utilities are decreasing their GHG emissions. Although one would not typically consider water utilities as a source of renewable energy, the technology exists to shift existing systems to work as a renewable energy source, decreasing their usage of non-renewable forms of energy. Water treatment facilities have "pumps, motors, and other equipment operating 24 hours a day, seven days a week" making them "among the largest consumers of energy in a community—and thus among the largest contributors to the community's total GHG emissions" (EPA 2013). Being able to capture different forms of renewable energy is a key for mitigating loss in the future.

Processes such as hydropower and geothermal heating can aid energy throughout heavy-toll systems. Hydropower is responsible for approximately 240 billion kilowatt hours of energy production in the United States, which adds up to 5.7% of the total energy generation (U.S. Energy Generation by Source 2024) and the US leads the world in geothermal electricity-generating capacity [at] almost 4 gigawatts (Energy.gov n.d.). One study discussed the ability to generate hydropower within wastewater treatment plants as "many sections of the water treatment lines are usually suitable for hydropower production" (Sinagra et al. 2022). Depending on the type of turbine, the total producible energy ranges from 87.2-186.8-megawatt hours per turbine (Sinagra et al. 2022). For example, the Albert Lea Wastewater Treatment Plant in Minnesota saving an approximate 70% of energy costs from installing an internal 120-kW microturbine (U.S. EPA 2015). As for geothermal heating, Princeton University began a plan to implement a geothermal heating system known as Exchange. This system would conserve energy by capturing thermal energy within the Earth as a source of retaining heat in water which is then used to heat the campus (Buckley 2024). A similar process is in place at the DC Water Headquarters building and the Toronto Deep Lake Cooling System. These two systems utilize thermal heat exchange, one with heated water in the sewer systems, and the other with cold water from deep within Lake Ontario. In the DC Water system, the heat coming off the sewers is used to heat the headquarters building in the winter and cool it in the summer by acting as a heat sink (dc Water 2021). The Toronto system runs the cold water through a series of pipes which interact with the pipes in buildings as a cooling system, the heated water after this then returns to the treatment facility where the heat is used as a form of energy to power the system all over again (Enwave 2021). Systems like these can be utilized to drive forward progress on renewable energy within these heavy taxing systems and offset some of the outputs of GHGs and drawdowns of energy and energy resources.

Section 3: Case Studies

3.1 Benchmark Infrastructure

To understand industry leaders for water utilities, it is important identify cities with water systems that are outdated. This section designates significantly outdated and older water and wastewater treatment systems. Many have current restructuring plans to help upgrade and begin transitioning towards a cleaner system. These heavily populated areas are historically large points for overburden, thus designating them viable targets for upgrade towards net-zero compliance.

Buffalo, NY

Buffalo is an example of a municipality in the Great Lakes region that has a combined sewer system that experiences overflows into local water ways. These overflows pump contaminated water into the riverways and lakes to divert flow away from the overburdened wastewater treatment facilities. This prevents backup into residents' houses, but in turn, contaminates local waters making them unfit for activity and more strenuous to treat for pre and post consumption. The EPA uses its enforcement and compliance history online system to deliver active reports to the public. The Bird Island Sewage Treatment Plant in Buffalo, reference NY0028410, has experienced at least one noncompliance overflow event detected every quarter since January of 2021 (EPA ECHO 2024). As of 2023, the Bird Island Sewage Treatment Plant in Buffalo was reported to control 60 separate combined sewer outflow locations.

Buffalo is geographically on the northeastern corner of Lake Erie and is close to the southwestern corner of Lake Ontario. Its location is directly in the water flow path from Lake Erie into Lake Ontario via the Niagara River. Companies like Xylem have been contracted to enter the restructuring process in places like Buffalo. Here Xylem worked to implement new Smart Sewer Systems which are used to control amount and flow paths of combined sewer system contents more accurately (Businesswire 2023). This upgrade to a marginally outdated system helps the Buffalo Sewer Authority minimize the amount of pollution sent out into the surrounding waters. This program shows numerous benefits by decreasing pollution, reducing associated costs of overflow events and post-event treatment, and reducing the resources needed and emissions from the treatment itself. (Xylem 2023) (Climate Smart Communities, 2012).

Cleveland, OH

Cleveland sits on the shores of Lake Erie and, like Buffalo, uses a combined sewer system. Cleveland is a municipality that has historically had an average of 4.5 billion gallons of Combined Sewage Overflows into local waters per year since 2010 which the EPA considered "in violation of the Clean Water Act because not all discharges were controlled to required levels" (NEORSD 2024).

Cleveland is at the center of the Project Clean Lake, an initiative set forth to upgrade systems throughout the northeastern Ohio area that interact with lake water. This 25-year long program "will reduce the total volume of raw sewage discharges from 4.5 billion gallons to 494 million gallons annually" with "over 98% of wet weather flows [into the] combined sewer system [being] captured and treated when the program is complete in 2036" (NEORSD 2024). The goal of this project is to reduce the pollution of Lake Erie and local waterways by revamping water treatment facilities to allow more water flow, efficiently reducing energy costs and resources. A section of this project was written to help administer a green infrastructure plan that will reduce all forms of CSO events surrounding the wastewater and stormwater treatment. As of December 2023, Project Clean Lake has awarded approximately $1.9 billion and completed 73 out of the designed 82 contracted projects. The current focus is installing storage tunnels designed to hold overflow sewage in a separate location to be later processed, reducing the amount of contaminated exposure into the lake. Another example of the work this project supports is the upgrades to the Renewable Energy Facility in 2014, which included a "fluidized bed incineration system" that "captures heat released from the incineration process and utilizes the steam generated to turn a turbine, producing power" (Uva, 2017).

Toledo, OH

Toledo uses a combined sewer system just like Buffalo and Cleveland; however, it differs by not having any sewage overflow outlets directly into Lake Erie, but instead into local rivers and waterways. The city is on the southwestern side of Lake Erie, an area of the Great Lake that suffers significantly from algal blooms. This presents a hurdle for drinking water treatment facilities as treating water with toxic algae creates heavy taxation on the drinking water utility, as it requires more work to produce safe water.

Over time Toledo has implemented multiple plans to help bolster the water systems. In 2023, Toledo had 75 CSO events into local waters from 25 outflow locations, totaling 709.48 million gallons (Jasinski 2024). This number is down from 2018 where 284 CSO events outflowed 324.45 million gallons and is due to the adaptation of new storage tunnels and an addition of a separate sewer system (McGibbeny 2019). In 2010, Toledo created a plan to restructure and modernize all the aspects of its Collins Park Water Treatment Plant. The goal aimed to update the existing system and promote less chemical consumption by implementing new ozonation systems, thus reducing energy usage and subsequent emissions (City of Toledo 2024). This water treatment facility holds the potential to reduce GHG emissions further by implementing some of the technology mentioned above such as hydropower turbines.

3.2 Water Utility Leaders

Reviewing case studies of municipalities that are leading the way in sustainability and reducing their greenhouse gas emissions provides a framework and guidance for those looking to do the same. When analyzing greenhouse gas impacts in the wastewater industry factors such as water consumption trends, "changes in wastewater treatment technologies and electricity mixes should be considered" (Gursel, et al. 2020). This section will review several United States cities, and two Canadian cities; all that have implemented technology and changes to support their goal of becoming more sustainable. We have organized these case studies in order of most to least impressive in our opinion.

Denver, CO

Denver Water "serves one-quarter of the state's population with less than 2% of all water used in the state" in terms of drinking water, and Colorado's population is "expected to nearly double by 2050" (Denver Water 2020). Their report outlines goals to be completed by 2025, including "reduce organization-wide greenhouse gas emissions 50% from 2015 baseline", "maintain energy neutrality while decreasing energy use (electricity and natural gas) 10% from baseline (2015-2019 average annual use)", "reduce municipal solid waste going to landfill 25% from 2020 baseline" and "incorporate standards that include stormwater runoff in the redevelopment of two Denver Water properties" (Denver Water 2020).

To continue their previous success to meet their goals, Denver Water wants to meet at least 50% of their energy needs from on-site generated renewable energy, and "continue to improve hydroelectric system operations with holistic integration of water resources, maintenance planning and contractual obligations" (Denver Water 2020). Denver Water made several building updates to their operations complex that increases efficiency by reducing energy demands. Some of these include rainwater capture for irrigation, 100% LED lighting with daylight harvesting from large windows and skylights, blackwater capture with onsite treatment and reuse for toilet flushing and irrigation, and radiant heating and cooling from a central utility plant that uses water from a large water pipeline for preheating and precooling in a process similar to geothermal energy (Denver Water 2020).

Metro Water Recovery provides wastewater treatment services to the Denver metropolitan area, operating two treatment facilities and a METROGRO Farm location (Metro Water Recovery n.d.). Although their population increased 16% between 2010-2018, they treated 20% less wastewater per person, and in that time, they decreased emissions by 34,000 metric tons of CO_2 eq. (Gursel, et al. 2020). Metro Water Recovery uses several forms of energy to power their wastewater treatment, with coal, nuclear, natural gas, wind, and biogas being among the tops forms of energy. Both treatment facilities generate electricity through the combustion of the biogas, with the production offsetting 40% of electricity costs at the Robert W. Hite Treatment Facility (Metro Water Recovery n.d). The Class B biosolids produced are reused as fertilizer, with over 500 dry tons a week being used on the 50,000-acre METROGRO Farm (Metro Water Recovery 2023). As mentioned above in Section 2.3, selling the biosolids decreases the costs otherwise used to properly dispose of the material and is a resource to replenish nutrient-deprived soils.

Metro Water Recovery has several projects underway to increase sustainable practices. A biogas conditioning system to produce renewable natural gas is in the design phase at the Robert W. Hite Facility, which will "provide a renewable fuel source for transportation and consumer heating" (Metro Water Recovery n.d.). A 17-mile-long gravity pipeline will increase the areas serviced by the Northern Treatment Plant, which will "reduce energy use, [their] carbon footprint, and [their] long-term maintenance costs" (Metro Water Recovery 2023). And lastly, Metro Water Recovery is partnering with the National Western Center to obtain thermal energy from sewer heat recovery systems. From this process, all Metro Water Recovery buildings "will source nearly 90% of its heating and cooling from a recycled source of thermal energy" and thereby "avoid emitting an estimated 2,600 metric tons of CO_2 per year" (National Western Center 2020).

Portland, OR

The city of Portland has several environmental goals classified under its Sustainable City Principles that it hopes to achieve by 2030. Some of these goals include "reduce carbon emissions from City operations 53% below fiscal year 2006-2007 levels", "reduce energy use in city operations by 2% annually", "generate or purchase 100% of all electricity for city operations from renewable resources", and "manage 50% of stormwater from city-controlled impervious surfaces with sustainable stormwater strategies" (Portland.gov n.d).

The Columbia Boulevard Wastewater Treatment plant began focusing on sludge processing infrastructure improvement in the 1980s, adding four anaerobic digesters in 1983 and a biosolids composter in 1984 (Environmental Services 2018). By 2017, 77% of the biogas from anaerobic digestion was being captured and utilized for combined heat and power (Portland.gov n.d.). In 2017, the city council authorized "Environmental Services to build the infrastructure to capture and clean almost 100 percent of the plant's biogas, and to enter into a partnership with NW Natural to distribute the resulting methane, or renewable natural gas (RNG)" (Portland.gov n.d). Some of this renewable natural gas is used to fuel city trucks that previously relied on diesel, this project has garnered the name 'Poop to Power' (Portland.gov n.d.).

In 2020, a pipeline was completed between Environmental Services and NW Natural allowing the biogas to be distributed beyond the plant's boundaries. Infrastructure that would clean and purify the biogas into renewable gas neared completion in 2023. This technology "uses water and pressure to clean biogas, extract methane, and remove impurities." (Portland.gov n.d.). As of 2023, Environmental Services in Portland "cut greenhouse gas emissions by 21,000 tons annually, generated upwards of $3 million in revenue a year for the city, and replaced 1.34 million gallons of dirty diesel truck fuel with clean renewable gas energy per year" (Portland.gov n.d.).

This project helps meet many of the goals mentioned above. Not only does capturing the methane gas from anaerobic digestion decrease GHG emissions, utilizing the biogas to offset City's vehicles has dropped emissions from 14,000 to 9,000 metric tons of CO_2 eq between 2006 to 2019 (Sustainable City Government Dashboard n.d.) In 2018, Portland "met its goal of supplying 100 percent of the electricity used by city operations from renewable resources" and while most of this is through renewable energy credits from wind farms, of the 9% of on-site renewable energy systems, the largest contributor is the heat and power energy produced at the wastewater treatment plant (Sustainable City Government Dashboard n.d.). Lastly Portland has greatly increased the amount of green infrastructure in the city, and "currently manages 51% of the city-controlled impervious surfaces" (Sustainable City Government Dashboard n.d.). Like Milwaukee, this type of infrastructure is important to decrease the amount of stormwater that enters Portland's combined sewer system.

Washington D.C

DC Water provides approximately 700,000 residents with drinking water and stormwater services and serves 1.6 million people with wastewater treatment for neighboring counties in Maryland and Virginia. Through two unique buildings, DC Water is reducing their GHG emissions: the DC Water Headquarters building and the Bailey Bioenergy Facility. Their headquarters building was built on top of the O Street Pumping Station, avoiding development on new land and the opportunity to "capture excess energy coming off the sewer lines below the pumping station" (dc Water 2021). In addition to energy saving building features like floor to ceiling windows and motion-detection lights, the heat from the flowing wastewater in the pump station is used to heat the building in winter and cool the building in summer by acting as a heat sink through thermal exchange. (dc Water 2021). In 2015, the Bailey Bioenergy Facility was opened. At the time it opened, it "was the first project to employ thermal hydrolysis in North America and was the largest such facility in the world when it was commissioned" (dc Water n.d.). Providing 10 megawatts of electricity, the facility includes "a dewatering building, 32 sleek thermal hydrolysis vessels, four concreate 80-foot high anaerobic digesters ... and three turbines the size of jet engines" (dc Water 2015).

About one-third of the energy consumed at the Blue Plains Wastewater Treatment Plant comes from the Bailey Bioenergy Facility on site (dc Water 2021). The biogas created from anaerobic digestion is then inputted into a combined heat and power system which produces electric power to be used in the facility and steam which is used for thermal hydrolysis (dc Water 2023). This on-site facility has improved efficiency by over 80% and is emitting less carbon (U.S. EPA 2024). From this technology, reductions of greenhouse gas emissions range between 130,000 to 160,000 metric tons of CO_2 a year (dc Water 2023). In addition to capturing methane gas, DC Water utilizes its Class A biosolids from anaerobic digestion for fertilization called Bloom, which can be "used in both rural and urban settings" (dc Water n.d.).

Blueprint 2.0, which is the current strategic plan put out by DC Water, outlines five imperatives that they want to achieve over the next five years and beyond, with one of the imperatives being sustainability. They want to mitigate the effects of climate change, make sure they are recovering and utilizing the resources produced at their facilities, and improve economic efficiency so that they can improve their aging infrastructure with new technology (dc Water 2021). Another way they are utilizing the resources produced at their plant is onsite renewable energy production. The treatment plant utilizes solar panels around its 150-acre campus, providing 4 MW of electricity. The next phase of their goal hopes to add more solar panels to produce an additional 11 MW of energy (dc Water 2021). Renewable energy supplies about 43% of the energy used by DC Water as a whole, and almost 60% of the energy used at the Blue Plains Facility (dc Water 2023).

Another portion of their sustainability goal focuses on green infrastructure. Back in 2021, DC Water "announced the success of both its first green infrastructure projects in Rock Creek and the innovative Environmental Impact Bond that financed them", reducing runoff by almost 20% (dc Water 2021). DC Water plans to increase the amount of green infrastructure in the Rock Creek watershed after this initial success. Projects like this one, and the one mentioned above in Milwaukee, show the importance of increasing the amount of green infrastructure to reduce runoff of stormwater.

Milwaukee, WI

The Milwaukee Metropolitan Sewerage District (MMSD) operates two wastewater treatment facilities, Jones Island and South Shore, and services 28 municipalities (Scanlan 2016). MMSD has three major goals outlined in their 'Vision 2035' plan: using renewable energy sources to meet 100% of their energy needs, having 80% of those renewable sources coming from MMSD, and reducing their carbon footprint by 90% compared to a baseline from 2005 (Strifling, et al. 2019). This is divided into two stages: "first, integrated watershed management, and second, climate change mitigation and adaptation, emphasizing energy efficiency" (Strifling, et al. 2019). MMSD looks to accomplish these goals by prioritizing landfill and digester gas generation, updating aging infrastructure, and installing more solar panels to generate electricity for the conveyance system and administration facilities (Greeley and Hansen 2024). As of 2024, renewable energy provides 27% of MMSD's energy needs, and has reduced GHG emissions 18% since 2005 (Shafer 2024).

Similar to Denver and Washington D.C, MMSD utilizes the biogas and biosolid products from anerobic digestion. Sludge from both treatment facilities is processed at the South Shore plant for anaerobic digestion, with the captured methane gas being used as energy to power the treatment process (MMSD 2020). The biosolids produced from wastewater treatment create a nutrient rich fertilizer, Milorganite, that is sold for landscaping and farming needs (Milorganite 2024). One unique feature of MMSD that reduces their carbon footprint and is not seen in the other case studies is the 19-mile-long pipeline that brings in landfill gas from Muskego, Wisconsin to help power the Jones Island facility. The landfill gas costs half of what natural gas does, with all those savings going directly to MMSD customers (MMSD 2016).

In addition to this they have a goal of capturing and cleaning 100% of stormwater and wastewater and utilizing green infrastructure to keep 740 million gallons of stormwater out of the sewers. While much of the serviced area utilizes separate sewer systems, approximately 6% of the area uses a combined sewer system (MMSD 2016). Similar to the stories mentioned above in sections 2.4 and 2.5, MMSD has had to make progress to decrease the number of overflow events. In 2023, "MMSD had only one combined sewer overflow event", and they captured and cleaned "99.7% of the stormwater and wastewater that entered [their] system" (Shafer 2024). This can be attributed to the Fresh Coast Protection Partnership started by MMSD and Corvia Infrastructure Solutions in 2020. In both the combined sewer and separate sewer system areas, the partnership "is intended to help the District ramp up green infrastructure implementation to meet the District's 2035 Vision goal of capturing the first half-inch of rainfall across impervious surfaces within the District's Service Area" (Fresh Coast Guardians 2021). Through this partnership, Marquette University constructed two projects on their campus, a pervious surfaced parking lot and a bioretention area, that "have the potential to prevent up to nearly 500,000 gallons of stormwater runoff during a single rain event" (Marquette News Center 2022). The partnership plans to create multiple projects, like those at Marquette, that in total will have the ability to capture 8.5 million gallons of stormwater runoff (Fresh Coast Guardians 2021).

Toronto, ON

Toronto is the largest city in Ontario with approximately 3 million people serviced by four drinking water treatment plants and four wastewater treatment plants. In 2021, the Canadian Government committed to the goal of net-zero emissions by 2050 across all sectors (Canadian Water Network 2022). Prior to this, the City of Toronto in 2019 developed the TransformTO Net Zero Strategy which outlines it's plans to achieve net zero emissions by 2040 (City of Toronto 2024). In the TransformTO Net Zero Strategy Report, strategies include more green infrastructure to reduce stormwater runoff as 23% of the sewers in Toronto are a combined sewer system (Hong 2016), increasing efficiency standards for new buildings to decrease stress on water systems, and producing renewable energy from biogas generated during wastewater treatment (City of Toronto 2021).

In 2017, the Environmental Commissioner of Ontario stated that "municipal water and wastewater systems account for 32% of reported municipal GHG emissions; almost half of that comes from energy-intensive sewage treatment." (Chattha 2020). Knowing the exact number of GHG emissions from this industry is challenging as Canada lumps wastewater emissions with emissions from the waste industry. In addition to this, emissions of CH_4 and N_2O are reported under the wastewater emissions category, however CO_2 emissions are not reported. (Government of Canada 2021). From the 2022 Annual Reports from each of the four wastewater treatment facilities, three of the four utilize the methane gas produced from anaerobic digestion for fuel to reduce the plant's operating costs and carbon footprint, and three of the four facilities utilize biosolids while the other facility incinerates it (City of Toronto 2023).

Additionally, one water-based technology that is helping to decrease GHG emissions in Toronto is Enwave's Deep Lake Water Cooling system. Supplying over 100 downtown buildings, this system takes in cold water from deep within Lake Ontario and passes it through a series of pipes to cool down buildings (Enwave 2022). Enwave described how this system works as such:

1. Three intake pipes extend 5km into Lake Ontario and at a depth of 83m. A fourth pipe is in the works and could increase capacity by up to 60%.
2. The cold water is pumped to the Island Filtration Plant, moving itself through the pipes using relatively little energy
3. The cold water is treated for use as drinking water before it is sent to a pumping station and then sent to buildings downtown. Water identified for potable city needs is minimally heated thus retaining its cold temperature.
4. This system operates via a series of three loops. One loop moves the lake water, another loop moves the water within the downtown area, and then loops in each building interact with the system serves (*Figure 1*)
5. The water supplied to downtown buildings helps cool down buildings through passive heat exchangers rather than energy-intensive air conditioners or chillers. This thermal heat exchange works but transferring the heat or coolness between water loops (*Figure 2*).
6. After the chilled water has circulated through and cooled the buildings, Enwave recycles the heat, returning the warm water to the pumping station to repeat the process.

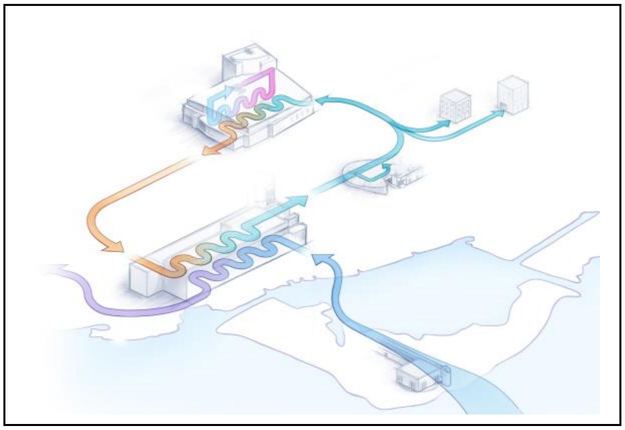

Figure 1 Loop System (Enwave 2022)

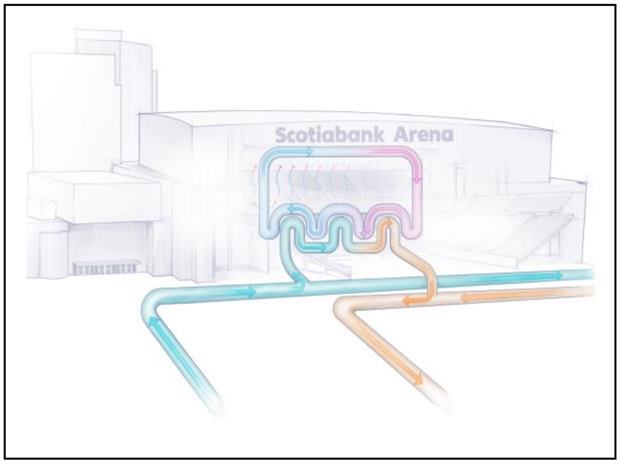

Figure 2 How the Process Works in a Building (Enwave 2022)

This system "currently displaces 55 MW of energy a year from Toronto's electricity grid" and "saves roughly 220 million gallons of water annually" (Enwave 2022, Enwave 2021). According to Enwave, "it's expected that 30% of the city's floor space will be connected to low-carbon heating and cooling by the year 2050" (Enwave 2022).

San Francisco, CA

San Fransisco Public Utilities Commission (SFPUC) is an unusual entity in that it supplies drinking water, treats wastewater, and offers hydroelectric and solar power to municipal departments. They operate two wastewater treatment plants 24 hours a day, 365 days a year, but they also have a third facility they only use during heavy rain events. This third facility plays an important role in reducing the number of system overflow events as San Franscico is the only coastal city in California to be serviced with combined sewer systems. Their unique hilly geography in the region decreases energy and maintenance costs as the water in the sewers is primarily moved by gravitational force. Like other water utility leaders, SFPUC generates a portion of its energy through biogases from anaerobic digestion, and they sell their biosolids to local farmers and ranchers for fertilizing (San Francisco Public Utilities Commission n.d.)

The city of San Francisco has goals to reduce GHG emissions by 40% below 1990 levels by 2025, and 80% below 1990 by 2050, and puts out performance scorecards for several industries including wastewater (City and County of San Francisco n.d.). Per the scorecard for the wastewater industry San Francisco emissions in metric tons of CO_2 has fluctuated between 4,000 to 6,000 since 1990 to 2020, however the percent total emissions reduction since 1990 was 48% in 2020. Of these emissions, 82% were fugitive emissions, 16% were process emissions, and 2% was sludge gas. In wastewater treatment, fugitive emissions are "emissions such as methane and nitrous oxide that escape from a process" (Federal Energy Management Program n.d.).

While decreasing greenhouse gas emissions is a goal for SFPUC, another major goal is water conservation and reuse. Through better plumbing, conservation outreach programs, and automated water meter technology that notifies customers about leaks in their system, they have saved on average 5.5 million gallons of water per day since 2005. With continued efforts "water savings are expected to reach an additional 4.2 million gallons per day" by 2045 (San Francisco Public Utilities Commision 2023). In addition to this, the Non-potable Water Ordinance "requires projects 100,000 gross square feet or more to collect and treat alternate water sources onsite for non-potable reuse" (San Francisco Public Utilities Commission 2021). This involves collecting precipitation and using it for non-drinking uses, so that the resulting graywater and blackwater is not treated drinking water, similar to the process being implemented at Denver Water. Not only does this ordinance help decrease the amount of drinking water that would need to be treated to supply these projects, but capturing the stormwater reduces the quantity that would otherwise make its way into the combined sewer system. These conservation efforts also help GHG reduction goals as "reduced water use through conservation can reduce electricity and gas used to distribute and heat water" (San Francisco Public Utilities Commission 2023).

Montreal, QC

Montreal is one of the larger target cities of this section. Montreal uses an extremely old system, that is primarily a combined sewage system. Over recent years, Montreal's system has been under scrutiny of the Canadian Government and a target for revitalization. Its high production of GHGs and significant volume of water treatment puts it high on the list for a strategic place to upgrade infrastructure. (Government of Canada 2023)

The Canadian Government has taken note of the scale of contributions Montreal water treatment contributes to GHGs and has since moved forward in implementing physical upgrades to the entire system. It began by creating a baseline for its consumption of resources and its output of GHG's in the mid 2010's. This baseline serves as a benchmark for the progress they are striving for. In 2011, water treatment, wastewater treatment, and pumping accounted for 38% (2,235 GWh) of overall municipal energy use, and "about 32% of municipal GHG emissions" (Every Drop Counts 2017). In 2002, the city of Montreal set a goal to reduce GHG emissions related to water and wastewater treatment by 20% by 2010 and "in 2013, the city renewed its commitment to further reduce GHG emissions by setting a new target of 30% by 2020" (GLSLCities 2016). In 2002, approximately 1,500 and 110,000 tons of CO_2 were emitted from water and wastewater treatment respectively. By 2015, these values decreased to 1,142 and 80,861 tons of CO_2 (GLSLCities 2016). "Most emissions (69.9%) were caused by sludge incineration. The rest were essentially due to fossil fuel combustion (29.7%), primarily used for incinerating sludge and heating buildings" (GLSLCities 2016).

Montreal hopes to work towards the net zero emissions by 2050 goal put out by the Canadian Government by targeting water and wastewater utilities. The plan is designed to reconfigure outdated systems such as Montreal's water works, implementing modern technologies such as installing modernized biodigesters and ozonation stations. These systems reduce GHGs and promote cleaner water reintroduced in circulation lessening subsequent costs and emissions (Olson 2023). The Canadian Government is aggressively progressing towards net zero emissions and setting the bar high by targeting one of their largest municipalities.

3.3 Best Practices and Recommendations

For water utilities to get to net zero, there are several approaches that have consistently appeared in the cases above about the leading water utilities. Upgrading every wastewater facility around the Great Lakes region with anaerobic digestors to capture 100% of the biogas emitted, installing solar panels and wind turbines to generate on-site renewable energy, and utilizing green infrastructure to minimize stormwater runoff that can be reused are shown to be recurringly effective strategies. However, implementing these strategies at the majority of regional wastewater facilities is no small task and may take decades. We suggest a strategic approach that involves upgrading municipal systems that are the most out of date due to their reliance on Combined Sewer Systems. We have identified several of those systems around the Great Lakes that have an active combined sewer overflow outfall and are member cities of the Cities Initiative (EPA 2023):

Illinois: Chicago

Indiana: East Chicago, Gary, Hammond

Michigan: Dearborn, Dearborn Heights, Detroit, Grand Rapids, Lansing, Wyandotte

New York: Buffalo, Dunkirk, Rochester

Ohio: Cleveland, Toledo, Sandusky

Pennsylvania: Erie

Wisconsin: Milwaukee, Superior

Based on the technology review and the case studies of utility leaders, we recommend the following changes if and where possible:

1) Search for efficiency and make upgrades that reduce energy demands. Optimize the building to cut down on energy consumption with features such as more windows for natural lighting, LED lighting, roof-top gardens to capture precipitation and utilize for non-potable water, and motion-sensor lighting to decrease consumption when there is no usage. Leading utilities to learn from are Denver, Washington D.C, and San Francisco.

2) Utilize anaerobic digestion in the wastewater treatment process to maximize captured methane gas and digestate and utilize this energy to self-supply renewables. Leading utilities to learn from are Milwaukee, Denver, Washington D.C., Portland, San Francisco, Montreal and Toronto.

3) Utilize the biosolids from wastewater treatment, decreasing the quantity to be disposed of per regulatory standards and instead sell as a form of fertilizer to farmers in neighboring communities. Leading utilities to learn from are Milwaukee, Denver, Washington D.C., Portland, and Toronto. If possible, use co-digestion of biosolids from drinking water treatment and other feedstock sources.

4) Increase green infrastructure, especially in municipalities with combined sewer systems, to decrease the amount of stormwater runoff entering the sewer system and overwhelming wastewater treatment plants. Additionally add systems that control overflow and output to minimize risk and pollution. Leading utilities to learn from are Milwaukee, Washington D.C., and Portland.

5) Consider onsite rainwater capture features to utilize the water for non-potable reuse. Leading utilities to learn from are Denver and San Francisco.

6) Install solar panels and micro-wind turbines at treatment facilities to increase on-site renewable energy production that can be utilized to decrease energy consumption and GHG emissions. Leading utilities to learn from are Denver, and Washington D.C.

7) Utilize thermal exchange systems capturing heat from sewer systems or cold water from deep within Great Lakes to heat and cool down facility buildings. Leading utilities to learn from are Denver, Washington D.C., and Toronto.

8) Continue monitoring technological improvements and modernize new systems as time goes on and capabilities allow it.

Section 4: Law and Policy Review

4.1 Policy Overview

The United States and Canada face various barriers to achieving net zero emissions within the water sector. Understanding these challenges is crucial for developing strategies to overcome these barriers. There are three major categories under which barriers fall: biogas utilization, implementation of green infrastructure, and decarbonization of water.

Regulations governing water utilities are often excessively complex and create frameworks that require site-specific solutions. This creates challenges to implementing renewable energy projects when navigating unique codes (Ren and Pagilla 2022). For instance, regulations which often exist to protect public health and the environment can make it difficult for water utilities to adopt practices like onsite renewable energy or onsite non-potable water reuse. The combination of public health, energy efficiency, and land use policies can result in costly and time-consuming research and technology analysis to bring a specific system into compliance (Ren and Pagilla 2022). Minimizing overly restrictive regulations would enable small and medium-sized facilities to collaborate more easily, incorporate technologies more swiftly, and benefit from cost sharing investments like co-digestion of biogas with other industries (Ren and Pagilla 2022).

The regulatory barriers around green infrastructure are unique to each municipality. Local municipal codes and ordinances provide a structure of governance to guide land use development, maintain public and private property, and provide public health amenities (Wisconsin Sea Grant n.d.). Many of these codes were established before the impacts of urbanization on hydrology were understood. Due to this, many regulations present outdated, unclear, or restrictive frameworks for adopting green infrastructure projects within a community (Wisconsin Sea Grant n.d.). Municipal codes may also lack clarity or remain silent on the use of these practices. The absence of such language can lead to subjective interpretations and can create barriers to implementing projects (Wisconsin Sea Grant n.d.).

For water utilities to make progress on net zero goals, they need to access renewable energy sources beyond what they can self-supply. Increasing the production of renewable energy to a level that can support massive decarbonization efforts requires upgrades to the grid and its transmission lines. The rate of transmission line construction can be viewed as an obstacle to renewable energy adoption. Historically, the process of permitting U.S. transmission lines has been a challenging process due to disjointed grid connections and public opposition from groups such as Not in My Back Yard (Cook 2022). Like the U.S., Canada’s slow and burdensome regulatory process can limit the placement of new transmission lines across interstate borders. On average it can take several years just to approve a new electricity generation project and even longer to approve the transmission line connections. For instance, the proposal of a transmission line connecting northern to southern Manitoba took over 11 years to become operational (Robinson 2023).

The barriers preventing net zero transitions create significant challenges for water utilities. First, we discuss policy barriers and then we identify policy supports, such as recent commitments by Canada and the United States to bolster renewable energy capacity. The supports signify a promising shift towards overcoming longstanding barriers and driving emissions reductions within the water sector.

4.2 Canadian Policy Barriers

Biogas

The main barriers facing the development of biogas and RNG in Canada are from the lack of clear or robust policy support. For instance, in 2023 Canada heavily incentivized clean technology and hydrogen initiatives through Investment Tax Credits but made no allocations to support biogas or RNG initiatives (Canadian Biogas Association 2023). While Canada has roughly 300 active biogas and RNG projects, 50 percent operate in Ontario and 16 percent in Quebec (Canadian Biogas Association 2023). Expanding biogas utilization at a wastewater treatment plant (WWTP) requires significant financial investments and collaboration in overcoming unique barriers. We can see the success of municipal co-digestion initiatives from the collaboration between Ontario cities Stratford, Cornwall, and the town of Petawawa. By working with the Ontario Clean Water Agency and other utilities, projects were streamlined under a single comprehensive Environmental Compliance Approval application, minimizing regulatory barriers (Chattha 2021). The initiative helped bring municipalities, utilities, regulators, and stakeholders together, facilitating a shift away from the risk-adverse and cost-centered behavior common within the WWTP. Instead, the collaboration encouraged a mindset that WWTPs can generate revenue (or at least break even) by co-digesting biogas (Chattha 2021). Ontario's accelerated pace of anerobic digestion draws attention to the barriers Quebec and other Canadian provinces face in implementing anerobic digestion at a WWTP. For instance, Ontario's Feed-in Tarriff Program has helped incentivize anerobic digestion and discourage fossil fuel use to a much greater extent than Quebec. Feed-in tariff programs guarantee a fixed rate of $165 to $258 Canadian dollars (CAD)/MWh for biogas generated electricity in Ontario. However, these rates are only $54 to $108 CAD/MWh in Quebec which can impact a project's feasibility (Lima, Appleby, and Li 2023).

Green Infrastructure

The major barriers slowing the adoption of green infrastructure in Canada stems from a lack of training in green infrastructure across disciplines, regulatory barriers, uncertainties over technical barriers, and ineffective leadership and collaborative governance structures on this issue (Johns 2018). While the technology for green infrastructure has been implemented in Canada for decades, policies related to green infrastructure are a relatively new focus. Concern over water conservation has not been a major driver of green infrastructure policies in Canada as it has been for regions less abundant in water (Johns 2018). The perceived purpose of green infrastructure can also have major implications for weighing the costs and benefits in municipal budgeting. What should and what should not be considered green infrastructure—from a policy perspective or funding lens—is dependent on the legal language defining its use (Ghadge 2019). Determining qualifying projects can be challenging, especially as green infrastructure concepts evolve to encompass water quality improvement, economic benefits, environmental services, or social benefits (Ghadge 2019). Funding eligibility may favor options such as permeable pavement, rain barrels, or bioswales in certain jurisdictions, while other projects might encounter obstacles in obtaining federal or provincial support if policy language does not encompass the full range of green infrastructure (Ghadge 2019).

Decarbonization of Water

Canadian Municipalities control over 44% of emissions either through municipal policy decisions or through the direct provisioning of municipal services (Patel and Parkins 2023). While this indicates significant control over emission reduction, overly complex legal framework and costs associated with grid connectivity represent the major barriers to renewable energy adoption (Patel and Parkins 2023). Lack of local leadership and support for renewable energy is often cited as another barrier to renewable energy adoption. However, studies indicate that projects promoting energy democracy rather than energy consumerism receive greater public support and foster greater social capital (Patel and Parkins 2023).

4.3 United States Policy Barriers

Biogas

A major barrier to successful biogas projects throughout the Great Lakes region occurs due to the absence of a supporting policy framework. The lack of comprehensive guidelines leaves industries struggling to overcome regulatory challenges (Wisconsin Public Service Commission 2016). Regulatory constraints also impact the industry dynamic negatively. For instance, Wisconsin has regulations limiting the import of outside feedstocks for co-digestion to 10% for Concentrated Animal Feeding Operations. These Import limits on feedstock create barriers that act as a disincentive to industry cooperation and could impact a project's financial feasibility (Wisconsin Public Service Commission 2016). Poor communication between different biogas producers can also create little incentive for a unified voice within the biogas industry to share information, collaborate on feedstock markets, and reduce production costs. With these barriers in place, many facilities resort to flaring off significant biogas quantities missing the benefits of harnessing biogas potential (Wisconsin Public Service Commission 2016).

The most promising biogas initiatives are likely to be those that facilitate co-digestion of combined feedstocks such as food waste, landfill gas, or agricultural residue with a pre-existing anerobic digestor at a WWTP (Cyrs, Feldmann, and Gasper 2020). Initiatives like food waste bans represent a state or local policy that can significantly improve biogas feasibility within a state by capitalizing on waste synergies. For instance, California's Senate Bill 1383 requires a diversion of 50% organic waste by 2022, ramping up to a 75% diversion by 2025, all measured against 2014 levels (CalRecycle.ca.gov n.d.). Currently all Great Lake states except Minnesota and New York lack state policies mandating the diversion of food waste from landfills that could otherwise be co-digested at a Wastewater Resource Recovery Facility (American Biogas Council 2021). While Minnesota’s food waste diversion is a step in the right direction, the initiative focuses on diverting food waste to compost facilities rather than wastewater facilities, missing the benefits of co-digestion (Gaetjens 2022). The California Department of Resources Recycling and Recovery recognizes that while WWTPs can process additional feedstock for co-digestion, the incentive to do so depends on available markets to sell biogas (Kester and Link 2023). If there is no market to sell excess biogas or upgrade biogas to RNG then there is little incentive for wastewater utilities to accept additional feedstocks (Kester and Link 2023).

The impact of food waste diversion can also be seen in Massachusetts which increased its anerobic digestor facilities from four to eight within three years of establishing a food waste ban (Ren and Pagilla 2022). Each year Wisconsin creates roughly 455,000 tons of food waste that could be utilized for energy and/or support consistent feedstock supply for anerobic digestion facilities (Wisconsin Public Service Commission 2016). While Wisconsin does have a strong biogas industry, food diversion laws could help overcome barriers to biogas by sustaining WWTP with adequate feedstock to generate renewable energy. It’s important to note that even in states like Massachusetts with strong policies favoring co-digestion, many facilities still struggle to compete with cheap natural gas pricing (Ren and Pagilla 2022).

Green Infrastructure

One of the barriers to green infrastructure is the perceived cost misconception of a project. Despite studies by the EPA and the American Society of Landscape Architects indicating that most green infrastructure projects typically have either no impact on cost or lead to reduced costs, green infrastructure investments are often perceived as riskier compared to gray infrastructure (Baker et al. 2022). The scale of municipal governance is also suggested to impact green infrastructure development. One study found that most communities leading green infrastructure projects operate at the city scale, indicating that municipalities operating at higher complexities (county or multi-county) may face greater challenges in securing green infrastructure funding. This study identified Milwaukee, Philadelphia, Syracuse, New York City, and Buffalo as the five leading communities that invested greater than 20% of their control plan budget into green infrastructure, with Milwaukee investing 71% of their total control plan budget (Hopkins, Grimm, and York 2018). The force that drives Milwaukee forward as leaders in green infrastructure can be found in the legal language surrounding green infrastructure practices. Wisconsin's Pollutant Discharge Elimination System (WPDES) requires the permit holder to develop a control plan for pollution and water quality improvements (Alliance for the Great Lakes 2020). In meeting this obligation, MMSD became the first in the U.S. to hold a permit requiring green infrastructure practices and control measures in maintaining the MMSD service area (Alliance for the Great Lakes 2020). Milwaukee's green infrastructure development showcases how explicit language can streamline processes and overcome regulatory hurdles.

Decarbonization of Water

The Federal Energy Regulatory Commission traditionally has not had the authority to deal with siting and permitting connections across multiple states, leaving project developers to navigate the patchwork of individual state regulations. Interstate projects must therefore obtain approval from multiple states which can delay or prevent project development, hindering the speed of renewable energy development (Cook 2022). For instance, a recent $1 billion dollar project in Massachusetts aimed to connect the grid to a Canadian hydropower plant was halted after Maine residents rejected the transmission line pathway over concerns with the clear cutting of forest habitat (Cook 2022).

Policies impacting the placement of wind turbines and solar panels can also have a negative impact on the rate of renewable energy transition. For example, Woodbury County in Iowa increased the distance wind turbines are required to be setback from neighboring properties (Meadows 2024). There is increasing opposition across midwestern states, mainly from local communities, looking to maintain cultural values and community aesthetics. This opposition can make it difficult for renewable projects to progress or even impossible due to laws banning renewable energy projects (Meadows 2024). In response to local versus state government tensions, some states like Illinois and Michigan have taken action to ban local governments from rejecting renewable energy projects that otherwise would interfere with the state's ability to achieve emission reduction targets (Meadows 2024).

Offshore wind in the Great Lakes has not gotten out of the starting gate due to a lack of policies that would allow for a logical and efficient way to evaluate environmental impacts, costs and benefits, and permit projects. The Icebreaker wind project was intended to be the first offshore wind farm in the Great Lakes. After facing legal challenges and push back from environmental groups and property owners, the $50 million federally funded project struggled to advance development (Jones 2023). The Ohio Power Siting Board placed restrictions on turbine operation including nighttime shutdowns to protect birds and bats, despite expert testimonies against the claim. The restriction, legal battles, and operation delays lead to financing issues that rendered the project uneconomical and created uncertainty for investors and stakeholders (Krouse 2023).

4.4 Shift from Biogas to Renewable Natural Gas

Over the last decade federal policy investments have shifted away from biogas markets and focused greater emphasis on producing renewable natural gas for pipeline injection (Michigan Public Service Commission 2022). This trend is also prominent in Canada due to little opportunities for biogas growth and the rise of RNG markets (Canadian Biogas Association 2023). While this has advanced development of RNG production there are still challenges facing RNG feasibility.

The major barriers to successful RNG projects are feedstock availability, operational/market risks, and capital costs (Cyrs, Feldmann, and Gasper 2020). The first challenge facing RNG production is the uncertainty surrounding feedstock availability and scalability. There are competing demands for feedstock sources from crop residue for fertilizers to sawmill residues for pelletized fuel, and even biogas itself for onsite electricity production (Cyrs, Feldmann, and Gasper 2020). Variations in feedstock availability can create concerns for two reasons: first because the energy potential and production efficiency of RNG decreases with time and second because feedstock inconsistency can lead to machine failure (Cyrs, Feldmann, and Gasper 2020).

The presence of surplus biogas is critical for WWTPs to upgrade biogas to RNG. As highlighted earlier, the facilitation of co-digestion at a WWTP and promotion of biogas markets can create a favorable case for utilities to harness biogas potential for electricity generation and sell excess into RNG markets. Portland Oregon's Columbia Boulevard Wastewater Treatment Plant showcases how a wastewater utility could successfully upgrade RNG to offset GHG to a greater extent. Prior to 2017, this facility captured 77% of its biogas for use in generating onsite electricity, with the remaining 23% flared and unutilized (Portland.gov n.d.). The facility partnered with the gas utility NW Natural in 2017 after the Portland City Council approved infrastructure upgrades to capture 100% of the biogas. While the facility does not accept food waste diversions, it maintains a natural gas fueling station injected with RNG (Portland.gov n.d.). This could potentially refuel food waste collection trucks with renewable gas when collecting food waste throughout the city, further offsetting emissions.

States across the Great Lakes face little policy structure to support RNG and there is no universal industry standard or regulatory framework governing RNG gas quality (Michigan Public Service Commission 2022) Concerns over gas quality/composition and lack of consistent industrywide standards also create uncertainty in RNG feasibility. For example, Michigan has the strictest limits on the oxygen composition allowed in pipeline injection set at $\leq$ 5 ppm (Michigan Public Service Commission 2022). Lower oxygen prevents pipeline rusting and damage but can disincentive RNG development because meeting this standard requires expensive removal of oxygen to purify RNG. This can cost an additional $600,000 to $1 million per RNG project and increase maintenance costs significantly (Michigan Public Service Commission 2022).

4.5 Policy Barriers Conclusion

The journey towards achieving net zero emissions within the water sector in both the United States and Canada is riddled with various policy barriers. These barriers, spanning across biogas utilization, implementation of green infrastructure, and the decarbonization of water, present significant challenges that must be addressed to pave the way for sustainable and environmentally friendly practices. Regulatory complexities in both countries hinder the adoption of renewable energy projects within water utilities. The lack of clear and robust policy support poses a significant obstacle to the development of biogas, renewable natural gas, and green infrastructure initiatives. Addressing these policy barriers requires a concerted effort from government agencies, industry stakeholders, and local communities. By implementing targeted policy interventions, fostering collaboration, and promoting innovation, both the United States and Canada can overcome these challenges and pave the way for a sustainable and resilient water sector that contributes to global efforts to combat climate change.

4.6 Emerging Policy Support

Historically, policies supporting a timely greenhouse gas emissions reduction within the water sector have been limited and challenging to implement due to the barriers mentioned above. However, Canada and the United States have made significant commitments in recent years to increase renewable energy capacity to meet climate targets. These commitments include pledges to invest in renewable energy projects, moves to support research and development, and policy providing incentivizing renewable energy adoption. This section identifies the supporting policies driving emission reductions in the water sector and highlights the recent policy changes that are addressing barriers to net-zero.

Canada – National Level

Canadian net-zero policies for water facilities are driven by national standards and goal setting, provincial action plans, and innovative municipal projects. On the national level, Canada's ambitious goals and direction are set by Canada's 2030 climate target and its goal of net-zero emissions by 2050. The 2021 Canadian Net-Zero Emissions Accountability Act "enshrines in legislation Canada's commitment to achieve net-zero emissions by 2050" (Government of Canada 2024). Through the Investing in Canada Infrastructure Program, the Climate Lens operates as an effective tool that evaluates projects based on their potential to mitigate GHGs. The Climate Lens also assesses a project's resilience to climate change impacts (Canada.ca 2023). This ensures that investments in water infrastructure align with climate objectives and helps facilitate carbon emission reductions within the water sector (Canada.ca 2023).

By aligning investments in water infrastructure with climate objectives, there are several methods by which Canada aims to achieve its net zero goals. These include pricing carbon pollution, increased technology development and implementation, and reducing non-renewable energy use in the wastewater treatment industry (Government of Canada, 2024). Several national policies are enacted to work towards net zero emissions by 2050 including the Low Carbon Economy Fund and the Green Municipal Fund. The Low Carbon Economy Fund supports projects that reduce Canada's greenhouse gas emissions and generate economic growth through sustainable practices (Government of Canada 2023). The Low Carbon Economy Fund has been used to support projects like the Toronto Deep Lake Water Cooling Fourth-Intake project, which plans to add an intake to the Enwave's Deep Lake Cooling system mentioned above in Section 3.2. This extra intake would "reduce GHG emissions by 714,000 tons CO_2 eq" over the lifetime of the system (Climate Action Map 2021).

The Green Municipal Fund "exists to enhance the quality of life for people in Canada by accelerating a transformation to resilient, net-zero communities" (Green Municipal Fund 2023). Active since 2020, the Green Municipal Fund is a $1.65 billion program funded by the Government of Canada and is delivered by the Federation of Canadian Municipalities. It has been used to pay for projects such as the McLoughlin Point Wastewater Treatment Plant in British Colombia, which incorporates a green roof for stormwater management and wastewater recovery for onsite heating (Federation of Canadian Municipalities 2020). Projects like McLoughlin Point and the Fourth-Intake project show Canada is directing funding toward achieving their goal of net-zero emissions by 2050.

Canada - Provincial Level

Provinces have some autonomy in how they adapt to the policies made at the national level, with much combatting climate change efforts occurring at the provincial level rather than the national. (Center for Climate and Energy Solutions). Provincial governments play a key role in the progress towards net zero emissions by investing research into tax and regulatory policies (Canadian Climate Institute 2022). However, some provinces have made more progress than others. Ontario, British Columbia, Quebec, and Alberta are leaders in the push for net-zero emissions, whereas New Brunswick, Newfoundland and Labrador, and Prince Edward Island are struggling to reduce reliance on carbon-emitting practices at companies in their regions (Canadian Climate Institute 2022). Despite these challenges, reductions in emissions are occurring. All ten Canadian provinces have published comprehensive climate action plans, some of which involve targeting wastewater treatment plants as a key for reducing emissions (Center for Climate and Energy Solutions 2024). For instance, Ontario seeks to manage sewage overflows by encouraging targeted investments and innovation in watershed strategies that reduce urban and agricultural runoff. This will reduce the overflow of stormwater and sewage from combined sewers, using fewer resources to treat the water at water treatment facilities (Ontario, A Made-in-Ontario Environment Plan).

United States - Federal Level

Net-zero policy initiatives for water facilities in the United States are driven by federal standards and goal setting, state policy drivers and funds, and local municipal efforts. Like Canada, the U.S. also has a goal of net-zero emissions by 2050 (United States Department of State 2021). Key initiatives on the federal level in the U.S. include renewable energy production tax credits, the Clean Water State Revolving Fund, and the Bipartisan Infrastructure Law.

The Clean Water State Revolving Fund encourages the use of green infrastructure at municipal wastewater facilities. The Fund was created in 1987 as part of the Clean Water Act as “a financial assistance program for a wide range of water infrastructure projects” (U.S. EPA 2024). Eligible projects include the implementation of green infrastructure and the construction of municipal wastewater treatment facilities. By providing loans for such projects, the Clean Water State Revolving Fund enables movement on the state-level toward net-zero emissions in wastewater treatment and elsewhere. Further, the Clean Water Indian Set-Aside Grant Program provides funding to Indian Tribes and Alaska Native Villages for wastewater infrastructure (U.S. EPA 2024).

The Bipartisan Infrastructure Law (BIL) adds money to the Clean Water State Revolving Fund and is an important federal policy driver. The BIL invests a total of over $50 billion to upgrade America’s water infrastructure. This includes allocating $2.6 billion to the Clean Water State Revolving Fund “for a range of projects to improve wastewater, sanitation, and stormwater infrastructure” (WhiteHouse.gov 2024). This enables states to pursue energy-saving improvements to their wastewater treatment facilities. The Great Lakes Restoration Initiative allocates $1 billion from the BILto provide “healthy ecosystems and safe drinking water” to Great Lake communities (WhiteHouse.gov 2024).

Production Tax Credits are “a per kilowatt-hour (kWh) federal tax credit included under Section 45 of the U.S. tax code for electricity generated by qualified renewable energy resources” (U.S. EPA 2023). These tax credits incentivize the use of renewable energy resources over non-renewable resources by wastewater treatment plants and elsewhere. These credits specifically incentivize the generation and use of renewable biogas from municipal solid waste resources, one of the key steps toward net-zero emissions (U.S. EPA 2023). Production Tax Credits also encourage higher Renewable Portfolio Standards at the state level.

United States - State Level

Renewable Portfolio Standards are regulations implemented by states that mandate a certain percentage of a utility's electricity sales come from renewable sources. These standards serve several key purposes. First, they diversify the sources of electricity generation within a state's energy portfolio. Second, the standards promote domestic energy production incentivizing renewable energy, energy independence, and enhanced energy security. Lastly, these standards can encourage economic development by creating opportunities for investment, job creation, and innovation in the renewable energy sector (National Conference of State Legislatures 2021).

Renewable Portfolio Standards are employed by thirty U.S. states, Washington D.C., and two U.S. territories. These standards encourage the adoption of renewable energy at wastewater treatment plants in participating states, including Minnesota, Illinois, Michigan, Ohio, Pennsylvania, and New York. Indiana has a voluntary renewable energy target of 10% use of renewables instead of a required standard, but Wisconsin's Renewable Portfolio Standard of 10% has expired (National Conference of State Legislatures, 2021).

In addition, other state policy drivers include state-wide energy goals such as Wisconsin's Focus on Energy, Wisconsin Governor's Task Force on Climate Change, Michigan's Rural Development Fund, and Michigan's Healthy Climate Plan and Clean Energy Future package. These projects and funds are some of the key initiatives taken on the state level to move toward net-zero emissions at wastewater treatment facilities.

Focus on Energy is a "statewide ratepayer-funded energy efficiency program" with the goal of helping non-residential Wisconsin energy utility customers "save energy and money while protecting the environment" (Focus on Energy 2016). While this program offers support to residential customers, it is also available for wastewater treatment plants. Focus on Energy provides information and financial incentives to complete energy efficiency projects on the municipal level, and they even offer rebates of up to $15,000 to help fund feasibility studies for biogas and biomass projects which can make wastewater treatment more energy efficient (Focus on Energy 2024). These initiatives have enabled improvements to wastewater treatment plants in Sheboygan and Milwaukee, showing how a statewide program can drive substantive results.

Michigan's Healthy Climate plan was released in 2022 as a roadmap for Michigan to reach 100% carbon neutrality by 2050, drive clean innovation, and decarbonize homes and businesses (Michigan.gov 2022). It is accompanied by the Renewables Ready Communities Award, which encourages renewable energy adoption in grid-connected wind, solar, or energy storage projects by funding $5,000 per megawatt of renewable energy added by such projects, up to $3 million (Michigan Department of Environment 2023). This may be useful for wastewater treatment plants who can implement and use a thermal battery like the Toronto Deep Lake Water project and reduce emissions doing so.

According to the Rural Development Grant Reports, between 2018 to 2023 the Rural Development Grant has invested over $550,000 into rural wastewater treatment facility improvements and construction since 2018 (Michigan Agriculture and Rural Development, 2024). This was calculated by locating every project related to wastewater treatment plant construction or improvement in each of the reports between 2018-2023 and summing up their funding amounts. Past applicants include the City of Escanaba, the City of Coldwater, the Bay Mills Indian Community, the Village of Colon, the City of Stephenson, and the City of Croswell. Each of these applicants received funding for improvements to or construction of wastewater treatment facilities between 2018 and 2023 (Michigan Agriculture and Rural Development, 2024). This funding can lead to energy savings and lower costs for local users if such improvements to wastewater treatment plants include greener technologies.

The Wisconsin Governor's Task Force on Climate Change encourages renewable energy. The Task Force document celebrates River Falls as the first town in Wisconsin to be run exclusively on renewable energy, including its wastewater treatment plant going green in 2020 (State of Wisconsin 2020). River Falls generates electricity through hydroelectric dams and powerhouses, uses energy-saving technology like automatic light sensors, and purchases "green" blocks of energy (from wind, solar, or biogas) to power its other needs (River Falls Municipal Utilities n.d.). These state-level policy initiatives exemplify the important role states play in pursuing net-zero emissions.

4.6 Policy Support Conclusion

The emerging policy support for greenhouse gas emissions reduction within the water sector represents a significant shift towards sustainable practices in both Canada and the United States. At the federal level, both countries have demonstrated strong commitments to achieving net-zero emissions by 2050 through comprehensive legislation and investment programs. The collaborative efforts between federal, provincial/state, and local governments, along with partnerships with indigenous communities, are driving positive change towards achieving net-zero emissions within the water sector. While challenges remain, the momentum generated by these emerging policy supports underscores a promising pathway towards a sustainable and resilient future for water management in both Canada and the United States.

Section 5: Funding Net Zero

5.1 Roadblocks and Financial Obligations in Achieving Water Affordability

An overarching consideration for setting and meeting net zero goals is how to pay for the improvements and ensure water is affordable. Buffalo, New York offers an excellent example of water infrastructure funding challenges that can be seen across Great Lakes communities. Despite the city investing $150 million into infrastructure upgrades, water utilities remain critically strained for funding infrastructure improvements (Congress.gov 2019). Buffalo needs to raise an additional $500 million to remove lead pipe infrastructure and these costs are being recovered through capacity charges. Roughly 30% of Buffalo residents live at or below the federal poverty level, making these groups disproportionately affected by the flat rate fees utilities have implemented to offset infrastructure costs (Congress.gov 2019).

Additionally, the legal restrictions applied to subsidies within the Clean Water State Revolving Fund compound this issue by hindering access to grants and loans, impacting communities with the greatest financial needs and those run by volunteers the most (Congress.gov 2019). In recent years, however, there has been a policy shift to address the barriers financially strained communities face. For instance, the Infrastructure Investment and Jobs Act of 2021 is funding drinking water, stormwater, and wastewater resilience through expansion of funding within the State Revolving Fund (U.S. EPA Report 2023). Executive order 14008, known as the justice40 Initiative, aims to direct 40 percent of federal investments toward disadvantaged communities overburdened historically through underinvestment (WhiteHouse.gov 2021). And Executive Order 14096 authorizes federal agencies to lead and strengthen efforts to promote environmental justice (White House Council on Environmental Quality 2023). While these laws aim to address funding disparities amongst disadvantaged communities, they leave individual states, tribes, and territories to establish their own criteria for identifying those communities. The EPA then reviews each states' definition of disadvantaged communities and affordability criteria described in an annual Intended Use Plan (Scanlan and Husain 2022).

5.2 Canadian Funding

Most of the funding for water treatment facilities comes from large grants provided by the national government of Canada. As mentioned above, the Green Municipal Fund is providing $1.65 billion in various municipalities funding. This program has are two grants/loans available to municipalities, but applications will close once all $1.65 billion has been awarded. One is for the retrofitting of any city's municipality, with up to $10 million in loans/grants, and the other is for the retrofitting of a small city's municipality, with up to $200,000 in grants. The Green Municipal Fund is the only national program providing funding for drinking and wastewater treatment facilities. However, roughly every three to five years the Canadian government releases more funding for cities that can be used for drinking and wastewater treatment plants. In 2017, the Clean Water and Wastewater Fund Program supplied $2 billion and in 2022, the Investing in Infrastructure Canada funded $33 billion. Both of these funds have since closed their applications.

5.3 United States Funding

There are a variety of resources available for funding the water sector in the United States. Government departments and agencies that offer funding programs for the public water sector include the Bureau of Reclamation (Reclamation), the Department of Agriculture (USDA), the U.S. Army Corp of Engineers (USACE), the Department of Housing and Urban Development (HUD), the Department of Commerce's Economic Development Administration (EDA), and the U.S. Environmental Protection Agency (EPA). While these agencies provide funding, each funding program contains different eligibility requirements and types of funding. Table 1 goes into depth for each of the departments and their funding programs.

There are two main funding approaches: individual project authorization and program authorization (Congressional Research Service 2023). If an agency uses individual project authorization, specific projects will be identified and then funding will be provided for the project at the beginning. There is no guarantee that the project will receive more funding in the future, even if the project is not completed. Program authorization creates criteria that fits a variety of recipients and will provide consistent funding throughout the year. Similarly, program authorization does not guarantee annual funding, although many water infrastructure programs do have some level of annual funding.

Table 1: Funding Programs from Reclamation, USDA, USACE, HUD, EDA, and EPA for drinking and wastewater treatment facilities

Agency/ Program	Purpose	Type of Funding	Federal/Nonfederal Cost-Share	Average Assistance	2023 Funding	2024 Funding Requested
Reclamation	Multipurpose projects including the water sector	De facto 40-50 year loan	0%/100% with interest for water sector	N/A	$1.93 billion	$1.45 billion
Reclamation Water Infrastructure Improvements for the Nation (WIIN) Act Water Storage Projects	Multipurpose projects including the water sector	Direct funding, with reimbursement of share cost with de facto loan	50%/50% for federal 25%/75% for nonfederal	N/A	$134 million	N/A
Reclamation (Title XVI)	Wastewater reclamation and reuse	De facto grant	Up to 25%/75%	N/A	$60 million	$4 million
Reclamation Rural Water Supply	Indian and Non-Indian rural water	De factor grant and loan	Non-Indian: 75%/25% to 80%/20%	N/A	$125.3 million	$57.8 million
USACE Multipurpose Reservoirs	Construct water storage reservoirs	Upfront financing: repaid through fees	0%/100% with interest	N/A	$7 million	$25 million
USACE Environmental Infrastructure Assistance	Drinking and wastewater infrastructure protection	Services or grant	75%/25%	N/A	148.5 million	$5 million

Agency/ Program	Purpose	Type of Funding	Federal/Nonfederal Cost-Share	Average Assistance	2023 Funding	2024 Funding Requested
USDA Rural Utilities Service: Water and Waste Disposal Program	Supply and treatment of wastewater facilities	Loans and grants	Grants: 75%/25% Loans: 0%/100%	N/A	Grant: $430 million Loan: $1.4 billion	Grant: $538 million Loan: $1.6 billion
USDA Rural Utilities Service: Emergency Community	Water treatment, storage, or distribution	Grants	100%/0%	Up to $1 million	$15 million	$15 million
USDA Watershed and Flood Prevention Operations Program	Multiple activities but must include flood control	Grants and advisory services	100%.0%	N/A	$145 million	$125 million
USDA Small Watershed Rehabilitation	Watershed rehabilitation	Grants and advisory services	100%/0%	N/A	$2 million	$10 million
EPA Clean Water State Revolving Fund (SRF) Loan Program	Wastewater treatment, and other activities	Grants to states for loans Loans by states to local projects	Grants: 80%/20% Loans: 0%/100%	Grants: $58 million Loans: $4.8 million	Grants: $1.6 billion Loans: $2.3 billion	Grants: $4.4 billion

Agency/ Program	Purpose	Type of Funding	Federal/Nonfederal Cost-Share	Average Assistance	2023 Funding	2024 Funding Requested
EPA Drinking Water State Revolving Fund (SRF) Loan Program	Updating water supply projects for regulations	Grants to states for loans Loans by states to local projects	Grants: 80%/20% Loans: 0%/100%	Grants: $45 million Loans: $2.8 million	Grants: $2.2 billion Loans: $6 billion	Grants: $3.4 billion Loans: $6.2 billion
EPA Water Infrastructure Finance and Innovation Act (WIFA) Program	Water sector projects with costs larger than $20 million	Loans	Funding cannot exceed 49% of total costs	$174 million	Subsidy cost: $68 million Credit Assistance: $12.5 billion	Subsidy cost: $72 million Credit Assistance: $12.5 billion
EPA Sewer Overflow and Stormwater Grant Program	Sewer and stormwater infrastructure	Grants	55%/45%	N/A	$50 million	$280 million
EPA Technical Assistance for Rural, Small, and Tribal Wastewater Systems	Assists systems to comply with the Clean Water Act	Grants	100%/0%	$4 million	$27 million	$18 million
EPA Technical Assistance for Rural, Small, and Tribal Drinking Water Systems	Assists systems to comply with the Safe Drinking Water Act	Grants	100%/0%	$12.4 million	$26 million	N/A

Agency/ Program	Purpose	Type of Funding	Federal/Nonfederal Cost-Share	Average Assistance	2023 Funding	2024 Funding Requested
EPA Small and Disadvantaged Communities Drinking Water Grant Program	Assists drinking water to meet federal requirements	Grants	55%/45%	N/A	$30.2 million	$80 million
EPA Small Water Systems Resilience and Sustainability Grant Program	Increase energy efficiency of treatment of drinking water	Grants	90%/10%	N/A	$7 million	$25 million
EPA Midsize and Large Water Systems Resilience and Sustainability Grant Program	Water conservation and watershed management	Grants	100%/0%	N/A	$5 million	$50 million
HUD Community Development Block Grant Program	Multipurpose community development	Grants	100%/0%	$20 million	$3.3 billion	$3.3 billion
Commerce, EDA, Public Works, and Economic Adjustment Assistance	Multipurpose economic development	Grants	50%/50%	$1.4 million	$161 million	$133 million

Conclusion

From our research, we have explored the contribution of GHG emissions from drinking water, stormwater, and wastewater treatment , delved into the processes and technology that goes into these utilities, reviewed case studies of water utility leaders that are making strides to become net zero in the coming decades, began to understand the policy barriers to achieving net zero while also seeing the emerging support for such projects, and identified funding opportunities that are available to assist a net zero transition. We understand the challenges municipalities are up against and hope that the research discussed in this report gives the Cities Initiative a stepping stone from which they can begin a program to aid municipalities work towards net zero emissions.

We have shown that upgrading wastewater facilities around the Great Lakes region with anaerobic digestors to capture 100% of the biogas emitted, utilizing biosolids as nutrient-rich fertilizers for agriculture, installing solar panels and wind turbines to generate on-site renewable energy, and utilizing green infrastructure to minimize stormwater runoff that can be reused are shown to be recurringly effective strategies. Utility leaders on the Great Lakes and St. Lawrence Seaway such as Montreal, Toronto, and Milwaukee show that a change towards more sustainable practices is possible, and additional cities, with the right guidance and support, can become leaders as well. We encourage the best practices and recommendations listed in Section 3.3.

With the funding opportunities outlined in Section 5, we hope that the financial burden and stress of a transition to net zero can be alleviated for municipalities. We recommend highlighting the cost-saving changes of generating on-site renewable energy, landfill and biogas utilization, and selling biosolids to farmers and landscapers. National and federal level goals of net zero emissions are a push in the right direction, but provincial, state, and municipal ordinances can put up barriers for biogas, green infrastructure, and the decarbonization of water. We encourage the Cities Initiative to work with their coalition of over 240 U.S. and Canadian mayors and elected officials to begin to dismantle the policies creating barriers for their water utilities. We encourage an integrated approach of the strategies and technologies identified throughout this report to meet the climate challenge.

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